Effect of Chicken Compost or Ammonium Phosphate and Solarization on Pathogen Control, Rhizosphere Microorganisms, and Lettuce Growth

A. GAMLIEL and J. J. STAPLETON, Statewide Integrated Pest Management Project, University of California, Kearney Agricultural Center, 9240 South Riverbend Avenue, Parlier, CA 93648

ABSTRACT

Two field experiments were conducted to determine effects of commercial chicken compost, ammonium phosphate fertilizer, and solarization, alone or combined, on several soilborne pathogens and the growth and yield of lettuce (Lactuca sativa). Southern root-knot nematode (Meloidogyne incognita) present at one of the sites was effectively controlled by the combination of these treatments, whereas solarization alone gave only partial control. Pythium ultimum was controlled by both solarization alone and combined with chicken compost. Lettuce yield was significantly increased by most solarization treatments in successive fall and spring crops at both locations. However, an inhibitory effect on lettuce growth and yield in the fall crop was observed in the plots that were amended with compost after solarization. The rhizosphere of lettuce plants grown on solarized soils was intensively colonized by fluorescent pseudomonads and Bacillus spp. Numbers of P. ultimum and other fungi were suppressed in solarized plots during the two successive lettuce crops.

Additional keywords: biological control

MATERIALS AND METHODS
Field sites. Two field experiments were conducted in the San Joaquin Valley during 1991–1992. One was on Hanford sandy loam soil at the University of California Kearney Agricultural Center (KAC) near Parlier, where grapes were previously grown. The soil is infested with southern root-knot nematode (M. incognita (Kofoid & White) Chitwood) and Pythium ultimum Trow. The second location was on Panoche sandy clay soil at the University of California West Side Field Station (WSFS) near Five Points. The plot was previously cropped with garlic and other vegetables and was not known to contain major plant pathogens other than P. ultimum.

Experimental design and soil treatment. Factorially designed experiments were done at both KAC and WSFS. Plots were arranged in a randomized block design with five replications per treatment, each of four adjacent beds 16 m long × 4 m wide. Commercially formulated chicken compost (2.15% N, 0.3% P, 1.7% K, at a rate of 10 t/ha; Foster Farms, Livingston, CA) or commercial ammonium phosphate fertilizer (16% N, 20% P2O5 at a rate of 500 kg/ha, which was equivalent to the total nitrogen content in the chicken compost; J. R. Simplot, Helm, CA) was manually spread on the plots, then incorporated into the soil by rototilling. Solarization of compost- or fertilizer-amended plots was done by mulching soil with 0.013-mm-thick clear polyethylene sheets. Each experiment was mulched for a period of 4 wk during August 1991. Soil temperature data were continuously collected with a micrologger (CR-21X, Campbell Scientific, Logan, UT). Post-solarization fertilizer treatments included incorporation of compost or ammonium phosphate at the same rates 7 days before planting. Controls were

Under suitable climatic conditions, soil solarization can be an effective method of controlling a broad spectrum of fungi, nematodes, weeds, and other plant pests in diverse agricultural systems, including in field and greenhouse production and in container media (2,14,16). Nevertheless, some soilborne pests such as root-knot nematodes (Meloidogyne spp.) are not always controlled effectively by solarization (25,26). Solarization frequently results in improved plant growth and yield increase (3,7,8,22–24) and in induced suppressiveness against reestablishment of major and minor fungal pathogens in treated soil (9,11,14). These effects can be partially attributed to increased populations of beneficial fungi and bacteria in the rhizosphere and roots of plants grown in solarized soils (3,8,9,23,26).

Addition of fertilizers and organic amendments, especially composts, can suppress soilborne plant pests in various cropping systems (4,5,12). The suppressive effect is attributed to shifts in microbial populations and activity in soil following the addition of the organic material (4,12). Antagonists of plant pathogens have been isolated from organic composts (5). Inorganic fertilizers containing ammoniacal nitrogen or formulations releasing ammonia from nitrogen in soil also have been effective in suppressing nematode populations when applied at high rates (17). Limited data are available on the effect of solarization of compost or fertilizer-amended soil on improved control of certain plant pathogens and weeds (2,16,24). The purpose of this study was to determine the effects of soil amendment with chicken compost or inorganic ammonium phosphate fertilizer, with and without soil heating, on pathogen control, microbial populations in soil and rhizosphere, and lettuce growth and yield.

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plots with no compost, fertilizer, or solarization. Beds (1 m wide) were shaped following incorporation of the post-solarization amendments.

Cultural practices. Two successive crops of leaf lettuce (Lactuca sativa L., 'Parris Island Cos') were grown in both fields. The first crop was planted in mid-September 1991, sprinkle-irrigated, and farmed according to the University of California recommendation for central California (27). Side-dressed fertilization of ammonium phosphate at a rate of 500 kg/ha was applied to all treatments after thinning (1 mo after planting). Plots were harvested in December 1991, and the beds were left undisturbed during the winter. A spring crop of leaf lettuce was planted in both fields on the same beds in February 1992 and farmed as the first crop.

Measurements of plant growth, yield, and disease severity. Stand counts were made before thinning in each crop to determine possible effect of soil treatments on seedling emergence. Fresh weight of lettuce plants was determined at 4 and 7 wk and at harvest. Galling of roots by M. incognita was assessed after 4 wk and at harvest at the KAC experiment. This was done by subjectively rating plants for percentage of the total volume of roots with galling, where 0 = roots with no galls and 100% = galling of the entire root system.

Greenhouse experiment. In order to estimate numbers of infective M. incognita individuals at KAC during the spring lettuce crop, soil samples were taken from each replication and placed in two 15-cm-diameter pots. Tomato (Lycopersicon esculentum Mill. 'Cherry Belle') transplants were planted in each pot and grown in a greenhouse for 6 wk, at which time plants were removed from the pots and the extent of root galling was determined as in the field.

Microbial colonization of the rhizosphere. Lettuce plants were uprooted along with adherent soil several times during the growing season. Loose soil clinging to roots was collected by shaking the plants in sterile tubes; soil adhering to roots (less than 50% of the total amount of rhizosphere soil) was collected by shaking the plants in sterile water agar (1 mg/ml) supplemented with 1 mg/ml of MgSO₄·7H₂O. Both soil fractions were combined to constitute the rhizosphere soil sample. Rhizosphere soil suspensions were serially diluted and 0.1-ml samples for bacterial counts and 0.2-ml samples for fungal counts were spread on five petri dishes containing the appropriate selective medium. Dishes were incubated in the dark at 28 C. Colonies were counted after 4-8 days. Results were expressed as colony-forming units per gram of soil (dried at 105 C for 48 hr).

Culture media. For enumeration of fluorescent pseudomonads from soil and rhizosphere, King's medium B (KB) modified by the addition of 100 mg/L of cycloheximide, 50 mg/L of ampicillin, and 12.5 mg/L of chloramphenicol (19-21) and supplemented with 5 mg/L of pentachloronitrobenzene (PCNB) to suppress Rhizopus spp. (7) was used. Martin's agar (6) was used for enumeration of fungi, and Mircetich's agar (15) was used for enumeration of P. ultimum. For enumeration of Bacillus spp., 523 agar (13) modified by the addition of 32 mg/L of polymyxin B sulfate, 2 mg/L of sodium azide, and 250 mg/L of cycloheximide (26) and supplemented with 5 mg/L of PCNB was used.

Statistical analyses. Data were first analyzed by analysis of variance to test possible interaction among the main effects, followed by mean separation using Fisher's protected least significance difference test. Regression analysis was conducted to test correlation between nematode infection and lettuce yield in the fall crop at KAC. Data taken as percentage were arcsine-transformed prior to analysis. All analyses were performed with the SAS program (SAS Institute, Cary, NC, release 6.04 for personal computer) at P ≤ 0.05.

RESULTS

Soil temperature. Temperature fluctuation in solarized and nonsolarized plots is shown in Figure 1. Compost amendment to soil before solarization increased soil temperature by approximately 2 C compared with the temperature of non-amended solarized soil. Maximal temperatures at depths of 10 and 20 cm in the compost-amended solarized soil were 52 and 45 C, respectively, compared with 50 and 43 C, respectively, in the non-amended solarized soil. There was no difference in soil temperature between ammonium-phosphate-amended and non-amended solarized treatments or between compost-amended and non-amended nonsolarized plots.

Plant growth and yield. The number of lettuce plants in the solarized plots during the fall crop at KAC was significantly higher than the number in the nonsolarized plots (7.4 and 4.2 plants per meter, respectively). There were no significant differences in the number of plants among soil amendment treatments or times of incorporation. None of the treatments had an effect on plant stand in the fall experiment at WSFS or in the spring crop at either location. Plant

![Fig. 1. Effect of compost amendment on soil temperature during solarization at depths of 10 and 20 cm.](image-url)
samples were taken for determination of fresh weight after 4 and 7 wk. Greater fresh weight amounts were recorded from plants grown in the solarized plots than from those grown in nonsolarized plots. In contrast, lower fresh weights were evident in lettuce plants grown in plots with postSolarization amendment of compost (data not shown).

Lettuce yield was increased in solarized plots at both locations in fall and spring crops (Table 1). In the fall crop, total yield was increased after solarization by 51 and 12% at KAC and WSFS, respectively. The corresponding yield increase in the spring crop was 93 and 9%, respectively. There was no significant interaction effect of solarization and fertilizer amendments on lettuce yield. Nevertheless, yield of lettuce in the presolarized compost-amended soils was 24 and 26% higher than that in the plots that were solarized without compost treatment at KAC and WSFS, respectively. In contrast, postSolarization compost amendment resulted in reduction in fall yield at both sites. Lettuce yield was reduced in this treatment by 24 and 4% compared with solarization alone at KAC and WSFS, respectively. The negative effect of the postSolarization compost amendment on lettuce yield was not evident in the spring crop in either experiment. Lettuce yields in the ammonium-phosphate-treated plots were not significantly different from those in the corresponding controls (Table 1). Differences in total yield among treatments were similar to those of mean fresh weight of lettuce heads (data not shown).

Nematode infection. Root galling caused by *M. incognita* was reduced significantly by solarization and to a lesser extent by soil amendment with compost and ammonium phosphate in the fall crop at KAC (Table 2). Galling was totally eliminated in solarized plots amended with compost during the entire crop season. A significant linear relationship was established between nematode infection and lettuce yield (*y* = 12.3 [gall percentage] − 0.36; *r*² = 0.713) in the fall crop. However, although nematode infection was very mild in the spring crop, there were still significant differences in yield among treatments. The greenhouse experiment conducted to determine if infective nematodes were present in soil during the spring crop showed low levels of galling in the nonsolarized treatments but not in the solarized treatments.

**Rhizosphere colonization.** Colony-forming units of *P. ultimum* were effectively reduced by solarization and slightly reduced by fertilizer amendments prior to harvest at both KAC and WSFS. The number of *Pythium* propagules in soil was reduced by solarization below detectable levels compared with 45 and 30 cfu/g of soil in the nonsolarized treatments at KAC and WSFS, respectively. Colonization of lettuce rhizosphere by *P. ultimum* was assayed four times during fall crops and three times during spring crops, and establishment of the fungus was found to be significantly suppressed in solarized plots at both sites (Table 3). Colonization of lettuce rhizosphere by *P. ultimum* during the fall crop was suppressed by 82 and

### Table 1. Effect of soil solarization, chicken compost, and ammonium phosphate fertilization on fresh yield of leaf lettuce in two successive crops, 1991–1992

<table>
<thead>
<tr>
<th>Site Soil treatment</th>
<th><strong>Fall crop fresh yield (t/ha)</strong></th>
<th><strong>Spring crop fresh yield (t/ha)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Compost</td>
<td>Early</td>
</tr>
<tr>
<td>Kearney Agricultural Center</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-solarized</td>
<td>6.6</td>
<td>9.0</td>
</tr>
<tr>
<td>Solarized</td>
<td>11.0</td>
<td>13.7</td>
</tr>
<tr>
<td>LSD of main effects (<em>P</em> = 0.05)³</td>
<td>Fall</td>
<td>Spring</td>
</tr>
<tr>
<td>Solarization</td>
<td>0.55</td>
<td>0.64</td>
</tr>
<tr>
<td>Fertilizer amendment</td>
<td>0.63</td>
<td>0.72</td>
</tr>
<tr>
<td>Time of fertilizer application</td>
<td>0.75</td>
<td>0.93</td>
</tr>
<tr>
<td>West Side Field Station</td>
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<td></td>
</tr>
<tr>
<td>Non-solarized</td>
<td>9.3</td>
<td>10.2</td>
</tr>
<tr>
<td>Solarized</td>
<td>10.2</td>
<td>12.9</td>
</tr>
<tr>
<td>LSD of main effects (<em>P</em> = 0.05)³</td>
<td>Fall</td>
<td>Spring</td>
</tr>
<tr>
<td>Solarization</td>
<td>0.47</td>
<td>0.42</td>
</tr>
<tr>
<td>Fertilizer amendment</td>
<td>0.63</td>
<td>0.53</td>
</tr>
<tr>
<td>Time of fertilizer application</td>
<td>0.51</td>
<td>0.74</td>
</tr>
</tbody>
</table>

³Compost and ammonium phosphate were applied either before solarization (early) or after termination of solarization and before planting (late).

³Because there were no significant interactions among the main effects, LSD values are given only for the main effects.

### Table 2. Effect of soil solarization, chicken compost, and ammonium phosphate fertilization on root galling of leaf lettuce by *Meloidogyne incognita* at Kearney Agricultural Center 28 and 70 days after planting

<table>
<thead>
<tr>
<th>Soil treatment</th>
<th><strong>28 Days after planting</strong></th>
<th><strong>70 Days after planting</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No amendment</td>
<td>Compost</td>
</tr>
<tr>
<td>Non-solarized</td>
<td>30.0</td>
<td>24.0</td>
</tr>
<tr>
<td>Solarized</td>
<td>4.8</td>
<td>0.0</td>
</tr>
<tr>
<td>LSD of main effects (<em>P</em> = 0.05)³</td>
<td>28 days</td>
<td>70 days</td>
</tr>
<tr>
<td>Solarization</td>
<td>5.8</td>
<td>4.2</td>
</tr>
<tr>
<td>Fertilizer amendment</td>
<td>6.4</td>
<td>3.8</td>
</tr>
<tr>
<td>Time of fertilizer application</td>
<td>5.5</td>
<td>4.1</td>
</tr>
</tbody>
</table>

³Compost and ammonium phosphate were applied either before solarization (early) or after termination of solarization and before planting (late).

³Because there were no significant interactions among the main effects, LSD values are given only for the main effects. Data were arcsine-transformed for statistical analysis.
100% in the solarized plots compared with the nonsolarized plots at KAC and WSFS, respectively. Suppression of *P. ultimum* remained evident in the spring crop at both locations (Table 3). Plants were uprooted at the KAC experiment at the end of spring crop and assayed for *P. ultimum* infection by root isolation; *P. ultimum* was recovered from 90% of the root segments showing symptoms of root rot.

Numbers of total fungi before planting were significantly reduced in solarized soil by 65–78% compared with numbers in nonsolarized soil at harvest (Table 4). Establishment of fungi in the rhizosphere of lettuce plants grown in solarized soil was suppressed in both KAC and WSFS fields. Results were inconsistent after soil amendment with compost or ammonium phosphate. Suppression of fungal establishment in the rhizosphere of lettuce plants in solarized plots was evident also in the spring crop in both fields, but to a lesser extent than in the fall.

In contrast to the effect of solarization on fungi, numbers of *Bacillus* spp. in soil were not significantly reduced after solarization, and numbers of colony-forming units increased in the rhizosphere of lettuce plants in solarized plots compared with nonsolarized plots when assayed at harvest (Table 5). Numbers of *Bacillus* spp. remained higher in rhizosphere of plants in the solarized plot in the spring crop at both sites. Numbers of fluorescent pseudomonads also were six to 10 times higher in the rhizosphere of lettuce plants in solarized plots than in plants in nonsolarized plots in the fall crop (Table 6). Numbers of these bacteria remained higher in the rhizosphere of plants in solarized soil in the spring crop at both field sites.

**Discussion**

Solarization of compost-amended soil was very effective in controlling *M. incognita* in lettuce at the KAC location.

### Table 3. Effect of soil solarization, chicken compost, and ammonium phosphate fertilization on survival of *Pythium ultimum* in the rhizosphere of leaf lettuce at two field locations, 1991–1992

<table>
<thead>
<tr>
<th>Site</th>
<th>Soil treatment</th>
<th>No amendment</th>
<th>Compost</th>
<th>(NH₄)₂PO₄</th>
<th>No amendment</th>
<th>Compost</th>
<th>(NH₄)₂PO₄</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Early</td>
<td>Late</td>
<td>Early</td>
<td>Late</td>
<td>Early</td>
</tr>
<tr>
<td>Kearney Agricultural Center</td>
<td>Non-solarized</td>
<td>232</td>
<td>222</td>
<td>155</td>
<td>230</td>
<td>226</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>Solarized</td>
<td>46</td>
<td>32</td>
<td>52</td>
<td>53</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>LSD of main effects (P = 0.05)</td>
<td>Fall</td>
<td>19</td>
<td>25</td>
<td>53</td>
<td>21</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>West Side Field Station</td>
<td>Non-solarized</td>
<td>80</td>
<td>70</td>
<td>66</td>
<td>60</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Solarized</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

### Table 4. Effect of soil solarization, chicken compost, and ammonium phosphate fertilization on survival of fungi in the rhizosphere of leaf lettuce at two field locations, 1991–1992

<table>
<thead>
<tr>
<th>Site</th>
<th>Soil treatment</th>
<th>No amendment</th>
<th>Compost</th>
<th>(NH₄)₂PO₄</th>
<th>No amendment</th>
<th>Compost</th>
<th>(NH₄)₂PO₄</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Early</td>
<td>Late</td>
<td>Early</td>
<td>Late</td>
<td>Early</td>
</tr>
<tr>
<td>Kearney Agricultural Center</td>
<td>Non-solarized</td>
<td>240</td>
<td>250</td>
<td>210</td>
<td>290</td>
<td>240</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Solarized</td>
<td>72</td>
<td>66</td>
<td>64</td>
<td>50</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>LSD of main effects (P = 0.05)</td>
<td>Fall</td>
<td>35</td>
<td>28</td>
<td>72</td>
<td>32</td>
<td>48</td>
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</tr>
<tr>
<td>West Side Field Station</td>
<td>Non-solarized</td>
<td>360</td>
<td>300</td>
<td>320</td>
<td>250</td>
<td>280</td>
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<tr>
<td></td>
<td>Solarized</td>
<td>60</td>
<td>64</td>
<td>62</td>
<td>84</td>
<td>74</td>
<td></td>
</tr>
</tbody>
</table>

**Compost and ammonium phosphate were applied either before solarization (early) or after termination of solarization and before planting (late).**

**Because there were no significant interactions among the main effects, LSD values are given only for the main effects.**
Solarization alone or combined with other fertilizer regimes gave only partial control of *M. incognita*, as reported in other studies (25,26). Soil amendment with chicken compost or ammonium phosphate without solarization resulted in slight reduction of root galling by *M. incognita* and of numbers of *P. ultimum*, as previously reported (16,17,24). Temperature of solarized soil amended with compost increased by two to three degrees centigrade, compared with non-amended solarized soil, which may be an important factor for improving control of *M. incognita* and other high-temperature organisms. Possible reasons for the increase in soil temperature are increased soil moisture and thermal conductivity in the compost-amended soil and/or exothermic microbial activity. The improved control of root-knot nematode in solarized soil amended with organic material also may be attributed to increased volatile evolution from the decomposing compost (10,28). Nematode infection was not evident in any treatment in the spring crop at KAC. Soil temperatures during the spring crop were probably too low for nematode activity, as supported by the greenhouse experiment, in which tomato plants grown in soil samples taken from the field became galled in the non-amended soil.

Yield of both fall and spring lettuce crops was increased by solarization at both locations. Increase in lettuce yield following solarization was evident in both total fresh yield (Table 1) and mean head weight (*data not shown*). Post-solarization compost treatment had a negative effect on lettuce growth and yield in the fall crop compared with solarization alone at both sites (Table 1). In contrast, other compost treatments showed no negative effects on plant growth. It is possible that post-solarization compost amendment decomposed more slowly in soil because of reduction of nitrifying bacteria and/or release of phytotoxic compounds during the first weeks of crop growth. This

### Table 5. Effect of soil solarization, chicken compost, and ammonium phosphate fertilization on survival of *Bacillus* spp. in the rhizosphere of leaf lettuce at two field locations, 1991–1992

<table>
<thead>
<tr>
<th>Site</th>
<th>Soil treatment</th>
<th>No amendment</th>
<th>Compost</th>
<th>(NH₄)₂PO₄</th>
<th>No amendment</th>
<th>Compost</th>
<th>(NH₄)₂PO₄</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td>Early</td>
<td>Late</td>
<td></td>
<td>Early</td>
<td>Late</td>
</tr>
<tr>
<td>Kearney Agricultural Center</td>
<td>Non-solarized</td>
<td>70</td>
<td>61</td>
<td>90</td>
<td>98</td>
<td>90</td>
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</tr>
<tr>
<td></td>
<td>Solarized</td>
<td>210</td>
<td>200</td>
<td>250</td>
<td>180</td>
<td>200</td>
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</tr>
<tr>
<td>LSD of main effects (P = 0.05)</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Solarization</td>
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<td></td>
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<tr>
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<tr>
<td>Time of fertilizer application</td>
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<tr>
<td>West Side Field Station</td>
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<td>250</td>
<td>122</td>
<td>215</td>
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<tr>
<td></td>
<td>Solarized</td>
<td>566</td>
<td>578</td>
<td>614</td>
<td>570</td>
<td>636</td>
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</tr>
<tr>
<td>LSD of main effects (P = 0.05)</td>
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</tr>
<tr>
<td>Solarization</td>
<td>41</td>
<td>43</td>
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<tr>
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<td>Time of fertilizer application</td>
<td>37</td>
<td>38</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

*Compost and ammonium phosphate were applied either before solarization (early) or after termination of solarization and before planting (late).

*Because there were no significant interactions among the main effects, LSD values are given only for the main effects.

### Table 6. Effect of soil solarization, chicken compost, and ammonium phosphate fertilization on survival of fluorescent pseudomonads in the rhizosphere of leaf lettuce at two field locations, 1991–1992

<table>
<thead>
<tr>
<th>Site</th>
<th>Soil treatment</th>
<th>No amendment</th>
<th>Compost</th>
<th>(NH₄)₂PO₄</th>
<th>No amendment</th>
<th>Compost</th>
<th>(NH₄)₂PO₄</th>
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<tbody>
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<td></td>
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<td></td>
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<td>Late</td>
<td></td>
<td>Early</td>
<td>Late</td>
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<tr>
<td>Kearney Agricultural Center</td>
<td>Non-solarized</td>
<td>5</td>
<td>12</td>
<td>10</td>
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<td>8</td>
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</tr>
<tr>
<td></td>
<td>Solarized</td>
<td>65</td>
<td>56</td>
<td>57</td>
<td>72</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>LSD of main effects (P = 0.05)</td>
<td>Fall</td>
<td></td>
<td></td>
<td></td>
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<td>Solarization</td>
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<td>15.2</td>
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<td>Non-solarized</td>
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<td>12</td>
<td>12</td>
<td>10</td>
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<td>LSD of main effects (P = 0.05)</td>
<td>Fall</td>
<td></td>
<td></td>
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<tr>
<td>Solarization</td>
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<td>11.4</td>
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<tr>
<td>Fertilizer amendment</td>
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<td>15.1</td>
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<tr>
<td>Time of fertilizer application</td>
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<td>11.2</td>
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</table>

*Compost and ammonium phosphate were applied either before solarization (early) or after termination of solarization and before planting (late).

*Because there were no significant interactions among the main effects, LSD values are given only for the main effects.

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possibility is supported by the fact that no other compost treatments had adverse effects on lettuce growth. No negative effect of post-solarization composting was observed in the spring crop at either experiment.

Yield of lettuce in the fall crop at KAC was highly correlated with the severity of root galling. However, increased parasitic yield after solarization was significant at KAC in the spring crop, even when nematode galling did not occur. Other factors, such as root infection by *P. ultimum* and other soilborne pathogens (18), could have been responsible.

*P. ultimum* extensively colonized the rhizosphere of lettuce plants grown in non-solarized soil in the fall and, especially, the spring crops. Rootlet injury was evident in plants grown in non-solarized soil in the spring crop at KAC, and *P. ultimum* was the predominant fungus isolated from those rootlets. This was perhaps due to cold spring soil temperature favoring *P. ultimum* activity following the buildup of populations during the fall crop. Rootlet injury was less evident in the spring crop at WSFS, where lower numbers of *Pythium* propagules in the rhizosphere were recorded (Table 3). Rootlet injury was not evident in either experiment in plants grown in solarized soil.

Numbers of both *Bacillus* spp. and fluorescent pseudomonads were increased in the rhizosphere of lettuce plants in solarized soils during fall and spring crops at the two sites. Populations of *Bacillus* spp. were not reduced during the solarization process as shown previously (26). In contrast, fluorescent pseudomonads that are heat-sensitive and do not survive solarization in high numbers also increased in the rhizosphere of plants in solarized soils in accordance with previous studies (7-9,22). Many species of both bacterial groups are considered to promote plant growth (1,8,19,20). Suppression of major and minor pathogens in solarized soil was related in a previous study to high numbers of fluorescent pseudomonads in the rhizosphere and roots (8). *Bacillus* spp. are also known for antibiotic production (5,23). Increased populations of both fluorescent pseudomonads and *Bacillus* spp. in the rhizosphere of plants grown in solarized soil might be an important factor in the suppression of pathogens and increased yield, as shown in previous studies (5,8,9,23). The direct interaction between these bacteria and pathogens was not tested in this study.

Combination of compost amendment and solarization was very effective in controlling *M. incognita* and *P. ultimum* and resulted in significantly improved lettuce yield in two consecutive crops.

The use of available organic amendments such as composts, plant residues, green manures, and fertilizers may be an effective, nonchemical way to improve pesticidal efficacy when solarization alone cannot provide adequate control of target pathogens. Further studies will be required to explore the wide range of possibilities.

**ACKNOWLEDGMENTS**

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**LITERATURE CITED**