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# Evaluation of Cover Crops with Potential for Use in Anaerobic Soil Disinfestation (ASD) for Susceptibility to Three Species of *Meloidogyne*

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*Abstract:* Several cover crops with potential for use in tropical and subtropical regions were assessed for susceptibility to three common species of root-knot nematode, *Meloidogyne arenaria*, *M. incognita*, and *M. javanica*. Crops were selected based on potential use as organic amendments in anaerobic soil disinfestation (ASD) applications. Nematode juvenile (J2) numbers in soil and roots, egg production, and host plant root galling were evaluated on arugula (*Eruca sativa*, cv. Nemat), cowpea (*Vigna unguiculata*, cv. Iron & Clay), jack bean (*Canavalia ensiformis*, cv. Comum), two commercial mixtures of Indian mustard and white mustard (*Brassica juncea* & *Sinapis alba*, mixtures Caliente 61 and Caliente 99), pearl millet (*Pennisetum glaucum*, cv. Tifleaf III), sorghum-sudangrass hybrid (*Sorghum bicolor* × *S. bicolor* var. *sudanense*, cv. Sugar Grazer II), and three cultivars of sunflower (*Helianthus annuus*, cvs. 545A, Nusun 660CL, and Nusun 5672). Tomato (*Solanum lycopersicum*, cv. Rutgers) was included in all trials as a susceptible host to all three nematode species. The majority of cover crops tested were less susceptible than tomato to *M. arenaria*, with the exception of jack bean. Sunflower cv. Nusun 5672 had fewer *M. arenaria* J2 isolated from roots than the other sunflower cultivars, less galling than tomato, and fewer eggs than tomato and sunflower cv. 545A. Several cover crops did not support high populations of *M. incognita* in roots or exhibit significant galling, although high numbers of *M. incognita* J2 were isolated from the soil. Arugula, cowpea, and mustard mixture Caliente 99 did not support *M. incognita* in soil or roots. Jack bean and all three cultivars of sunflower were highly susceptible to *M. javanica*, and all sunflower cultivars had high numbers of eggs isolated from roots. Sunflower, jack bean, and both mustard mixtures exhibited significant galling in response to *M. javanica*. Arugula, cowpea, and sorghum-sudangrass consistently had low numbers of all three *Meloidogyne* species associated with roots and are good selections for use in ASD for root-knot nematode control. The remainder of crops tested had significant levels of galling, J2, and eggs associated with roots, which varied among the *Meloidogyne* species tested.

*Key words:* Anaerobic soil disinfestation, ASD, *Brassica juncea* & *Sinapis alba*, *Canavalia ensiformis*, cover crops, cowpea, *Eruca sativa*, *Helianthus annuus*, jack bean, management, *Meloidogyne arenaria*, *M. incognita*, *M. javanica*, mustard, pearl millet, *Pennisetum glaucum*, root-knot nematodes, sorghum-sudangrass, sunflower, *Vigna unguiculata*.

Vegetable and ornamental crop production in Florida remains highly dependent on chemical soil treatments for plant parasitic nematode control (Zasada et al., 2010). The ban on methyl bromide has resulted in the need for an effective alternative pest control and an understanding of the effects of these control strategies on populations of soilborne organisms, particularly root-knot nematodes (*Meloidogyne* spp.) (Rosskopf et al., 2005). One such strategy is the use of anaerobic soil disinfestation (ASD), which can utilize cover crops that could be planted in the summer fallow period in the Florida production system (Butler et al., 2012a; 2012b). In order to successfully employ cover crops in any alternative cropping system for nematode control, an understanding of the cover crop's effects on survival and reproduction of predominant root-knot nematode species is important.

In the southeastern United States, rotation of nematode susceptible crops with cover crops has been routinely recommended for parasitic nematode control. However, although nematode populations often recover following rotation crops, fumigation with methyl bromide is generally reported to result in nematode numbers in soil that remain low throughout the production season of the susceptible cash crop (McSorley, 2011). This has led to the conclusion that rehabilitation of heavily infested sites could require several years of rotation crops, and benefits may only last through one susceptible crop (McSorley, 2011). In-depth studies on effects of soil fumigants on soil nematode populations have shown that the reduction in soil nematode populations following fumigation can be short-term (Kokalis-Burelle et al., 2010). In previous research, field trials were performed in east-central Florida in sandy soil heavily infested with plant parasitic nematodes. Trials included untreated control plots and methyl bromide fumigated plots. Root-knot nematode (*Meloidogyne arenaria*) populations in soil rebounded to higher numbers in fumigated soil compared with untreated soil only a few months after fumigation (Kokalis-Burelle et al., 2010). Additional in-depth research on the effects of all soil treatments on nematode and microbial populations is required for developing cropping systems that can lead to more stable soil ecosystems in the post-methyl bromide era.

Recent research on the development of ASD techniques for reducing soilborne pest populations during warm-season months in Florida has contributed to a better understanding of the effects of cover crops on root-knot nematode populations (Butler et al., 2012a, 2012b). ASD involves the use of organic amendments and soil saturation under plastic tarps to create anaerobic soil conditions that reduce nematode, pathogen, and weed populations in soil. Organic amendments for ASD can be grown as cover crops and incorporated into soil before tarp installation and irrigation to achieve anaerobic soil conditions.

The goal of this research was to determine the host status and effects on nematode reproduction of cover crops previously identified as potential organic inputs

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for use in ASD applications. Our objectives were to assess crops suitable for use in ASD for effects on reproduction and disease caused by three common root-knot nematode species, and to compare the crops with each other, as well as to tomato, a known susceptible host.

## Materials and Methods

*Cover crops tested:* Experiments were designed to determine the effect of various cover crops on nematode populations in soil; specifically the response of the three primary species of *Meloidogyne*. Crops were selected for evaluation based on their potential for use as summer (off-season) cover crops in Florida ASD application and included the following: arugula cv. Nemat (*Eruca sativa*, High Performance Seeds, Inc., Moses Lake, WA), cowpea cv. Iron & Clay (*Vigna unguiculata* ssp. *unguiculata* [L.] Walpers, Adams-Briscoe Seed Co., Jackson, GA), jack bean cv. Comum (*Canavalia ensiformis* (L.) DC., Wolf & Wolf Seeds, Orlando, FL), two commercial mixtures of Indian mustard and white mustard (*Brassica juncea* & *Sinapis alba*) Caliente 61 and Caliente 99 (High Performance Seeds, Inc., Moses Lake, WA), pearl millet cv. Tifleaf III (*Pennisetum glaucum*, Adams-Briscoe Seed Co., Jackson, GA), sorghum-sudan grass hybrid cv. Sugar Grazer II (*Sorghum bicolor* L. Moench × S. *bicolor* var. *sudanense*, Adams-Briscoe Seed Co., Jackson, GA), sunflower cvs. 545A, Nusun 5672, and Nusun 660CL (*Helianthus annuus* L., Triumph Seed Co., Inc., Ralls, TX). The universal host for all species of *Meloidogyne* tested was tomato cv. Rutgers (*Solanum lycopersicum* L., Totally Tomatoes, Randolph, WI), which was included as a positive control in all trials.

*Plant propagation:* Germination and growth rates were predetermined for all seed used in these experiments. Seed were planted to simultaneously obtain seedlings with at least one true leaf at the time of nematode inoculation. Seed were planted into 128 cell flats containing a mixture of washed builder's grade sand and steamed Fafard® germination mix (Conrad Fafard, Inc., Agawam, MA) at a ratio of 0.4 cubic m of Fafard mix to 91 kg sand. This will be referred to as the soil mix and was used to conduct all experiments. Round plastic pots (15-cm-diam.) were filled with approximately 1,500 ml of the soil mix. When plants reached the one to two true leaf stage, one plant was transplanted into the 15-cm pots, watered daily, and fertilized once a week with 20-10-20 at 250-ppm nitrogen (J. R. Peters, Inc., Allentown, PA). Plants were separated on the greenhouse bench by 6-mm-thick polycarbonate dividers to eliminate cross-contamination of nematodes, with each plant in a grid square measuring 30 × 30 cm. Plants were sprayed at label rates on an as-needed basis to control powdery mildew (Bayleton®, triadimefon, Bayer CropScience; Cabrio®, pyraclostrobin, BASF Corp., Research Triangle Park, NC), mites (Horticultural oil, Abamectin), aphids (M-Pede, propylene glycol: potassium hydroxide, Dow AgroSciences, Indianapolis, IN), thrips and whitefly (Safari®, Dinotefuran, N-methyl-N'-nitro-N"-[(tetrahydro-3-furanyl)methyl] guanidine, Valent U.S.A. Corp.; Talstar®, bifenthrin, FMC Corp. Philadelphia, PA).

*Nematode inoculation:* Nematode inoculum was extracted from pure cultures of *M. incognita*, *M. arenaria*, and *M. javanica*, maintained in the greenhouse on tomato (*Solanum lycopersicum*, 'Rutgers'). *Meloidogyne* spp. eggs were extracted from tomato roots by cutting galled roots into 2- to 3-mm pieces, and placing root pieces in a stoppered 500-ml flask containing approximately 100 ml of a 10% commercial bleach solution. Flasks containing roots and bleach were then was placed on a wrist-action shaker for 2 min. Roots and liquid were then poured through nested stainless steel sieves of 80 mesh (180 μm), 325 mesh (45μm), and 500 mesh (25 μm) and rinsed. Eggs were collected on the 500-mesh sieve and were quantified by placing 1 ml of agitated solution on a nematode counting slide (Chalex Corp., Issaquah, WA). The final concentration of eggs was adjusted to approximately 1,000 eggs/ml. Plants were inoculated with nematode eggs by pipetting 1 ml of egg suspension into a 2-cm deep impression in the premoistened soil mix approximately 1.5 to 2.0 cm from the plant stem. Inoculation sites were covered by pressing the soil mix into place. Experiments were maintained in the greenhouse for 8 wk.

*Plant evaluation:* At the end of all experiments, fresh root weight was recorded and roots were evaluated for galling and root condition. Root condition was used as a general indicator of root disease and was assessed using a subjective scale of 1 to 5 with 1 = 0% to 20% discolored roots, 2 = 21% to 40%, 3 = 41% to 60%, 4 = 61% to 80%, and 5 = 81% to 100%. Root galling was assessed using a root gall index based on a scale of 1 to 10, with 1 representing no galls and 10 representing severe (100%) galling (Bridge and Page, 1980). Following root condition and gall ratings, nematode J2 were extracted from the soil and half of the root system using separate Baermann funnels for soil and roots. Nematodes extracted from soil and roots were counted microscopically after 72-hr incubation in funnels. The second half of the root system was used for nematode egg extraction. Eggs were extracted by placing macerated roots into a flask that contained approximately 100 ml of a 10% commercial bleach solution. Flasks were agitated on a wrist-action shaker for 2 min. after which roots were rinsed over a series of nested stainless steel sieves with pores measuring 180 μm, 45 μm, and 25 μm. Eggs were captured on the 25-μm mesh sieve and rinsed into a test tube. Eggs were counted immediately following extraction using a nematode counting slide and are reported as number of eggs per gram of root tissue.

*Statistical analysis:* All treatments in all experiments were replicated four times and arranged in a completely randomized design. All experiments were repeated. Data from both experiments for each of the

three nematode species were subjected to a t-test and subsequently combined if no differences were found between tests. Data were analyzed according to standard statistical procedures including SAS general linear model (GLM) and least significant difference (Fisher's Protected LSD) procedures (SAS 9.2, Cary, NC). Unless otherwise stated, effects and differences were considered significant at $p < 0.05$.

## Results

The majority of the cover crops tested were less susceptible to *M. arenaria* than the susceptible host, 'Rutgers' tomato, with the exception of jack bean, and the three sunflower cultivars (Table 1). Evaluation of J2 in roots and soil, and eggs extracted from roots gave the most consistent results. Root morphology among the crops tested was highly diverse and may have contributed to variation in gall ratings on the subjective scale used. Arugula, cowpea, both mustard mixtures, pearl millet, and sorghum-sudangrass all suppressed *M. arenaria* populations in soil and roots, and nematode egg production (Fig. 1) compared with tomato. Arugula, pearl millet, and sorghum-sudangrass did not produce visible galls in response to *M. arenaria* and had fairly low egg production per gram of root (Table 1; Fig. 1). Cowpea also had low numbers of J2 isolated from roots but had fairly high gall index values (Table 1). This may indicate that, although galls were produced, the nematodes were not completing their life cycle on this host.

The number of *M. incognita* J2 and eggs isolated from roots of all crops tested were low compared with *M. arenaria* and *M. javanica* (Table 2; Fig. 1). However, overall numbers of *M. incognita* J2 isolated from soil were comparable with those of *M. arenaria* and *M. javanica*. As with *M. arenaria*, tomato had high levels of galling, nematode J2, and eggs isolated from roots and soil. Jack bean and all sunflower cultivars also had moderate to high numbers of nematode J2 and eggs isolated from roots and soil. Jack bean and both mustard cultivars also had notable gall index values for *M. incognita* (Table 2). Most of the cover crops tested did not support high populations of *M. incognita* in roots or exhibit significant galling, although comparatively high numbers of *M. incognita* J2 were isolated from soil (Table 2). The cover crops tested which consistently did not support *M. incognita* in soil or roots were arugula, cowpea, and mustard mixture Caliente 99. Although sorghum-sudangrass and pearl millet had low levels of *M. incognita* isolated from roots and low gall index values, high numbers of J2 were isolated from soil.

Although several of the cover crops tested had similar numbers of *M. javanica* J2 isolated from roots and soil, galling on all cover crops tested was less severe than tomato (Table 3). However, sunflower cultivar 545A had higher numbers of eggs isolated from roots than tomato (Fig. 1). Sunflower, tomato, jack bean, and both mustard mixtures exhibited significant galling in response to *M. javanica* (Table 3). Sorghum-sudangrass, pearl millet, and cowpea had low gall index values and relatively low numbers of *M. javanica* J2 isolated from soil and roots. Arugula also had very low numbers of *M. javanica* J2 isolated from roots and soil, and relatively low gall index values, although gall index values for this host were not as low as those for sorghum-sudangrass and cowpea (Table 3).

## Discussion

This research is part of an ongoing program to develop ASD techniques by identifying cover crops with potential for use as the organic amendment (labile carbon source) component. ASD has proven to be an effective alternative soil disinfestation technique for

Table 1. Root-knot nematode juveniles (J2) in roots and soil, plant root weight, plant root condition, and nematode gall index values for both experiments on cover crop susceptibility to *Meloidogyne arenaria*.

| | *M. arenaria* (J2/g root) | *M. arenaria* (J2/100cm$^3$ soil) | Root weight (g) | Root condition[1] | Gall index[2] |
|---|---|---|---|---|---|
| *Solanum lycopersicum* Tomato cv. Rutgers | 106.6 a[3] | 165.9 ab | 9.3 cde | 0.45 d | 5.21 a |
| *Eruca sativa* Arugula cv. Nemat | 0.3 c | 24.1 c | 9.4 cde | 3.11 a | 0.41 ef |
| *Vigna unguiculata* Cowpea cv. Iron & Clay | 0.5 c | 0.0 c | 11.4 bcde | 1.35 c | 3.10 c |
| *Canavalia ensiformis* Jack bean cv. Comum | 25.4 bc | 38.3 bc | 8.7 de | 1.68 c | 1.73 d |
| *Brassica juncea* & *Sinapis alba* Mustard mixture Caliente 61 | 1.4 c | 22.7 c | 13.1 bcd | 3.05 a | 1.13 de |
| *Brassica juncea* & *Sinapis alba* Mustard mixture Caliente 99 | 6.8 c | 8.5 c | 13.9 bc | 2.99 a | 1.74 d |
| *Pennisetum glaucum* Pearl Millet cv. Tifleaf III | 4.2 c | 0.0 c | 7.3 e | 2.46 b | 0.18 f |
| *Sorghum bicolor* × *S. Bicolor* var. *sudanense* Sorghum-sudangrass cv. Sugar Grazer II | 7.3 c | 5.7 c | 11.6 bcde | 2.66 ab | 0.18 f |
| *Helianthus annuus* Sunflower cv. 545A | 79.7 ab | 69.5 abc | 9.7 cde | 0.26 d | 4.46 ab |
| *Helianthus annuus* Sunflower cv. Nusun 660CL | 66.6 ab | 19.9 c | 16.2 b | 0.36 d | 4.50 ab |
| *Helianthus annuus* Sunflower cv. Nusun 5672 | 7.2 c | 174.4 a | 21.9 a | 0.47 d | 4.25 b |
| LSD (0.05) | 57.3 | 129.8 | 5.0 | 0.52 | 0.87 |

[1] Root condition: 0 = clean, white roots, 5 = completely rotted and discolored roots.
[2] Gall index: 0 = no galling, 10 = complete galling (Bridge and Page, 1980).
[3] Means with the same letter are not significantly different according to least significant difference (LSD) procedures ($P < 0.05$).

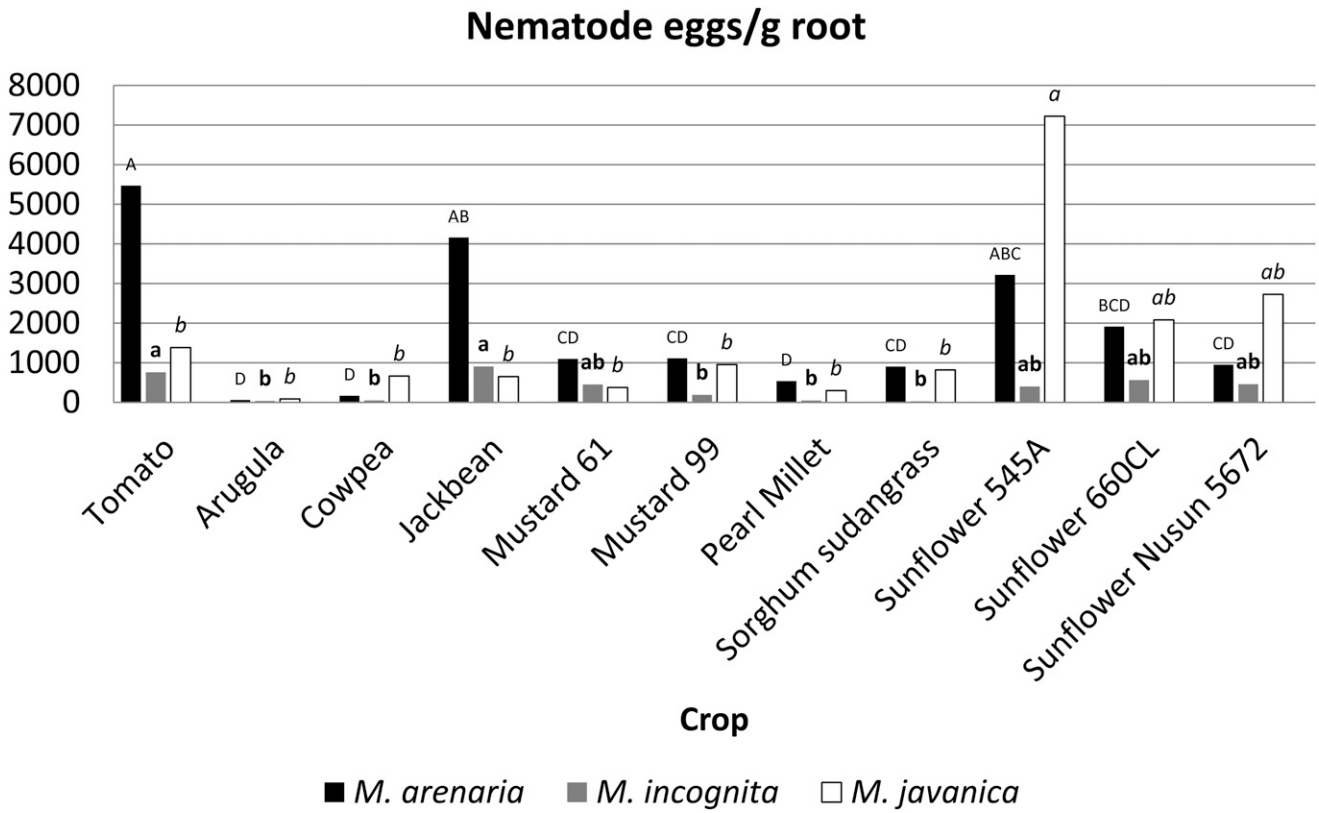


FIG. 1. Nematode eggs extracted per gram of fresh root tissue for the three species of *Meloidogyne* tested on all crops. Letters indicate statistical differences among crops for each individual nematode species. Nematode species are not compared statistically with each other. Means with the same letter and font type are not significantly different according to least significant difference (LSD) procedures ($P < 0.05$).

vegetables and ornamentals in Florida. This method has potential to be customized to address specific pests by the choice of cover crop produced as the carbon source during the warm season. Current methods for applying ASD include incorporating a nitrogen and carbon soil amendment and covering the beds with plastic mulch while adding high levels of water to create anaerobic soil conditions. Preliminary research on cover crops for use in ASD indicated that the number of *M. incognita* extracted from tomato root tissue at the end of greenhouse trials was lower in all treatments with an added carbon source, in the form of cover crop residue, than when no crop residue was incorporated (Butler et al., 2012b). The research presented in this study builds on previous work in determining potential for nematode reproduction on cover crops for three

TABLE 2. Root-knot nematode juveniles (J2) in roots and soil, plant root weight, plant root condition, and nematode gall index values for both experiments on cover crop susceptibility to *Meloidogyne incognita*.

| | *M. incognita* (J2/g root) | *M. incognita* (J2/100 cm$^3$ soil) | Root weight (g) | Root condition[1] | Gall index[2] |
|---|---|---|---|---|---|
| *Solanum lycopersicum* Tomato cv. Rutgers | 3.3 ab[3] | 120.5 ab | 24.6 c | 0.80 b | 4.43 a |
| *Eruca sativa* Arugula cv. Nemat | 0.0 d | 0.0 b | 24.2 c | 3.03 a | 0.40 de |
| *Vigna unguiculata* Cowpea cv. Iron & Clay | 0.7 bcd | 0.0 b | 20.0 c | 2.56 a | 0.28 e |
| *Canavalia ensiformis* Jack bean cv. Comum | 4.3 a | 163.4 a | 10.0 c | 2.24 a | 2.73 bc |
| *Brassica juncea* & *Sinapis alba* Mustard mixture Caliente 61 | 0.2 d | 26.9 ab | 22.7 c | 2.81 a | 2.35 bc |
| *Brassica juncea* & *Sinapis alba* Mustard mixture Caliente 99 | 0.2 d | 2.8 b | 40.2 b | 2.51 a | 1.54 cd |
| *Pennisetum glaucum* Pearl Millet cv. Tifleaf III | 0.5 cd | 41.1 ab | 72.0 a | 2.63 a | 0.21 e |
| *Sorghum bicolor* × *S. Bicolor* var. *sudanense* Sorghum-sudangrass cv. Sugar Grazer II | 0.5 cd | 45.4 ab | 50.9 b | 2.48 a | 0.10 e |
| *Helianthus annuus* Sunflower cv. 545A | 3.2 abc | 55.3 ab | 10.7 c | 0.69 b | 3.53 ab |
| *Helianthus annuus* Sunflower cv. Nusun 660CL | 1.4 bcd | 95.0 ab | 22.0 c | 0.99 b | 3.24 ab |
| *Helianthus annuus* Sunflower cv. Nusun 5672 | 1.5 abcd | 69.5 ab | 48.7 b | 0.98 b | 3.24 ab |
| LSD (0.05) | 2.8 | 142.1 | 15.3 | 0.81 | 1.25 |

[1] Root condition: 0 = clean, white roots, 5 = completely rotted and discolored roots.
[2] Gall index: 0 = no galling, 10 = complete galling (Bridge and Page, 1980).
[3] Means with the same letter are not significantly different according to least significant difference (LSD) procedures ($P < 0.05$).

TABLE 3. Root-knot nematode juveniles (J2) in roots and soil, plant root weight, plant root condition, and nematode gall index values for both experiments on cover crop susceptibility to *Meloidogyne javanica*.

| | *M. javanica* (J2/g root) | *M. javanica* (J2/100cm$^3$ soil) | Root weight (g) | Root condition[1] | Gall index[2] |
|---|---|---|---|---|---|
| *Solanum lycopersicum* Tomato cv. Rutgers | 6.4 ab[3] | 113.4 abc | 22.3 c | 0.35 d | 5.59 a |
| *Eruca sativa* Arugula cv. Nemat | 0.0 b | 5.7 c | 21.1 cd | 2.96 a | 1.64 cde |
| *Vigna unguiculata* Cowpea cv. Iron & Clay | 1.2 b | 55.3 c | 22.8 c | 1.21 cd | 0.13 ef |
| *Canavalia ensiformis* Jack bean cv. Comum | 10.7 ab | 275.0 a | 9.5 ef | 1.88 bc | 2.31 bcd |
| *Brassica juncea* & *Sinapis alba* Mustard mixture Caliente 61 | 0.0 b | 78.0 c | 17.1 cde | 2.61 ab | 1.75 cd |
| *Brassica juncea* & *Sinapis alba* Mustard mixture Caliente 99 | 1.6 b | 117.7 abc | 19.3 cde | 2.61 ab | 3.03 bc |
| *Pennisetum glaucum* Pearl Millet cv. Tifleaf III | 1.7 b | 89.3 c | 56.7 a | 1.53 c | 0.83 def |
| *Sorghum bicolor* × *S. Bicolor* var. *sudanense* Sorghum-sudangrass cv. Sugar Grazer II | 0.0 b | 38.3 c | 39.4 b | 3.09 a | 0.09 f |
| *Helianthus annuus* Sunflower cv. 545A | 47.4 a | 106.3 bc | 5.6 f | 1.81 bc | 3.71 b |
| *Helianthus annuus* Sunflower cv. Nusun 660CL | 16.8 ab | 262.2 ab | 13.6 cdef | 1.45 c | 3.71 b |
| *Helianthus annuus* Sunflower cv. Nusun 5672 | 39.9 ab | 172.9 abc | 11.5 def | 1.68 c | 3.43 b |
| LSD (0.05) | 43.8 | 168.2 | 10.1 | 0.93 | 1.52 |

[1] Root condition: 0 = clean, white roots, 5 = completely rotted and discolored roots.
[2] Gall index: 0 = no galling, 10= complete galling (Bridge and Page, 1980).
[3] Means with the same letter are not significantly different according to least significant difference (LSD) procedures ($P < 0.05$).

important root-knot nematode species, compared with reproduction on a known susceptible host, tomato.

Literature is available on the use of some of the crops included in our research as biofumigants or green manure crops (Wang et al., 2003; Melakeberhan et al., 2010), and on their host status to some species of nematodes (McLeod et al., 2001; Timper et al., 2002; Curto et al., 2005; Timper and Wilson, 2006; Brito et al., 2007). However, very few studies have evaluated this group of cover crops under controlled conditions to directly compare their effects on multiple species of root-knot nematode reproduction and populations in roots and soil as reported in this study.

Previous research on cowpea as a cover crop combined with soil solarization established the value of a combination of approaches in reducing root-knot nematode populations, as well as enhancing beneficial nematodes and yield in bell pepper production (Wang et al., 2006; Saha et al., 2007). However, a comparable level of nematode suppression could not be achieved by either cowpea or soil solarization alone. Earlier work by Wang et al. (2003) demonstrated that cv. Iron & Clay cowpea suppressed *M. incognita* population densities because it is a poor host rather than an allelopathic effect from crop residue incorporated as an amendment. However, this nematode suppression was only significant in crops that were highly susceptible to *M. incognita*, such as bush bean (*Phaseolus vulgaris*) and lima bean (*P. lunatus*), and which were planted immediately following the cover crops.

Results reported in this study for cowpea are consistent with previous research (McSorley and Dickson, 1995; McSorley, 1999) testing several cover crops for susceptibility to *Meloidogyne arenaria* race 1, *M. incognita* race 1, and *M. javanica*. No galls or egg masses were observed on roots of cowpea (*Vigna unguiculata* cv. Iron & Clay), or American jointvetch (*Aeschynomene americana*). Results for susceptibility of *A. americana* to these three species of *Meloidogyne* are not consistent with a recent report in which *A. americana* was found to be susceptible to these species of *Meloidogyne* (Kokalis-Burelle and Rosskopf, 2012) in trials where it was evaluated as a weed following the detection of root galling in a heavy volunteer infestation of an experimental field in southeastern Florida. Although it is often recommended as a cover crop in southern regions of the United States, it was determined that potential exists for *A. americana* to serve as an important host of these three species of root-knot nematode.

In research including other species of *Meloidogyne*, Brito et al. (2007) found cowpea, horse bean (jack bean), and the mustard cv. Florida Broad Leaf, were good hosts for *M. mayaguensis*. Results from our studies are consistent in finding jack bean highly susceptible to *M. arenaria*, *M. incognita*, and *M. javanica,* whereas cowpea was more resistant to those nematode species. Arim et al. (2006) found that intercropping of maize with jack bean reduced lesion nematode (*Pratylenchus zeae*) populations in the roots of maize by up to 32%, reduced disease caused by this nematode, and increased yield. These results on the reduction of lesion nematodes on maize using jack bean are not similar to the results of our research with this crop that indicated that jack bean is highly susceptible to all three species of root-knot nematode tested. This highlights the need to determine which parasitic nematodes are present in fields before implementing a cover crop or crop rotation strategy for nematode control.

In previous research, sorghum-sudangrass was found to be a poor or nonhost to *M. javanica* (Sipes and Arakaki, 1997). These results are supported by our research that includes data on two additional nematode species, none of which produce galls or large numbers of eggs on sorghum-sudangrass. However, sorghum-sudangrass has been shown to increase populations of some other important parasitic nematodes. Crow et al.

(2001) found that population densities of *Belonolaimus longicaudatus*, *Paratrichodorus minor*, *Tylenchorhynchus* sp., and *Mesocriconema* sp. increased on sorghum-sudangrass, and that population densities of *B. longicaudatus* and *Mesocriconema* spp. on a subsequent potato crop were also increased. Therefore, sorghum-sudangrass should be used carefully, and only in fields with known species of parasitic nematodes, such as the three root-knot nematode species included in this report, which were not found to produce galls or large numbers of eggs on sorghum-sudangrass.

Differences have been reported among *Brassica* species for effects on root-knot nematode species, and growth and yield of vegetable crops following incorporation of *Brassica* cover crops into soil (Monfort et al., 2007). Rosa et al. (2013) reported *Brassica* cvs. Bruxelas and Tronchuda Portuguesa as immune to *M. javanica*, whereas sunflower cv. Uruguai, and pearl millet were reported as resistant. Our research, conducted using different varieties of sunflower (*Helianthus*), did not indicate any resistance to the three species of *Meloidogyne* tested, including *M. javanica*. McLeod et al. (2001) investigated invasion, development, and egg laying by *Meloidogyne javanica* in 11 Brassicaceae and four non-Brassicaceae crop species/subspecies and found that three weeks after inoculation, more *M. javanica* had developed to the mature female stage in tomato than in the eight Brassicaceae species/subspecies. Egg masses from four Brassicaceae species contained fewer eggs than egg masses from tomato at 6 wk after inoculation.

There is a limited amount of research available on use of Arugula (*Erucasativa*) as a cover crop or amendment in southern regions. Arugula is a green vegetable crop and has been reported to be an effective trap crop for populations of *Meloidogyne hapla* in sandy loam soil (Melakeberhan et al., 2010). Results presented here for arugula are consistent with those of Melakeberhan et al. (2006) who studied the effects of arugula cv. Nemat on three glasshouse populations of *M. hapla* from Rhode Island, New York, and Michigan. In those studies, arugula was shown to interfere with nematode development and reproduction. Egg and egg mass production was normal in all nematode-infected tomatoes, but no eggs were produced in more than 80% of arugula plants, and approximately 17% of the arugula samples had fewer than five loose eggs and no egg masses. Curto et al. (2005) also found that *Eruca sativa* cv. Nemat was considered "poor to non-host" to *M. incognita*.

Research on the effects of pearl millet on nematode reproduction is somewhat limited. McSorley (1999) Found that egg-mass levels and numbers of hatched J2 of *M. incognita* on pearl millet (*Pennisetum typhoides*, Tifleaf II hybrid) were comparable with those on a susceptible tomato (*Lycopersicon esculentum*, cv. Rutgers). Timper et al. (2002) reported that in a field naturally infested with *M. incognita*, experimental pearl millet hybrids, with inbreds 114 and 117 as the pollinators, had fewer numbers of J2 than a nematode-susceptible hybrid. Both *M. incognita* and *M. arenaria* produced fewer eggs on pearl millet hybrids with certain pollinators, and reproduction of *M. incognita* was less on the resistant pearl millet hybrids than on corn (Timper et al., 2002). Further research by Timper and Wilson (2006) studied resistance of pearl millet to *M. incognita* in order to reduce nematode populations that can damage crops grown in rotation with pearl millet. Pearl millet from West and East Africa was examined for resistance, and to determine if heterogeneity for resistance exists within selected cultivars. All African cultivars tested expressed some level of resistance, whereas progeny reaction varied from highly resistant to highly susceptible. Our research indicates that the pearl millet cultivar tested does not support high levels of galling or reproduction of any of the root-knot nematode species studied.

These trials were undertaken to address basic questions affecting root-knot nematode control strategies for Florida crop production using controlled environmental conditions and nematode inoculum levels. Understanding the effect of several cover crops with potential for use in ASD on root-knot nematode populations will enhance the development of these techniques for nematode control.

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