RESEARCH NOTE - NOTA DE INVESTIGACION

HOST STATUS AND AMENDMENT EFFECTS OF COWPEA ON *MELOIDOGYNE INCOGNITA* IN VEGETABLE CROPPING SYSTEMS

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ABSTRACT

Wang, K.-H., R. McSorley, and R. N. Gallaher. 2003. Host status and amendment effects of cowpea on *Meloidogyne incognita* in vegetable cropping systems. Nematropica 33:215-224.

A field experiment was conducted to study the mode of action of cowpea (*Vigna unguiculata*) on plant-parasitic nematode suppression, and to differentiate the nematode suppressive effect from the green manure effect performed by cowpea. The experiment was a 3 × 3 split-plot design in which the main plots were summer planting of *Meloidogyne incognita* resistant ('Iron Clay') and susceptible ('White Acre') cowpea, and fallow. The three subplots received biomass of 'White Acre' cowpea or 'Iron Clay' cowpea or no biomass. Planting of cowpea (regardless of cultivar) resulted in phytotoxicity to 'Purple Top' turnip (*Brassica rapa*) when planted immediately after the cowpea cover crop. Planting of 'Iron Clay' cowpea suppressed *M. incognita* population densities due to poor host effect rather than from any allelopathic effect from crop residue amendments. However, this nematode suppression was only significant in crops that were very susceptible to *M. incognita* such as bush bean (*Phaseolus vulgaris*) and lima bean (*P. lunatus*). Green manure (crop fertility) effect from growing cowpea was negligible on leguminous cash crops. However, the yield of turnip, a non-leguminous crop, was higher when plots were previously 'Iron Clay' cowpea followed by the cover crop amendment as compared to plots that were fallow without cowpea amendment.

Key words: allelopathy, bush bean, cover crop, green manure, lima bean, poor host, root-knot, turnip, *Vigna unguiculata.*

RESUMEN

Wang, K.-H., R. McSorley, y R. N. Gallaher. 2003. Estado del huésped y efectos de enmiendas de caupi sobre *Meloidogyne incognita* en sistemas de cultivos de vegetales. Nematropica 33:215-224.

Un experimento de campo fue llevado a cabo para estudiar el modo de acción de caupi (*Vigna unguiculata*) sobre la supresión de nemátodos parásitos de plantas, y para diferenciar el efecto supresivo sobre nemátodos del efecto del estiércol verde efectuado por fríjol. El experimento era de un diseño "split plot" de 3 × 3 en el cual el efecto mayor era la plantación de verano de caupi resistente a *Meloidogyne incognita* ('Iron Clay') y caupi susceptible a *Meloidogyne incognita* ('White Acre'), y barbecho. Las tres subparcelas recibieron biomasa de caupi 'White Acre' o caupi 'Iron Clay' y un control negativo sin biomasa de caupi. La plantación de caupi (sin tener en cuenta el cultivar) resultó en fitotoxicidad a nabo 'Purple Top' (*Brassica rapa*) cuando este cultivo fue plantado directamente después del cultivo caupi como cubierto. Plantación de caupi 'Iron Clay' reprimió las densidades de populaciones de *M. incognita* por medio de efecto de huésped reducido más que por medio de cualquier efecto alelopático de enmiendas de residuos de cultivo. Sin embargo, la supresión del nemátodo solamente era significativa en cultivos que eran muy susceptibles a *M. incognita* como *Phaseolus vulgaris* y fríjol lima (*P. lunatus*). El efecto de cultivar caupi como estiércol verde (fertilidad de cultivo) era insignificante sobre cultivos comerciales leguminosos. Sin embargo, la cosecha de nabo, un cultivo no leguminoso, era mayor cuando los campos fueron cultivados anteriormente con caupi 'Iron Clay' seguido por la enmienda del cultivo de cubierto comparado con los campos en barbecho sin enmiendo de caupi.

Palabras claves: alelopatia, fríjol, cultivo de cubierto, estiércol verde, fríjol lima, huésped inefectivo, agalladuras, nabo, *Vigna unguiculata*.

INTRODUCTION

One approach to achieving sustainable agriculture is by utilizing cultural management practices that result in multiple environmental benefits. Efforts to integrate nematode and nitrogen management have been pursued since the 1920s, when researchers were looking for leguminous cover crops to suppress plant-parasitic nematodes (Godfrey, 1928; Watson, 1992). A leguminous cover crop can provide a source of nitrogen (N) to the subsequent crop, and can reduce soil erosion (Power and McSorley, 2000). In fact, cowpea was recommended as a viable alternative to chemical N fertilizer in tropical Asia (Morris *et al.*, 1989; John *et al.*, 1989) and West Africa (Muleba, 1999). Several tropical legumes have been demonstrated to be suppressive to plant-parasitic nematodes. These include crops such as velvetbean (*Mucuna deeringiana* (Bort.) Merr.) (Rodriguez-Kabana *et al.*, 1992; McSorley and Gallaher, 1992; McSorley *et al.*, 1994b; McSorley and Dickson, 1995), *Crotalaria* spp. (Wang *et al.*, 2002), and some cultivars of cowpea (*Vigna unguiculata* (L.) Walp.) (McSorley and Gallaher, 1992; McSorley *et al.*, 1994a; McSorley and Dickson, 1995; McSorley, 1999).

While research in this area has been widely conducted, the mode of action of each crop on nematode suppression and crop improvement still needs further clarification. Utilizing cover crop rotation for nematode management may seem to simply involve a host-susceptibility concept, but the mechanisms for nematode management could be more complicated. This is because a cover-cropping system typically involves two major components, i.e., first growing the cover crop and then incorporating the crop residues into soil as an amendment. The mechanisms involved in the suppression of plant-parasitic nematodes by a cover crop could be a poor host effect, an allelopathic effect as crop residues decomposed, or effect from enhancing nematode-antagonistic fungi (Wang *et al.*, 2001).

The current project was conducted to better understand the mode of action of cowpea for suppressing plant-parasitic nematodes and their damage. Cowpea has been shown to be an effective cover crop for plant-parasitic nematode management (McSorley and Gallaher, 1992), but the effect depends on cowpea cultivar, and on nematode species or even race. Cowpea cultivars such as 'White Acre' (McSorley and Gallaher, pers. obs.), 'Whippoorwill', 'Pinkeye Purplehull', 'Texas Purplehull' are susceptible to *Meloidogyne incognita* (Kofoid & White) Chitwood) race 1 (Gallaher and McSorley, 1993), whereas 'Crimson', and 'Elite' are susceptible to *M. incognita* race 3 (Kirkpatrick and Morelock, 1987). *Meloidogyne incognita*, especially race 1, is the key nematode pest in many cropping systems in North Central Florida (Gallaher and McSorley, 1993; McSorley and Gallaher, 1991). 'California Blackeye #5', 'Erectset', 'Iron Clay', 'Magnolia Blackeye', 'Mississippi Purple', 'Mississippi Silver', 'Tennessee Brown' and 'Zippercream' (Fassuliotis and Skucas, 1969; Gallaher and McSorley, 1993; McSorley and Dickson, 1995; McSorley and Gallaher, 1992; 1993; McSorley *et al.*, 1999) are relatively resistant to *M. incognita* race 1 or 3 or both.

The differential susceptibility of cowpea cultivars to *M. incognita* provides an opportunity to study the modes of action of cowpea on plant-parasitic nematode suppression, and to differentiate the nematode suppressive effect from the green manure effect performed by cowpea. This can be achieved by growing resistant or susceptible cowpea cultivars, compared to fallowing, followed by incorporation or without incorporation of those cowpea residues as amendments. The objectives of this research were to 1) differentiate the host susceptibility effect of cowpea from the cowpea residue amendment effect on *M. incognita*, and 2) determine the nematode suppressive effect and green manure effect from cowpea on growth of several vegetable crops.

MATERIALS AND METHODS

During the summer and fall of 2001, an experiment was conducted at the University of Florida, Experimental Designs Field Teaching Laboratory, Gainesville, FL (29°39'N, 82°22'W) to examine the cover crop or amendment effects of two cowpea cultivars on plant-parasitic nematodes. The soil was Millhopper sand (loamy, siliceous, hyperthermic, Grossarenic Paleudult, 92% sand, 3% silt, and 5% clay) with low soil organic matter (<2%), naturally infested with *M. incognita* race 1 and several other genera of plant-parasitic nematodes. Previously, the field site was cropped with short-term rotations of various vegetable crops. On 9 July 2001, a 3 × 3 split-plot experiment was initiated. The main plots were either planted with: 1) 'White Acre' cowpea, a *M. incognita*-susceptible cultivar; 2) 'Iron Clay' cowpea, a *M. incognita*-resistant cultivar; or 3) left fallow (weed free) by frequent mechanical cultivation. Treatments were arranged in randomized complete blocks with 5 replications. Each main plot was 18.28 m × 1.98 m in size with a 0.60-m-wide alleys between plots. Cowpeas were planted at 56 kg/ha using a Tye no-till drill. The field was irrigated as needed using overhead sprinkler irrigation without fertilizer application during this period. On 23 August, 3 subplot treatments (6.08 m × 1.98 m) were superimposed on each main plot treatment. All the cowpea biomass was harvested by hand pulling from each subplot and either remained in the same location, or was moved to another subplot according to random assignment. The 3 subplots received either: 1) biomass of 'White Acre' cowpea, 2) biomass of 'Iron clay' cowpea, or 3) no biomass. The biomass was laid on top of the ground for 4 days to allow mortality of nematodes attached in the root system, followed by tandem harrowing of the biomass, and incorporation of the biomass into the soil using a rototiller. The amount of biomass incorporated into each subplot was determined by the biomass produced per subplot by the designated cowpea cultivar. On 30 August, 'Purple Top' turnip (*Brassica rapa* L.), was planted in 0.91-m-wide rows per subplot. Based on a previous soil test, 134 kg K_2O/ha was broadcast as KCl. However, the turnip suffered phytotoxicity in cover crop plots, with poor, erratic germination. Stand counts of turnip in all subplots were determined on 10 September. The field was tilled and replanted on 18 September with 4 *M. incognita*-susceptible vegetable crops: 'Shogoin' turnip (at 15 seeds/m row), 'Jackson Wonder' lima bean (*Phaseolus lunatus* L. at 40 seeds/m row), 'Golden Top

Wax' bush bean (*P. vulgaris* L., at 40 seeds/m row), and 'White Acre' cowpea (40 seeds/m row). Each vegetable planting within a subplot consisted of 2 rows (0.91 m apart × 1.98 m long) of each crop, but locations within subplots were not randomized, so data from the four vegetable crops were analyzed separately. No N fertilizer was used other than the cowpea crop residues, and crops were irrigated according to standard practice. Weeds were managed manually. Crops were harvested between 6 and 17 of December 2001. At harvest, shoot biomass, and pod or root weights in a 1.5-m^2 area per subplot were measured for lima bean, cowpea, and turnip.

Soil samples for nematode analysis were collected by removing and compositing six cores of soil (2.5 cm-diam. × 20 cm-deep) from each plot, or from each subplot once subplots were established. Soil samples were collected on 20 July 2001 to estimate initial nematode densities shortly after cowpea cover crop planting, at termination of cowpea cover crop on 24 August 2001, following the initial planting of the four vegetable crops on 1 October 2001, and at termination of cowpea and bush bean on 6 December, turnip on 13 December, and lima bean on 18 December. Nematodes were extracted from a subsample of 100-cm^3 soil by a modified sieving and centrifugal flotation method (Jenkins, 1964). At harvest, four plants were removed from each subplot and rated for root galling on a 0-5 scale, where 0 = 0 galls per root system; 1 = 1-2 galls; 2 = 3-10 galls; 3 = 11-30 galls; 4 = 31-100 galls; and 5 = >100 galls per root system (Taylor and Sasser, 1978).

Nematode counts were log-transformed ($\log_{10}[x + 1]$) before analysis of variance (ANOVA). Data collected at termination of cover crop planting, at early crop planting, and at termination of cowpea and bush bean planting were subjected to one way analysis of variance, whereas data at termination of turnip and lima bean were subjected to 3 × 3 split-plot ANOVA, where cover crop was the main plot factor and amendment was the subplot factor. Turnip survival rate at first planting and crop biomass for each crop harvested was also analyzed by ANOVA for 3 × 3 split-plot experimental design. Means were separated using Waller-Duncan k ratio (k = 100) t-test when the treatment effects were significant ($P \leq 0.05$).

RESULTS

Cover crop effect on turnip seedlings

Emergence and growth of the 'Purple Top' turnips planted immediately after the cowpea cover crop were poor. Seedlings exhibited phytotoxicity symptoms including yellowing, stunting, and poor stand. Turnip survival rates were lower ($P \leq 0.05$) in both of the treatments that had been planted with cowpea cover crops (14 and 28 turnip plants survived per 1.98 m row for 'White Acre' and 'Iron Clay' respectively) compared to the fallow control (67 turnip plants per 1.98 m row). However, the survival rate was not affected by cowpea residues used as an amendment ($P >$ 0.05), nor was it affected by the interaction between cover crop and amendment effects ($P > 0.05$).

Cover crop effect on nematodes

At termination of the cowpea cover crop growing period, 'Iron Clay' suppressed *M. incognita* significantly compared to 'White Acre' but 'Iron Clay' still supported higher population densities of *M. incognita* than the fallow soil. 'Iron Clay' also had lower number of *Paratrichodorus minor* (Colbran) Siddiqi than 'White Acre' (Table 1) although the nematode number was low.

Table 1. Effect of cowpea as cover crop or amendment on plant-parasitic nematode population densities on four vegetable crops, summer-fall, 2001.

	Nematodes per 100 cm^3 soil			
Cowpea treatment	*Meloidogyne incognita*	*Paratrichodorus minor*	*Helicotylenchus* spp.	*Mesocriconema* spp.
Cover crop effect	20 July 2001 (shortly after cover crop planting)			
'White Acre'	2 ab[z]	2 a	45 a	42 a
'Iron clay'	2 b	1 a	24 a	35 a
Fallow	11 a	3 a	34 a	97 a
	24 August 2001 (after cover crop incorporation)			
'White Acre'	106 a	2 a	17 a	25 a
'Iron clay'	25 b	0 b	15 a	15 a
Fallow	1 c	1 ab	28 a	23 a
	1 October 2001 (after vegetable crop planting)			
'White Acre'	11 a	0 a	2 a	11 a
'Iron clay'	2 b	0 a	6 a	9 a
Fallow	1 b	1 a	5 a	16 a
	6 December 2001 (after cowpea harvest)			
'White Acre'	106 a	5 a	0 a	4 a
'Iron clay'	80 a	7 a	1 a	6 a
Fallow	22 a	3 a	3 a	6 a
	6 December 2001 (after bush bean harvest)			
'White Acre'	1254 a	5 b	6 a	5 b
'Iron clay'	658 ab	13 a	6 a	13 a
Fallow	198 b	15 a	15 a	15 a
	13 December 2001 (after turnip harvest)			
Cover crop effect				
'White Acre'	210 a	5 a	7 a	5 a
'Iron clay'	145 a	3 a	10 a	4 a
Fallow	71 a	4 a	10 a	5 a
Amendment effect				
'White Acre'	154 a	1 b	13 a	6 a
'Iron clay'	148 a	5 ab	6 a	5 a
No amendment	124 a	6 a	8 a	3 a

[z] Means are average of 5 replications. Data collected at termination of turnip and lima bean are analyzed by 3 × 3 split-plot analysis of variance. No interaction was detected between cover crop and amendment effects ($P > 0.05$). Means in columns for each sampling date and effect followed by the same letters are not different according to Waller-Duncan k ratio ($k = 100$) t-test at $P \leq 0.05$ based on log (x + 1).

Table 1. (Continued) Effect of cowpea as cover crop or amendment on plant-parasitic nematode population densities on four vegetable crops, summer-fall, 2001.

	Nematodes per 100 cm^3 soil			
Cowpea treatment	*Meloidogyne incognita*	*Paratrichodorus minor*	*Helicotylenchus* spp.	*Mesocriconema* spp.
	18 December 2001 (after lima bean harvest)			
Cover crop effect				
'White Acre'	466 a	5 a	6 b	6 a
'Iron clay'	348 ab	5 a	18 ab	3 a
Fallow	201 b	3 a	25 a	3 a
Amendment effect				
'White Acre'	400 a	2 b	22 a	3 a
'Iron clay'	351 a	8 a	8 a	2 a
No amendment	265 a	3 b	20 a	6 a

[z]Means are average of 5 replications. Data collected at termination of turnip and lima bean are analyzed by 3 × 3 split-plot analysis of variance. No interaction was detected between cover crop and amendment effects ($P > 0.05$). Means in columns for each sampling date and effect followed by the same letters are not different according to Waller-Duncan *k* ratio ($k = 100$) t-test at $P \leq 0.05$ based on log (x + 1).

On 1 October, 5 weeks after cowpea cover crop residues were incorporated into the soil, population densities of *M. incognita* were reduced greatly from the previous sampling date (Table 1). In plots that had been planted to 'Iron Clay' during the summer, *M. incognita* was suppressed to a level that was not different from that in the fallow soil, whereas plots previously planted to 'White Acre' maintained a higher *M. incognita* level (Table 1). No differences among the treatments were observed ($P > 0.05$) for the other plant-parasitic nematodes during the first two sampling dates.

However, after vegetable crops susceptible to *M. incognita* were planted, population densities of most plant-parasitic nematodes increased (Table 1). Among the four vegetable crops tested, bush bean and lima bean had very high population densities of *M. incognita* (average of 703 and 338/100 cm^3 soil respectively) at harvest, but population levels on cowpea and turnip were relatively low (average of 69 and 142/100 cm^3 soil respectively; Table 1). Significant ($P \leq 0.05$) effects of cowpea cover crop treatments on *M. incognita* population densities were observed in bush bean and lima bean but not in turnip or cowpea. At termination of bush bean and lima bean crops, higher levels ($P \leq 0.05$) of *M. incognita* occurred in main plots that had been planted to a previous cover crop of 'White Acre' cowpea than in plots that were previously fallowed (Table 1). At crop harvest, main plots with a summer cover crop of 'Iron Clay' had intermediate *M. incognita* population densities among the cowpea cover crop treatments, but the nematode numbers were not different from that in the 'White Acre' and fallow treatments ($P > 0.05$). However, 'Iron Clay' and fallow control summer treatments resulted in lower ($P \leq 0.05$) root-gall indices (1.0 and 1.1 respectively) on lima bean plants than 'White Acre' summer treatment (1.98). Cover crop treatments did not affect root gall indices on other crops ($P > 0.05$). It is interesting that numbers of *Helicotylenchus* spp. were lowest in the lima bean planted after 'White Acre' ($P \leq 0.05$; Table 1).

Amendment effect on nematodes

The effects of cowpea residues as amendments were only evaluated in two vegetable crops, i.e. turnip and lima bean. Population densities of *M. incognita* (Tables 1) and root gall index (data not shown) were not different among the amendment treatments at termination of crop harvest ($P > 0.05$). However, amendment with crop residues of 'Iron Clay' cowpea slightly increased *P. minor,* although numbers of this nematode were relatively low.

Cover crop and amendment effect on crop yield

Among the three crops harvested, only yield of lima bean was affected by cowpea cover crop treatments. Plots previously planted with 'White Acre' cowpea cover crop produced the least lima bean fresh shoot and pod weight as compared to 'Iron Clay' or fallow planted plots ($P \leq 0.05$, Table 2). Cowpea amendment had no effect on yield or biomass of any of the vegetable crop evaluated (Table 2). However, there was an interaction between cover crop and amendment treatments on the fresh shoot weight of turnip (P _ 0.05). When no amendment was added, plots previously planted with 'Iron Clay' supported higher turnip shoot weight than the fallow treatment ($P \leq 0.05$, Table 3). When summer treatment was fallow, amendment of either 'White Acre' or 'Iron Clay' residues provided higher turnip shoot fresh weight than the plot received no amendment ($P \leq 0.05$, Table 3).

Table 2. Effect of cowpea as cover crop or amendment on the crop yield or biomass of three vegetable crops, summer-fall, 2001.

	Lima bean		Cowpea	Turnip	
Cover crop treatment	Shoot	Pod	Shoot	Shoot	Root
	------------------------ Fresh weight (g)/1.5 m^2 ------------------------				
Cover crop effect					
'White Acre'	833 b[z]	791 b	458 a	1,603 a	1,640 a
'Iron Clay'	1,092 a	974 a	429 a	1,995 a	2,063 a
Fallow	978 ab	1,003 a	470 a	1,724 a	1,898 a
Amendment effect					
'White Acre'	972 A	918 A	437 A	1,827 A	1,883 A
'Iron Clay'	984 A	901 A	393 A	1,656 A	1,789 A
No amendment	947 A	949 A	527 A	1,839 A	1,929 A

[z] Means are average of 15 replications. Data collected are analyzed by 3 × 3 split-plot analysis of variance. No interaction was detected between cover crop and amendment effects ($P > 0.05$) except fresh shoot weight of turnip. Means followed by the same letters in a column are not different according to Waller-Duncan k ratio ($k = 100$) t-test at $P \leq 0.05$ based on log $(x + 1)$.

Table 3. Effect of cowpea as cover crop or amendment on fresh shoot weight of turnip, summer-fall, 2001.

	Cover crop effect		
Amendment effect	'White Acre'	'Iron Clay'	Fallow
	Fresh weight (g)/1.5 m^2		
'White Acre'	1,368 a B[z]	1,806 a AB	2,308 a A
'Iron Clay'	1,508 a A	1,864 a A	1,524 b A
No amendment	1,862 a AB	2,316 a A	1,340 b B

[z]Means are average of 5 replications. means in a column followed by the same lower case letters or means in a row followed by the same capital letters were not different according to Waller-Duncan *k* ratio (*k* = 100) t-test at $P \leq 0.05$ based on log (x + 1).

DISCUSSION

The current study revealed that growing of the cowpea cover crop rather than the use of cowpea residues as amendments resulted in turnip phytotoxicity. These results suggested that allelopathic compounds may be released from cowpea roots and remain active in the soil for a sufficient period of time (1 to 2 weeks) to affect a sensitive vegetable crop planted soon after the cover crop. A similar result was obtained by Schroeder *et al.* (1998), where plots with cowpea residues increased broccoli (*Brassica oleracea* L. (Italica Group)) transplant mortality. Such effects were short lived in that the replanted vegetable crops 25 days later showed no adverse effects, and in fact lima bean fresh shoot and pod weights were enhanced by cover crop growth of 'Iron Clay' cowpea. Nonetheless, cover crops should be examined more closely for allelopathic effects that may be beneficial in weed management, but a potential problem if effects extend to crop plants.

We hypothesized that a nematode-resistant cowpea variety would suppress plant-parasitic nematodes by poor host and allelopathic effects, and enhance the subsequent crop yield through nematode suppressive and green manure effects. Results in this experiment are consistent with previous research in that population density of *M. incognita* tended to be higher on 'White Acre' than on 'Iron Clay'. However, these differences were only apparent on the bush bean and lima bean crops, which were especially susceptible to *M. incognita*. This study showed that suppression of *M. incognita* using 'Iron Clay' cowpea is short-lived, and did not reduce the number of *M. incognita* better than the fallow treatment at cash crop harvest. Results suggest that maybe we cannot rely on cowpea cover crop alone as an effective nematode management tool. Further studies are required to examine the host status of these cowpea varieties on races of *M. incognita* other than race 1 and on other species of root-knot nematodes.

Occasional effects on other nematodes were noted but need to be followed up more to establish consistent trends. In any event, some of these nematodes (e.g. *Helicotylenchus* spp.) are not of particular concern in vegetable crop production.

The results partially support our hypothesis that the main mechanism of cowpea in suppressing *M. incognita* appears to be the non-host effect of the cover crop rather than allelopathic effect from crop residues. The effect of cowpea amendment on the population densities of *M. incognita* was not significant. This result also alleviates any concern that *M. incognita* might have been spread around while moving the cowpea hay into the subplot treatments. A third mode of action, stimulation of natural enemies by cover crop residues, was not evaluated here because such effects generally require a long term for buildup and activity (Stirling, 1987; McSorley and Gallaher, 1996; Wang *et al.*, 2002), rather than on a quickly decomposing green manure residue.

Of the three crops harvested, only the yield of lima bean was affected by the cowpea cover crop effect. Lima bean yield was higher following 'Iron Clay' than 'White Acre', but yield following 'Iron Clay' was not higher than yield following fallow. This pattern strongly suggested that the higher yield of lima bean in the 'Iron Clay' cover crop treatment than 'White Acre' was not due to a green manure effect but to the lower population densities of *M. incognita* in this treatment. Results from the crop biomass measurements indicated that green manure effects from cowpea residue amendments were negligible except on the non-leguminous cash crop, turnip. Due to their symbiotic relationship with N-fixing bacteria, leguminous crop are generally not as N-demanding as a non-leguminous crop, which clearly benefited from the green manure used here. Turnip growth benefited from growing 'Iron Clay' cowpea in combination with receiving its biomass as an amendment, as opposed to the lowest yield obtained from plots that were fallowed in the summer and received no cowpea amendment. This result is consistent with the finding of Ngouajiio et al. (2003) that incorporation of cowpea residues into soil improved yield of a subsequent lettuce (*Lactuca sativa* L.) crop. However, growing cowpea as a green-manure did not provide sufficient N for optimum broccoli (Schroeder *et al.*, 1998) or corn (*Zea mays* L.) production (Pieters, 1917).

In conclusion, mode of action for 'Iron Clay' to suppress *M. incognita* was due to its poor host effect rather than any allelopathic effect from biomass incorporation. Although 'Iron Clay' cowpea was neither an efficient cover crop for managing *M. incognita* in an infested field as compared to fallow treatment, nor an efficient green manure for the leguminous cash crops tested, a non-leguminous crop can benefit from growing 'Iron Clay' cowpea as a cover crop.

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