CHITINOUS MATERIALS FROM BLUE CRAB FOR CONTROL OF ROOT-KNOT NEMATODE II. EFFECT OF SOYBEAN MEAL

R. Rodríguez-Kábana, D. Boubé, and R. W. Young

Department of Plant Pathology, Auburn University, Alabama Agricultural Experiment Station, Auburn, Alabama 36849-5409, U.S.A.

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ABSTRACT


The efficacy of mixtures of soybean meal (SBM), urea and a chitinous material (Clandosan 601) derived from blue crab (Callinectes sapidus) wastes for control of Meloidogyne arenaria was studied under greenhouse conditions. Soil amendments containing 2–4 g SBM/kg of soil were most effective in reducing galls caused by M. arenaria in squash (Cucurbita pepo) roots when SBM was added to soil together with 1 g of Clandosan 601 and 0.5 g urea/kg of soil. These amendments stimulated microbial activity of soil as evidenced by increased soil enzymatic activities. Soil chitobiase activity increased with increasing rates of SBM added to soil and was related inversely to the number of galls/g of fresh squash root. Microplot studies demonstrated that a mixture containing by weight 50% SBM, 25% urea, and 25% Clandosan 601 when applied to soil at 8 t/ha was effective in suppressing M. incognita and increasing yield of ‘Purple Hull’ cowpea (Vigna unguiculata), ‘Black Beauty’ eggplant (Solanum melongena), and ‘Culbro’ tobacco (Nicotiana tabacum). The amendment also reduced numbers of M. incognita in ‘Jewel’ sweet potato (Ipomea batatas) but did not increase yield.

Key words: biological control, Callinectes sapidus, chitin, chitobiase, Clandosan 601, invertase, Meloidogyne, M. arenaria, M. incognita, organic amendments, phosphatase, root-knot nematodes, soil enzymes, urea, urease.

RESUMEN


Se estudió en un experimento de invernadero la eficacia de mezclas de harina de torta de soya (HTS) con urea y con un material quitinoso de desecho Clandosan 601 derivado del cangrejo azul (Callinectes sapidus) para combatir Meloidogyne arenaria. La incorporación de HTS al suelo a razón de 2–4 g/kg de suelo resultó ser muy eficaz para reducir el agallamiento causado por M. arenaria en las raíces de calabacín (Cucurbita pepo) cuando el HTS se añadió al suelo en conjunto con 1 g Clandosan 601 y 0.5 g de urea/kg de suelo. La incorporación de estos materiales al suelo estimuló las actividades microbianas evidenciadas por aumentos en las actividades enzimáticas del suelo. La actividad de la quitobiasa del suelo aumentó proporcionalmente con la cantidad de HTS añadida al suelo y esta
actividad estuvo inversamente correlacionada con el número de agallas causadas por *M. arenaria* en las raíces de calabacín. Estudios con microparcelas demostraron que la incorporación al suelo de 8 t/ha de una mezcla que contenía por peso 50% HTS, 25% urea y 25% Clandosan 601, redujo la incidencia de *M. incognita* y aumentó la producción de frijol de costa 'Purple Hull' (*Vigna unguiculata*), berenjena 'Black Beauty' (*Solanum melongena*) y tabaco 'Culbro' (*Nicotiana tabacum*). También se observó que si bien la incorporación de esta mezcla al suelo controló *M. incognita* en boniato 'Jewel' (*Ipomea batatas*) esto no resultó en aumento en la producción.


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**INTRODUCTION**

The use of nitrogenous organic matter to amend soil to suppress plant-parasitic nematodes and provide nutrients to crops can be a successful strategy to manage *Meloidogyne* spp. in vegetables and other susceptible crops (8,11,16). The most effective amendments are those with narrow C:N ratios that generate ammonia at nematicidal levels when incorporated into soil (8,14). A special category of these nitrogenous amendments are those that contain chitin. When added to soil chitinous matter stimulates the activities of microorganisms capable of decomposing this aminated polymer (6,10,17). Several of these microbial species are capable of destroying eggs and egg masses of *Meloidogyne* spp. (2,3,12). Previous research at Auburn University has shown that combinations of chitinous matter (Clandosan 601, IGENE Biotechnology, Columbia, Maryland, 21045, U.S.A.) with urea can be effective for control of *Meloidogyne* spp. (9). These combinations stimulate ureolytic and chitinolytic microflora in soil, resulting in reduction of ammonia and increased soil chitinolytic activity—phenomena that are detrimental to *Meloidogyne* spp. The objective of the work was to determine if fertilizer amendments consisting of mixtures of soybean meal (SBM) with urea and Clandosan 601 could be used to control *Meloidogyne* spp.

**MATERIALS AND METHODS**

*Greenhouse study: A greenhouse experiment was established to determine the effect of mixtures of soybean (*Glycine max* (L.) Merr.) meal, urea, and Clandosan 601 on plant-parasitic nematodes. The composition and properties of Clandosan 601 were presented previously (9). Soil for the experiment was a sandy loam (74% sand, 15% silt, 10% clay) from a peanut (*Arachis hypogaea* L.) field at the Wiregrass substation, near Headland, Alabama with the following characteristics: pH = 6.1, organic matter content < 1.0%, and cation exchange capacity < 10 meq./100 g of soil. The soil was infested with root-knot nematode (*M. arenaria* (Neal) Chitwood). Plant debris and large particles were removed*
by screening (1-mm-pore sieve) and the soil was mixed 1:1(v:v) with builder's fine (< 1 mm) sand. In this paper the soil-sand mixture will be referred to as soil. The moist (60% of field capacity [FC]) soil was apportioned in 1-kg amounts and placed in 3-L capacity plastic bags and was treated with the appropriate amendment. After thorough mixing the amended soils were transferred to 10-cm-diam, 1-L-capacity plastic pots. Pots with soil were maintained moist (60% FC) for 15 days when five 'Summer Crookneck' squash (Cucurbita pepo L.) seed were planted in each pot. Plants were allowed to grow for 6 weeks and then were removed. For each plant, shoot height and the fresh weight of shoots and roots were recorded. The number of root galls caused by M. arenaria were counted and a root-knot index value was assigned according to Zeck's scale (19). Soil samples for nematode analysis consisted of 100 cm³ from each pot. Nematode populations in the soil were determined with the "salad bowl" incubation method (13); root populations also were assessed with the same method by incubating roots from each pot. The remainder of the soil from each pot was air-dried at 26–28 C, placed in a plastic bag and stored in a dry, dark, cool (4 C) atmosphere until analyzed for enzymatic activity and other biochemical parameters. Determinations of soil pH, conductivity of soil water extract, and chitobiase (β-N-acetyl-D-glucosaminidase), phosphatase, and urease activities of soil were as described previously (9). All biochemical determinations were performed within 6 weeks after termination of the experiment.

Amendments in the experiment were with soybean meal (SBM) at rates of 0,1,2,3, and 4 g/kg of soil. In addition, each rate of soybean meal was mixed with 1.0 g of Cladosan 601 and 0.5 g of urea/kg of soil so as to have 20 treatments representing all possible combinations of soybean meal rates with Cladosan 601 and urea. Each treatment was replicated eight times and the pots (experimental units) were arranged in a completely randomized design.

All data were analyzed according to standard procedures for analysis of variance (18); Fisher's least significant differences were calculated and are included in the figures. Curve fitting was by the least square method (5). Unless otherwise stated all differences referred to in the text were significant at the 5% or lower level of probability.

Microplot study: Four microplot experiments were established to assess the efficacy of amending soil with a mixture of Cladosan 601 + SBM + urea for controlling root-knot nematode. The microplots were located at the old Agronomy Farm on the Auburn campus in a soybean field with soil free of root-knot nematodes. Microplots were delimited by square terra-cotta chimney liners 60 cm long × 30 cm wide. Each liner was buried into the soil to a depth of 50 cm leaving 10 cm of wall above the ground surface. A 15-cm-diam plastic cylinder 46 cm long was
placed at the center of each microplot and the space between the cylinder and the inside wall of the liner was filled with soil from outside of the plot. Each plastic cylinder was then filled with soil infested with *M. incognita* which had received the appropriate treatment. Soil for the treatments was a sandy loam from a soybean field in south Alabama infested with *M. incognita*. This soil had similar properties and composition to that used for the greenhouse experiment. The soil was sifted to remove debris and large particles and sand was added as described for the greenhouse experiment. The soil was apportioned in 7-kg amounts and placed in 10-L capacity plastic bags so as to have 32 bags with soil for each experiment, i.e., one bag for each microplot. Soil in 16 bags was left untreated and the soil in each of the remaining bags was placed in a concrete mixer and treated with a mixture of urea (1.0 g/kg of soil), Clandosan 601 (1.0 g/kg of soil) and SBM (2 g/kg of soil) which will be referred to as the chitinous amendment in this paper. After thorough mixing the soil was placed back in the plastic bag for delivery to the appropriate microplot. Bags with untreated soil also were transferred to the microplots. The soil in the microplots was kept moist (60% FC) for 2 weeks when the plots were planted. At planting time eight of the microplots with untreated soil and eight of those with the chitinous amendment were treated with 0.83 g of the 15G formulation of aldicarb (13.5 kg a.i./ha, broadcast basis). The nematicide granules were spread evenly on the area delimited by the plastic cylinder at the center of each plot and were then incorporated to a depth of 3–4 cm. Each microplot experiment thus consisted of four treatments with eight replications (microplots) arranged in a randomized complete block design. The treatments were: control, adicarb, chitinous amendment, and chitinous amendment + aldicarb.

One microplot experiment was with ‘Black Beauty’ eggplant (*Solanum melongena* L.), one with ‘Purple Hull’ cowpea (*Vigna unguiculata* (L.) Walpers), one with ‘Culbro’ wrapper tobacco (*Nicotiana tabacum* L.) and one with ‘Jewel’ sweet potato (*Ipomea batatas* (L.) Lam.). The eggplant and tobacco seedlings were 10–12 cm tall at time of transplant (one seedling/microplot). Sweet potatoes were planted using one rooted stem piece (slip) per microplot and cowpeas were planted using five seeds per microplot. In all cases the planting was done in the area enclosed by the plastic cylinder which was removed immediately before planting.

All microplots were fertilized 2 weeks after planting with 8-8-8 fertilizer. Weed control was by hand and control of foliar insects was as needed using malathion. Foliar diseases were not a problem and no fungicide was used. The microplots were watered as needed.

Soil samples for nematode analysis were collected at termination of the experiments. Each sample consisted of four 2.5-cm-diam cores/plot taken to a depth of 20–25 cm from the area originally delimited by the
plastic cylinder. The cores from each microplot were composited and a 100-cm³ subsample was used to assess nematode numbers with the "salad bowl" incubation technique.

Yield data were collected as the crops matured. At termination of each experiment the total weight of above-ground plant growth also was determined. Data were analyzed statistically as described for the greenhouse experiment.

RESULTS

Greenhouse study: The number of galls/g of fresh root declined proportionately in response to increasing amounts of soybean meal (Fig. 1A). The addition of urea increased the effectiveness of the soybean meal amendments in reducing numbers of galls. The Clandosan 601 amendment alone resulted in a 50% reduction in the number of galls and the mixture of Clandosan 601 with the 1-g rate of SBM resulted in lower numbers than those obtained with SBM alone at the 1-g rate. There was no difference in numbers of galls between the SBM treatments and those with SBM + Clandosan 601 when SBM was applied at rates > 1.0 g/kg of soil. Differences between treatment with SBM + urea and those with SBM + urea + Clandosan 601 were not significant. Treatment with SBM + urea + Clandosan 601 resulted in lower numbers of galls/g of fresh root than amendments with SBM alone.

Plants with the lowest root-knot index values were those in soils treated with urea (Fig. 1B). With one exception (urea alone) all treatments with urea resulted in index values that were not different from zero. In contrast, treatments with soybean meal alone or with SBM + Clandosan 601 resulted in index values > 1.0.

Fresh shoot weight increased directly in response to increasing rates of soybean meal in all treatments containing Clandosan 601 (Fig. 1C); treatments with SBM alone at rates of 1 and 2 g/kg of soil resulted in increased shoot weights. The addition of urea + SBM to soil increased shoot weights directly in proportion to the amount of the meal in the range of 0–3 g SBM/kg of soil; however, shoots of plants grown in soil with urea + the 4-g rate of SBM were not heavier than those from soil with urea alone.

Plants in soils treated with Clandsan 601 generally were taller than those grown in soils without Clandosan 601 (Fig. 1D). Shoot height increased in response to the amount of soybean meal in treatments with SBM + Clandosan 601 when SBM was in the range of 0–3 g/kg of soil, but when urea was added to these treatments maximal response to SBM was obtained with the 1-g rate of SBM. No additional increase in shoot height was observed in response to mixtures of urea with higher rates of SBM. Treatments with SBM alone resulted in maximal shoot heights
Fig. 1. Effect of amending soil with soybean meal alone and in combination with 1.0 g of Clandosan 601 and 0.5 g of urea/kg of soil on development of root-knot nematode (Meloidogyne arenaria) and growth of 'Summer Crookneck' squash in a greenhouse experiment. A) Galls/g of fresh root. B) Root-knot index. C) Fresh shoot weight. D) Shoot height.
when the meal was added at the 1- and 2-g rates; the 3- and 4-g rates resulted in plants that were taller than those from the control without SBM. The addition of urea + SBM to soil in the range of 0–3 g/kg of soil resulted in shoot height responses directly proportional to the amount of SBM added; the 4-g SBM rate + urea resulted in plants no taller than those from soil with urea and no SBM.

Soil pH declined sharply in response to increasing rates of SBM in the treatments consisting of SBM alone (Fig. 2A). Mixtures of SBM + Clandosan 601 resulted in higher soil pH values than the treatments with SBM alone; however, the pattern of changes in pH observed for treatments with SBM alone also was true for the SBM + Clandosan 601 treatments. The addition of urea alone to soil resulted in increased pH values in a manner proportionate to SBM rates. Treatments with SBM + urea + Clandosan 601 resulted in pH values > 5.9; the highest pH value for these mixtures was in soil treated with the 1-g rate of SBM. Soil pH values for all other SBM + urea + Clandosan 601 treatments were not different from 6.0, the pH of the unamended soil.

Conductivity values of the water extract were generally lower for soils with SBM alone or with SBM + urea than for soils treated with Clandosan 601 (Fig. 2B).

Fig. 2. Effect of amendments with soybean meal alone and in combination with 1.0 g of Clandosan 601 and 0.5 g of urea/kg of soil on soil pH (A) and conductivity of soil water extract (B) in a greenhouse experiment with soil infested with *Meloidogyne arenaria*.
Fig. 3. Effect of amending soil with soybean meal alone and in combination with 1.0 g of Cldosan 601 and 0.5 g of urea/kg of soil on enzymatic and galls/g of fresh root of a soil infested with *Meloidogynearenaria* and planted with 'Summer Crookneck' squash. A) Chitobiase (β-N-acetyl-D-glucosamidase) activity. B) Relation between soil chitobiase activity and the amount of soybean meal added. C) Relation between number of root galls caused by *M. arenaria* and soil chitobiase activity.

Soil chitobiase activity increased with increasing rates of soybean meal (Fig. 3A). This pattern of chitobiase activity \(Y\) in response to
Fig. 4. Effect of amending soil alone and in combination with 1.0 g of Clandosan 601 and 0.5 g of urea/kg of soil infested with *Meloidogyne arenaria* and planted with 'Summer Crookneck' squash on activity of (A) urease, (B) invertase, and (C) acid phosphatase.

soybean rates ($X$) was true for all treatments (Fig. 3B) and could be expressed ($R^2 = 0.99$) in a general manner by:

$$\frac{[-3.39-\ln X]^2}{Y = 5.68e^{27.43}}$$

for $0.1 < X < 4.0$. 
With some exceptions, soils treated with Clandosan 601 and SBM at rates > 1.0 g/kg of soil, exhibited higher chitobiase activity than soils with SBM alone. The relationship between soil chitobiase activity (X) and the number of galls/g of fresh root (Y) was defined ($R^2 = 0.59$) by:

$$Y = -13.29 + \frac{234.55}{X}$$

for $4 < X < 18$ (Fig. 3C).

In general, soil urease activity (Fig. 4A) was lowest in soils treated with SBM + urea and highest for soils with SBM alone or with SBM + Clandosan 601; soils with SBM + urea + Clandosan 601 were intermediate in activity.

Soil invertase activity increased in response to increasing SBM rates in the range of 0–3 g/kg of soil for soils treated with SBM alone or with SBM + urea + Clandosan 601 (Fig. 4B). Treatments with SBM + urea resulted in lower invertase activity values than treatments with SBM alone. Invertase activities of soils treated with SBM alone or with SBM + Clandosan 601 were equivalent.

Acid phosphatase activity of soils treated with SBM alone or with SBM + urea + Clandosan 601 increased directly in response to increasing SBM rates (Fig. 4C). This also was true for soils that received SBM + Clandosan 601, except that the range of direct response was from 0–3 g SBM/kg of soil. The SBM + urea amendments increased soil phosphatase activity, but there was no clear relation between activity values and rates of SBM.

*Microplot study*: Application of aldicarb and of the chitinous amendment resulted in increased eggplant yield and more fruits per microplot (Table 1). The chitinous amendment + aldicarb treatment also in-

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Table 1. Comparison of the effects of chitinous amendment and aldicarb on growth and yield of 'Black Beauty' eggplant and on populations of *Meloidogyne incognita* second-stage juveniles (J2) in a microplot experiment at Auburn, Alabama.

<table>
<thead>
<tr>
<th></th>
<th>Number of fruits</th>
<th>Fresh shoot weight (kg/plot)</th>
<th>Yield (kg/plot)</th>
<th><em>M. incognita</em> (J2/100 cm$^3$ of soil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>8.5</td>
<td>1.07</td>
<td>2.43</td>
<td>232</td>
</tr>
<tr>
<td>Aldicarb†</td>
<td>14.1</td>
<td>1.75</td>
<td>3.88</td>
<td>269</td>
</tr>
<tr>
<td>Amendment‡</td>
<td>15.6</td>
<td>1.52</td>
<td>3.98</td>
<td>175</td>
</tr>
<tr>
<td>Amendment + aldicarb</td>
<td>18.8</td>
<td>2.21</td>
<td>5.20</td>
<td>161</td>
</tr>
<tr>
<td>FLSD (0.05)</td>
<td>3.4</td>
<td>0.52</td>
<td>0.69</td>
<td>52</td>
</tr>
</tbody>
</table>

†13.5 kg a.i./ha on a broadcast basis.
‡8 t/ha on a broadcast basis.
creased fresh shoot weights when compared to plants in plots that received the chitinous amendment alone. The highest yields and the greatest number of fruits were obtained from plots that received aldicarb + chitinous amendment. Aldicarb alone did not have any effect on final populations of M. incognita juveniles in soil (Table 1); however, plots treated with the chitinous amendment or with aldicarb + chitinous amendment had lower juvenile populations than the control or those treated with aldicarb alone.

Populations of M. incognita juveniles in soil at harvest were lower in the cowpea experiment than in the eggplant experiment (Table 2). All treatments reduced juvenile populations of the nematode in soil and plots with the chitinous amendment in combination with aldicarb had the lowest juvenile populations of the nematode. All plots with the chitinous amendment had higher numbers of nonparasitic nematodes than the control, but treatment with aldicarb alone had no effect on populations of these nematodes. Microplots with the chitinous amendment alone were the only ones that had higher yields than the control (Table 2). The treatments had no effect on the number of pods/plot, and aldicarb alone was the one treatment that resulted in increased fresh vine weights.

On tobacco all treatments resulted in increased leaf and shoot weights, and plants in plots with the chitinous amendment had heavier shoots and greater fresh leaf weights than those treated with aldicarb alone (Table 3). All treatments suppressed M. incognita juvenile populations in soil, and microplots treated with chitinous amendment + aldicarb had the lowest population. Plots treated with aldicarb alone or with the chitinous amendment without the nematicide had the highest numbers of nonparasitic nematodes.

Table 2. Comparison of the effects of chitinous amendment and aldicarb on growth and yield of ‘Purple Hull’ cowpea and on populations of Meloidogyne incognita second-stage juveniles (J2) in soil in a microplot experiment at Auburn, Alabama.

<table>
<thead>
<tr>
<th></th>
<th>Number of pods/plot</th>
<th>Fresh weight (kg/plot)</th>
<th>Yield (kg/plot)</th>
<th>M. incognita (J2/100 cm³ of soil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>193</td>
<td>1.79</td>
<td>0.99</td>
<td>37</td>
</tr>
<tr>
<td>Aldicarb</td>
<td>196</td>
<td>2.64</td>
<td>1.02</td>
<td>18</td>
</tr>
<tr>
<td>Amendment</td>
<td>198</td>
<td>1.68</td>
<td>1.16</td>
<td>4</td>
</tr>
<tr>
<td>Amendment + aldicarb</td>
<td>182</td>
<td>1.94</td>
<td>1.12</td>
<td>0</td>
</tr>
<tr>
<td>FLSD (0.05)</td>
<td>ns</td>
<td>0.43</td>
<td>0.15</td>
<td>13</td>
</tr>
</tbody>
</table>

1 13.5 kg a.i./ha on a broadcast basis.
2 8 t/ha on a broadcast basis.
Table 3. Comparison of the effects of chitinous amendment and aldicarb on growth and yield of ‘Culbro’ tobacco and on populations of *Meloidogyne incognita* second-stage juveniles (J2) in soil in a microplot experiment at Auburn, Alabama.

<table>
<thead>
<tr>
<th></th>
<th>Fresh shoot weight (g/plot)</th>
<th>Fresh leaf weight (g/plot)</th>
<th><em>M. incognita</em> (J2/100 cm³ of soil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>134</td>
<td>167</td>
<td>586</td>
</tr>
<tr>
<td>Aldicarb⁷</td>
<td>272</td>
<td>299</td>
<td>365</td>
</tr>
<tr>
<td>Amendment⁸</td>
<td>403</td>
<td>367</td>
<td>226</td>
</tr>
<tr>
<td>Amendment + aldicarb</td>
<td>402</td>
<td>347</td>
<td>72</td>
</tr>
<tr>
<td>FLSD (0.05)</td>
<td>84</td>
<td>26</td>
<td>166</td>
</tr>
</tbody>
</table>

³13.5 kg a.i./ha on a broadcast basis.
⁸8 t/ha on a broadcast basis.

Sweet potato plots that received aldicarb + chitinous amendment were the only ones with higher tuberous root yields than the control (Table 4). None of the treatments had any effect on vine production, but the weights of fibrous roots were increased by treatment with the chitinous amendment alone. All treatments resulted in lower soil populations of *M. incognita* juveniles than the control (Table 4), and numbers of nonparasitic nematodes were highest in plots treated with the chitinous amendment either alone or in combination with aldicarb.

**DISCUSSION**

Results from the greenhouse experiment showed that there are several combinations of Clandosan 601, SBM, and urea that provide good nematode control compatible with adequate plant growth. The nematicidal action of nitrogenous organic amendments is due principally to

Table 4. Comparison of the effects of chitinous amendment and aldicarb on growth and yield of ‘Jewel’ sweet potato and on populations of *Meloidogyne incognita* second-stage juveniles (J2) in soil in a microplot experiment at Auburn, Alabama.

<table>
<thead>
<tr>
<th></th>
<th>Fresh vine weight (kg/plot)</th>
<th>Fibrous root weight (kg/plot)</th>
<th>Yield (kg/plot)</th>
<th><em>M. incognita</em> (J2/100 cm³ of soil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>7.07</td>
<td>0.19</td>
<td>2.90</td>
<td>41</td>
</tr>
<tr>
<td>Aldicarb⁷</td>
<td>7.72</td>
<td>0.19</td>
<td>3.38</td>
<td>8</td>
</tr>
<tr>
<td>Amendment⁸</td>
<td>7.72</td>
<td>0.28</td>
<td>2.55</td>
<td>1</td>
</tr>
<tr>
<td>Amendment + aldicarb</td>
<td>7.77</td>
<td>0.24</td>
<td>4.22</td>
<td>8</td>
</tr>
<tr>
<td>FLSD (0.05)</td>
<td>ns</td>
<td>0.06</td>
<td>0.80</td>
<td>13</td>
</tr>
</tbody>
</table>

³13.5 kg a.i./ha on a broadcast basis.
⁸8 t/ha on a broadcast basis.
the production of ammonia at nematicidal levels (8,14). Soybean meal and urea were the principal sources of nitrogen in the treatments of the experiment. Clandosan 601 also provided nitrogen in the form of chitin-protein complex (9). The action of organic amendments on nematodes is dependent on the activities of the soil microflora. Stimulation of these activities by the amendments depends on adequate supply of metabolizable carbon and nitrogen in such proportions that microbial activities are not inhibited either by excess nitrogen and inadequate carbon or vice versa. Soil enzymatic activities reflect the activities of the soil microflora (1). The data on invertase and phosphatase activities of soil provided an estimate of effects of the amendments on the general soil microflora. These enzymatic activities are common to most soil microorganisms (1). Invertase and phosphatase activities increased with increasing amounts of SBM for all treatments except those with SBM + urea. This indicates that the C:N ratio of the SBM + urea treatments was too narrow (excess nitrogen) and resulted in a “poisoning” or inhibitory effect on the soil microflora. These treatments, while effective in suppressing root-knot nematodes, were not as successful as those containing Clandosan 601 for increasing shoot weights, indicating a degree of phytotoxicity from the SBM + urea treatments.

Soil chitinase activity and its correlative chitobiase activity reflect the activities of enzymes produced by a select group of actinomycetes, bacteria, and fungi in soil (7). The addition of SBM to soil resulted in increased chitobiase activity for all amendments; however, treatments with Clandosan 601 resulted in soils with maximal chitobiase activity. This is to be expected since the addition of chitin material stimulates the activities of microorganisms capable of decomposing chitin (7,10).

Previous work in our laboratory (9) with a soil system identical to that used in the present study, showed that there is an inverse relationship between suppression of root-knot nematode and chitobiase activity measured 8 weeks after amending soil with Clandosan 601 containing amendments. The relationship between root-knot nematodes and chitobiase activity also was true for this study. The relation between soil chitobiase activity and the number of galls/g fresh root was inverse and hyperbolic (Fig. 3B) and may be based on the ability of chitinolytic organisms to destroy Meloidogyne spp. eggs and egg masses (2,3,12). Stimulation of chitinolytic microflora in soil through addition of amendments could result in increased numbers of organisms capable of destroying Meloidogyne eggs.

Urease activity is ubiquitous in all fertile soils and urease is produced by a large number of soil microorganisms (11). Data from this study showed that addition of SBM resulted in stimulation of ureolytic activity in the soil. The inclusion of urea in the amendment mixtures could be expected to increase urease activity in the soil; however, this was not the
case since treatments with SBM + urea resulted in lower urease activity than those with SBM alone or those with SBM + Clandosan 601. We interpret this as the result of too narrow a C:N ratio in the SBM + urea treatments which may have resulted in accumulation of ammonia and inhibition of general microbial activities (low invertase and phosphatase activities). Accumulation of ammonia may be inhibitory to ureolytic and other microorganisms, but it is a desired effect for control of nematodes. Urease activity was correlated negatively with the number of galls/g of fresh root only in treatments that contained urea and not for those that contained SBM alone or SBM + Clandosan 601.

Results from the greenhouse study indicate that suppression of root-knot nematode depends on an optimal balance in the proportions of SBM, Clandosan 601, and urea used to prepare the amendment. The proportions for mixing the three materials should be so as to provide for stimulation of chitobiasa and urease activities of the soil without inhibition of general microbial activity and no phytotoxic effect to the host plant. The mode of action of the amendments is based on production of ammonia (high urease activity) and concomitant stimulation of soil chitobiasa activity.

Results from the microplot experiments indicate that a formulation containing SBM + urea + chitinous waste can be used to suppress root-knot nematodes and increase yields. The amount of chitinous amendment used in these experiments was equivalent to 8 t/ha on a broadcast basis. Although large, this amount of material is 8–10 times lower than that reported in the literature to obtain nematode suppression using other nitrogenous amendments (8,11,16). The data indicate that the effect of the chitinous amendment on root-knot nematode is equivalent to that of the aldicarb treatment; however, results of the eggplant and tobacco experiments also suggest that the effect of the chitinous amendment is not long lasting since at harvest populations of M. incognita juveniles in plots treated with the chitinous amendment were sufficient to regenerate the root-knot problem in a succeeding susceptible crop (4,15).

Yield data from the sweet potato experiment indicated that the value of the chitinous amendment for suppressing root-knot nematode populations does not necessarily correspond to increased yields. For sweet potatoes, the large amount of nitrogen added to the soil with the chitinous amendment may have been detrimental to the plant, a problem that was obviated in some manner when the chitinous amendment was added together with aldicarb.

The tobacco experiment demonstrated the efficacy of the chitinous amendments for suppressing root-knot nematode and increasing yield. However, the quality of the leaf was affected by the high nitrogen content of the chitinous amendment. Analysis for nitrate content of the
leaves evidenced levels of the anion too high for commercial use of the leaves (data not presented). This fact serves to illustrate that although chitinous amendments may be effective for nematode control their use may be limited to crops that can tolerate high amounts of nitroen.

LITERATURE CITED


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