Journal of Nematology 34(4):358–361. 2002.

Non-Traditional Legumes as Potential Soil Amendments for Nematode Control

J. B. Morris and J. T. Walker[1]

Abstract: Dried ground plant tissues from 20 leguminous species were mixed with *Meloidogyne incognita*-infested soil at 1, 2 or 2.5, and 5% (w/w) and incubated for 1 week at room temperature (21 to 27 °C). Tomato ('Rutgers') seedlings were transplanted into infested soil to determine nematode viability. Most tissues reduced gall numbers below the non-amended controls. The tissue amendments that were most effective include: *Canavalia ensiformis, Crotalaria retusa, Indigofera hirsuta, I. nummularifolia, I. spicata, I. suffruticosa, I. tinctoria,* and *Tephrosia adunca.* Although certain tissues reduced the tomato dry weights, particularly at the higher amendment rates (5%), some tissues resulted in greater dry weights. These non-traditional legumes, known to contain bioactive phytochemicals, may offer considerable promise as soil amendments for control of plant-parasitic nematodes. Not only do these legumes reduce root-knot nematodes but some of them also enhance plant height and dry weight.
Key words: bioactive, genetic resources, legumes, root-knot nematode, soil amendment.

The legume family (*Fabaceae*) contains taxa of considerable agricultural utility. They are desirable rotational and cover crops because they fix nitrogen, adding up to 500 kg of nitrogen to soil per ha per year (NAS/NRC, 1979). In addition, legumes are also used as human food and forage for animals. Several uncultivated non-traditional legumes have agronomic potential. Genetic variation in legume species and their wild relatives is essential to successful breeding of improved crop cultivars with new "added value" uses. The USDA/ARS Plant Genetic Resources Conservation Unit (PGRCU) is dedicated to acquiring, conserving, and evaluating the genetic resources of crops adapted to the southern United States. Seed of more than 4,000 accessions of non-traditional legumes are stored at the PGRCU in Griffin, Georgia.

Legume species can serve as soil amendments as well as rotational or green manure cover crops for reducing nematode populations (Johnson et al., 1992; Mojtahedi, et al., 1991, 1993; Rhoades, 1976; Stirling, 1991) and other soil-borne pathogens (Blum and Rodríguez-Kábana, 1997; Hampson and Coombes, 1991; Hoitink et al. 1997; Khan and Reeleder, 1996; Lewis et al., 1992; McSorley and Gallaher, 1997). Neem (*Azadirachta indica*) (Riga and Lazarovits, 2001; Roosti and Deses, 1989) and other natural products from plants (Alphey and Robertson, 1988; Insuaza, 1988) have been found to reduce plant-parasitic nematode populations. American jointvetch and hairy indigo, as forage or green manure crops, have potential for managing soybean nematodes in Alabama (Rodríguez-Kábana et al., 1989). Some legumes may be useful forages (Morris, 1997); others contain pharmaceutical and nutraceutical chemicals (Beckstrom-Sternberg and Duke, 1994; Morris, 1997). Nutraceutical is defined as a food constituent or phytochemical with human health promoting characteristics. Legumes produce economically important organic compounds such as lectins from *Canavalia ensiformis* and rotenone, tephrosin, and deguelin from *Tephrosia vogellii,* which are used as pesticides (Beckstrom-Sternberg and Duke, 1994; Gaskins et al., 1972; Minton and Adamson, 1979; Tyler et al., 1976). The use of legumes as organic amendments for pest control may not yet be a widespread practice except in developing countries, but the practice may receive greater emphasis in the future because of the phaseout of methyl bromide as a soil fumigant. Most legume species have just begun to be surveyed for nematicidal constituents (Walker et. al., 1997), and new sources of nematicidal compounds in other plant families remain to be discovered (Ferris and Zheng, 1999). The incorporation of dried legume tissues as a pest control method can lead to various results depending on the type of legume amendment, soil moisture, and microbial flora and fauna (Campbell, 1989). Nematicidal activity of organic amendments in soil can be attributed to chemical mineralization with the ultimate release of ammonia, increasing nitrogen and carbon dioxide, lowered oxygen levels, release of toxic compounds from plant tissues, or growth of fungi and bacteria antagonistic to nematodes. Soil amendments may also provide an acceptable, economic way to increase yields in developing countries (Pyndji et al., 1997).

The objective of this study was to use dried tissue of non-traditional legume species (*Aeschynomene* spp., *Canavalia* spp., *Crotalaria* spp., *Indigofera* spp., *Leucaena* spp., *Rhynchosia* spp., *Senna* spp., *Sesbania* spp., and *Tephrosia* spp.) as soil amendments to determine their effects on root galling by the root-knot nematode *Meloidogyne incognita* (Koford & White) Chitwood.

Materials and Methods

Leaf, stem, and flower tissues from different leguminous plant species (Table 1) were harvested from field plots at the USDA, Plant Genetic Resources Conservation Unit, Griffin, Georgia, during fall 1998 for experiments conducted in 1999. The 1999 experiment was

Received for publication 16 July 2001.
[1] USDA, ARS, Plant Genetic Resources Conservation Unit and Department of Plant Pathology, University of Georgia, Griffin, GA 30223-1797.
The authors thank the S9 Regional Project and the University of Georgia for the support of this research and Jerry Davis, Station Statistician, for his assistance with statistical analysis.
E-mail: (bmorris@gaes.griffin.peachnet.edu)
This paper was edited by Patricia Timper.

TABLE 1. Legume species investigated as amendments for their nematicidal effect on root-knot nematode (*Meloidogyne incognita*) of tomato.

Taxon	Common name	Accession (PI) number	Origin
Aeschynomene indica L.		225551	Zambia
Canavalia ensiformis (L.) DC.	Jackbean	164695	India
Crotalaria juncea L.	Sunn hemp	299567	South Africa
Crotalaria retusa L.		346294	India
Indigofera cassioides Rottler Ex DC.		200075	India
Indigofera glandulosa J. C. Wendl		213521	India
Indigofera hirsuta L.	Hairy indigo	213523	India
Indigofera microcarpa Desv.	Indigo	337538	Argentina
Indigofera nummularifolia (L.) Liv. Ex Alston	Indigo	189493	India
Indigofera semitrijuga Forsskal.	Indigo	199504	India
Indigofera spicata Forsskal.	Spicate indigo	365597	Tanzania
Indigofera suffruticosa Miller	Anil indigo	163159	Brazil
Indigofera tinctoria L.	Common indigo	260642	India
Leucaena leucocephala (Lam.) de Wit	Leadtree	281609	Mexico
Leucaean leucocephala (Lam.) de Wit	Leadtree	281775	New Guinea
Leucaean leucocephala (Lam.) de Wit	Leadtree	443556	Mexico
Rhynchosia minima L. (DC.)	Snout bean	322540	Brazil
Senna angulata (J. Vogel) H. Irwin & Barneby		322312	Brazil
Sesbania speciosa Taubert	Brazilian lucerne	321747	Pakistan
Tephrosia adunca Benth.		308580	Venezuela
Tephrosia candida DC.	White tephrosia	304569	Madagascar
Tephrosia oxygona Welw. Ex Baker		185583	South Africa

repeated in 2000 with nine of the more promising plant species. Tissue of each species was dried in a forced-air oven for 1 month at 70 °C, ground in a Wiley mill (Thomas Scientific, Swedesboro, NJ) through a 4-mm screen, and stored dry until use. Dried legume tissue was chosen over fresh green materials for experiments because amendments would be approximately the same moisture content. Ground material was mixed at 1, 2.5, and 5% in 1999 and 1 and 2% (w/w) in 2000 with 1 kg of dry steam-pasteurized soil (piedmont-clay-loam; pH 5.96) in polyethylene clear bags. Nematode-infested soil without tissue served as controls. Approximately 6,000 eggs of *Meloidogyne incognita,* obtained from Rutgers tomatoes, were pipeted in 5 to 10 ml of water (depending on dilution factor) into each bag and mixed with soil. Soil moisture was not too wet, thus creating anaerobic conditions, but was moist enough for seed germination. The bag contents were mixed thoroughly by hand and then sealed. Each treatment included three replications.

After incubation at 21 to 27 °C for 1 week, the contents of each bag were distributed equally among three 320-cm^3 styrofoam cups (subreps) and one 2-week-old tomato [*Lycopersicon esculentum* Mill., prom. cons. var. *esculentum* (Rutgers)] seedling was transplanted into each cup. Cups containing tomato plants, amendments, and nematodes were arranged in a randomized split-plot design on greenhouse benches. Whole plots were legume amendments and sub-plots were amendment rates (1, 2 or 2.5, and 5% w/w) arranged in randomized complete blocks. Each replicate consisted of three tomato plants per legume and amendment rate combination. Greenhouse temperatures varied both years from 11 to 35 °C. Plants were fertilized 10 days after transplanting and at weekly intervals during the experiment with Peters water-soluble 20N-20P-20K (Grace-Sierra, Milpitas, CA) at the rate of 20 ml of solution containing 2.6 g/liter. After 2 months, tomato roots were washed free of soil, plant heights recorded, and the number of root-galls counted. Whole plant weights were recorded after drying tomato plants at 70 °C for 2 weeks. The means of the three subsamples were analyzed by Analysis of Variance, and differences in means for each dependent variable were determined by Fisher's protected LSD test at $P \leq 0.05$.

RESULTS AND DISCUSSION

Dried tissues of non-traditional leguminous plants reduced ($P = 0.0001$) the number of root galls on tomato when added to nematode-infested soil. In both the 1999 and 2000 experiments, the legume species ($P \leq 0.05$) and rate of incorporation ($P \leq 0.05$) affected the number of root galls per tomato plant. There was an interaction between legume species and amendment rate on root galling in the 1999 experiment ($P \leq 0.05$) but not in the 2000 experiment. Except for the pine straw, there was a decline in root galling with increasing rates of incorporation. All legumes ($P \leq 0.05$) reduced nematode galls when compared with the non-amended control. In the first experiment, tissues of *Canavalia ensiformis, Crotalaria retusa, Indigofera hirsuta, I. nummularifolia, I. spicata, I. suffruticosa, I. tinctoria,* and *Tephrosia adunca* were effective in reduc-

TABLE 2. Mean number of root-knot nematode galls, mean plant heights, and dry weights of tomato transplants grown in soil infested with 6000 *Meloidogyne incognita* eggs/kg and amended with different leguminous tissues and pine straw in 1999.

	Number galls/plant[a] amendment rate (% w/w)					
Amendment tissue (Taxon)	1.0	2.5	5.0	Mean	Plant height[a] (cm)	Dry weight[a] (g)
Canavalia ensiformis	18.1 a[b]	3.4 b	1.8 b	7.8 f[c]	18.8 bc[c]	3.28 cde[c]
Indigofera nummularifolia	16.7 a	3.3 b	2.4 b	7.5 f	20.9 abc	4.94 abc
Indigofera spicata	18.8 a	3.8 b	0.4 b	7.7 f	18.6 bc	3.09 de
Tephrosia adunca	18.6 a	9.2 ab	3.2 b	10.3 ef	20.5 abc	3.91 bcd
Crotalaria retusa	25.4 a	7.1 ab	1.6 b	11.4 def	21.2 abc	4.07 bcd
Indigofera suffruticosa	25.4 a	7.9 b	2.4 b	11.9 def	21.6 ab	5.27 ab
Indigofera tinctoria	22.1 a	11.9 a	2.2 a	12.1 def	20.3 abc	4.07 bcd
Indigofera hirsuta	20.9 a	16.2 a	2.2 b	13.1 def	21.1 abc	4.07 bcd
Aeschynomene indica	26.7 a	16.6 ab	4.1 b	15.8 cdef	22.2 ab	4.46 abcd
Crotalaria juncea	26.6 a	16.3 ab	5.7 b	16.2 cdef	21.5 ab	4.69 abcd
Senna angulata	31.4 a	13.0 b	6.4 b	17.0 cdef	20.9 abc	3.71 bcde
Tephrosia oxygona	35.0 a	13.2 b	5.6 b	17.9 cdef	20.1 abc	4.94 abc
Rhynchosia minima	31.2 a	18.6 b	11.6 c	20.4 cde	22.7 a	5.96 a
Indigofera glandulosa	47.9 a	9.4 b	5.4 b	20.9 cde	21.7 ab	4.57 abcd
Indigofera semitrijuga	31.3 a	22.3 ab	10.0 b	21.2 cd	22.7 a	4.91 abc
Tephrosia candida	42.8 a	20.9 b	2.7 c	22.1 cd	23.1 a	5.25 ab
Indigofera cassioides	49.1 a	18.1 b	5.1 b	24.1 c	21.7 ab	4.22 bcd
Indigofera microcarpa	48.7 a	13.7 b	10.6 b	24.3 c	20.8 abc	4.64 abcd
Pine Straw	55.9 a	29.3 b	23.4 b	36.2 b	17.7 c	2.15 e
Control (no tissue)				71.9 a	22.9 a	4.26 bcd

[a] Mean number based on three replications with three sub-samples in each. Percentage reduction for plant height, and weight data based on three rates combined.
[b] Means followed by the same letter across columns for the different amendment rates indicate no differences at $P = 0.05$ by Fisher's protected LSD test.
[c] Means followed by the same letter within columns indicate no differences at $P = 0.05$ by Fisher's protected LSD test.

ing galling on tomato by 80 to 90% (Table 2). In the second experiment, nematode galls per plant were reduced in soil amended with *I. nummularifolia* and *C. ensiformis* (Table 3).

Plant dry weights were higher from the *Rhynchosia minima* and *Tephrosia candida* in the first experiment, while *C. ensiformis* and the *Leucaena leucocephala* treatments were higher in the second experiment than other legume amendments. In both experiments, *I. suffruticosa* was consistent for having high tomato dry weights when compared with other legumes. In a previous study (Walker et al., 1997), tomato plants in soil amended with *Desmodium gangeticum* had reduced plant heights and dry weights. Examination of these roots revealed necrotic tips that were not present on control plants, suggesting a phytotoxic effect of the amendment to tomato. In this study, these symptoms were not observed with any of the soil amendments, and none of the legumes reduced the dry weight of tomato plants.

TABLE 3. Mean number of root galls and plant weights of tomato grown in legume-amended soils infested with *Meloidogyne incognita* in 2000.

Tissue	Mean[a] number of galls/plant	Gall reduction (%)	Mean dry weight[c] (g)
Indigofera nummularifolia	21.8 de[b]	82	2.09 cd[b]
Canavalia ensiformis	29.4 d	75	7.15 a
Tephrosia adunca	54.4 c	54	3.24 cd
Sesbania speciosa	56.0 c	53	5.68 ab
Indigofera suffruticosa	62.4 c	47	7.59 a
Indigofera cassioides	62.1 c	47	1.29 d
Indigofera semitrijuga	73.6 bc	38	3.75 bc
Leucaena leucocephala	75.8 bc	36	6.24 a
Crotalaria retusa	87.6 b	26	2.58 cd
Control with nematodes	118.2 a		2.00 cd
Control without nematodes	0.0 e		1.13 d

[a] Based on three replications with three sub-samples for each tissue rate (1% and 2%).
[b] Means followed by different letters within columns are significant at $P = 0.05$ by Fisher's LSD test.
[c] Mean number based on three replications with three sub-samples in each. Plant weight data based on two rates combined in this experiment.

Pine straw, which is widely used as mulch in landscapes, was included for comparison with the leguminous tissues in 1999. Pine straw reduced ($P = 0.0001$) root galling when compared to the non-amended soil. However, there was more root galling in soil amended with pine straw than in soil with most legume species (Table 2). The pine straw amendment decreased height and dry weight of the tomato transplants.

Legumes in the genera *Canavalia* and *Indigofera,* particularly *C. ensiformis* and *I. nummularifolia,* suppressed root galling by *M. incognita* when incorporated into steam-heated soil as dry tissue. There is widespread experimental evidence that various organic plant residues reduce numbers of plant-parasitic nematodes (Johnson, 1985; Ritzinger and McSorley, 1998; Rodríguez-Kábana et. al., 1989) by ammonification, secondary phytochemicals, or perhaps their breakdown products. Phytochemicals such as canavanine from *C. ensiformis,* indigotin from *I. tinctoria,* and rotenone or tephrosin from *T. candida* could be nematicidal. Based on these results, leguminous species vary in their effectiveness for controlling nematodes. However, this is an initial study and the activity of these plants during growth and following incorporation into soil needs to be determined under field conditions.

Two potential uses for these legumes are as dried organic amendments and incorporation as a green manure following plant growth to reduce plant-parasitic nematodes and growth and yield of the following crop. Stimulating soil microorganisms by the addition of soil amendments may be more realistic than introducing biological control microbes (Bridge, 1996). However, the quantities of dried tissue used in our studies, if commercially available, may not be practical for large-scale crop production. One percent (w/w) of certain leguminous tissues generally suppressed the number of galls on the tomato assays, which is similar to the amendment level found to be effective with castor bean and velvetbean (Ritzinger and McSorley, 1998). As additional information becomes available on the active mechanism(s) in legume amendments (Marban-Mendoza et al., 1992), smaller quantities of tissues could be efficacious. In large-scale cropping systems, it may be more practical to grow the legumes and incorporate them as green manures. Several legumes were identified with plant-enhancing capabilities, especially for plant height and dry weight. These include *Aeschynomene indica, C. ensiformis, Indigofera semitrijuga, I. suffruticosa, R. minima,* and *Tephrosia candida*. The added income to producers of legumes that have dual purposes may increase utilization of these crops in large- and small-scale agricultural systems. For example, a crop may be harvested for valuable phytochemicals and the remaining plant material incorporated into soil as a green manure for nematode control.

Literature Cited

Alphey, T. J. W., and W. M. Robertson. 1988. Assessment of the nematicidal potential of natural plant products. Nematologica 34:253 (Abstr.).

Beckstrom-Sternberg, S. M., and J. A. Duke. 1994. The phytochemical database. http://probe.nalusda.gov:8300/cgi-bin/query? dbname = phytochemdb.

Blum, L. E., and R. Rodríguez-Kábana. 1997. Benzaldehyde, kudzu, velvetbean, and pine bark powder as soil amendments for the management of *Rhizoctonia solani* and *Sclerotium rolfsii*. Phytopathology 87:89 (Abstr.).

Bridge, J. 1996. Nematode management in sustainable and subsistence agriculture. Annual Review Phytopathology 34:201–255.

Campbell, R. 1989. Biological control of microbial plant pathogens. United Kingdom: Cambridge University Press.

Ferris, H., and L. Zheng. 1999. Plant sources of Chinese herbal remedies: Effects on *Pratylenchus vulnus* and *Meloidogyne javanica*. Journal of Nematology 31:241–263.

Gaskins, M. H., G. A. White, F. W. Martin, N. E. Delfel, E. G. Ruppel, and D. K. Barnes. 1972. *Tephrosia vogelii:* A source of rotenoids for insecticidal and pesticidal use. U.S. Department of Agriculture, Technical Bulletin No. 1445.

Hampson, M. C., and Coombes. 1991. Use of crabshell meal to control potato wart in Newfoundland. Canadian Journal of Plant Pathology 13:97–105.

Hoitink, H. A. J., A. G. Stone, and D. Y. Han. 1997. Suppression of plant diseases by composts. Horticultural Science 32:184–187.

Insuaza, V. 1988. Potential of nematicidal plants in peasant agriculture in Chile: Screening of plant extracts on *Ditylenchus dipsaci*. Nematologica 34:274 (Abstr.).

Johnson, A. W. 1985. Specific crop rotation effects combined with cultural practices and nematicides. Pp. 283–301 *in* J. N. Sasser and C. C. Carter, eds. An advanced treatise on *Meloidogyne:* Biology and control, vol. 1. Raleigh, NC: North Carolina State University Graphics.

Johnson, A. W., A. M. Golden, D. L. Auld, and D. R. Sumner. 1992. Effects of rapeseed and vetch as green manure crops and fallow on nematodes and soil-borne pathogens. Journal of Nematology 24:117–126.

Kahn, N. I., and R. D. Reeleder. 1996. Use of biowaste amendments to reduce soil populations of *Phytophthora cactorum*. Phytopathology 86:S83 (Abstr.).

Lewis, J. A., R. D. Lumsden, P. D. Millner, and A. P. Keinath. 1992. Suppression of damping off of peas and cotton in the field with composted sewage sludge. Crop Protection 11:260–266.

Marban-Mendoza, N., M. B. Dicklow, and B. Zuckerman. 1992. Control of *Meloidogyne incognita* on tomato by two leguminous plants. Fundamentals of Applied Nematology 15: 2, 97–100.

McSorley, R., and R. Gallaher. 1997. Managing plant-parasitic nematodes in crop sequences. Soil and Crop Science Society of Florida Proceedings 51:42–45.

Minton, N. A., and W. C. Adamson. 1979. Response of *Tephrosia vogelii* to four species of root-knot nematodes. Plant Disease Reporter 63:514.

Mojtahedi, H., G. S. Santo, A. N. Hang, and J. H. Wilson. 1991. Suppression of root-knot nematode populations with selected rapeseed cultivars as green manure. Journal of Nematology 23:170–174.

Mojtahedi, H., G. S. Santo, and R. E. Ingham. 1993. Suppression of *Meloidogyne chitwoodii* with sudangrass cultivars as green manure. Journal of Nematology 25:303–311.

Morris, J. B. 1997. Special-purpose legume genetic resources conserved for agricultural, industrial, and pharmaceutical use. Economic Botany 51:251–263.

NAS/NRC. 1979. Tropical legumes: Resources for the future. Report by an ad hoc advisory panel of the Advisory Committee on Technology Innovation, Board on Science and Technology for International Development, Commission on International Relations, National Academy of Sciences and the National Research Council, Washington, D.C.

Pyndji, M., G. S. Abawi, and R. Buruchara. 1997. Use of green manures in suppressing root rot severity and damage to beans in Uganda. Phytopathology 87:S80 (Abstr.).

Rhoades, H. L. 1976. Effect of *Indigofera hirsuta* on *Belonolaimus longicaudatus, Meloidogyne incognita,* and *M. javanica* and subsequent crop yields. Plant Disease Reporter 60:384–386.

Riga, E., and G. Lazarovits. 2001. Development of an organic pesticide based on neem tree products. Journal of Nematology 33:274 (Abstr.).

Ritzinger, C. H. S. P., and R. McSorley. 1998. Effect of castor and velvetbean organic amendments on *Meloidogyne arenaria* in greenhouse experiments. Supplement to Journal of Nematology 30:624–631.

Rodríguez-Kábana, R., D. T. Robertson, L. Wells, P. S. King, and C. F. Weaver. 1989. Crops uncommon to Alabama for the management of *Meloidogyne arenaria* in peanut. Journal of Nematology 21: 712–716.

Roosti, L., and K. V. Deses. 1989. Effects of neem kernal extract on Steinernematid and Heterorhabditid nematodes. Nematologica 35: 493–496.

Stirling, G. R. 1991. Biological control of plant-parasitic nematodes: Progress Problems, and Prospects. Wallingford, UK: C. A. B. International.

Tyler, V. E., L. R. Brady, and J. E. Robbers. 1976. Glycosides. Pages 76–103 *in* Pharmacognosy. Philadelphia, PA: Lea and Febiger.

Walker, J. T., J. B. Morris, and J. Melin. 1997. *Desmodium, Leucaena, Senna,* and *Sesbania* tissues as amendments to root-knot infested soil. Journal of Nematology 29:611–612 (Abstr.).