

Organic and Inorganic Nitrogen Amendments to Soil as Nematode Suppressants

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Abstract: Inorganic fertilizers containing ammoniacal nitrogen or formulations releasing this form of N in the soil are most effective for suppressing nematode populations. Anhydrous ammonia has been shown to reduce soil populations of *Tylenchorhynchus claytoni*, *Helicotylenchus dihystera*, and *Heterodera glycines*. The rates required to obtain significant suppression of nematode populations are generally in excess of 150 kg N/ha. Urea also suppresses several nematode species, including *Meloidogyne* spp., when applied at rates above 300 kg N/ha. Additional available carbon must be provided with urea to permit soil microorganisms to metabolize excess N and avoid phytotoxic effects. There is a direct relation between the amount of "protein" N in organic amendments and their effectiveness as nematode population suppressants. Most nematicidal amendments are oil cakes, or animal excrements containing 2-7% (w:w) N; these materials are effective at rates of 4-10 t/ha. Organic soil amendments containing mucopolysaccharides (e.g., mycelial wastes, chitinous matter) are also effective nematode suppressants.

Key words: amendments, biological control, fertilizers, microbial ecology, nonchemical control, pest management, waste management.

Man has added organic and inorganic amendments to soil for centuries to improve soil fertility and increase crop yield. The nematicidal effect of some of these amendments has been recognized for some time, and reviews on the subject have been published (46,61). In developed countries the availability of effective nematicides has superseded the use of fertilizers and organic amendments for control of nematodes. Consequently, most of the research on the use of organic amendments for suppressing nematodes has been conducted in developing countries, principally in India (46). Linford et al. (29) were the first to study the nematicidal effects of organic amendments, incorporating chopped pineapple (*Ananas comosus*) leaves into soil for control of *Meloidogyne* spp. in cowpea (*Vigna unguiculata*). They noted that the population of free-living nematodes increased while that of *Meloidogyne* spp. decreased, and suggested that the increased organic matter supported microbial and animal species antagonistic to nematodes. Since then, many different types of organic amendments have been applied to a variety of crops to reduce populations of plant parasitic nematodes. Table 1 presents a list of selected nitrogenous amendments and

the nematodes they have been found to be effective against.

As the potential of amendments to control parasitic nematodes became recognized, researchers began more complex studies. Miller et al. (40,41) and Kirmani et al. (27) varied the C:N ratio of organic amendments and found that when more nitrogen was available, nematode control was enhanced. Other researchers examined different forms of nitrogen to determine their relative effectiveness against nematodes. Eno et al. (15) demonstrated the effectiveness of anhydrous ammonia in field soil infested with species of *Hoplolaimus*, *Criconemoides*, *Trichodorus*, and *Belonolaimus*. More recently, Rodríguez-Kábana et al. (53,55) reexamined the nematicidal properties of anhydrous ammonia. In greenhouse studies, ammonia reduced soil populations of *Tylenchorhynchus claytoni* and *Helicotylenchus dihystera* when applied at rates of 62 mg N/kg soil or higher; root populations of *H. dihystera* or of *Hoplolaimus galeatus* were reduced only with rates of 125 mg N/kg soil. In three field experiments with soybean (*Glycine max*), planting time applications of anhydrous ammonia at rates of 0-224 kg N/ha were relatively ineffective in reducing late-season juvenile population densities of *Meloidogyne arenaria* (Neal) Chitwood, although significant yield increases were obtained in one experiment in response to the treatments. In another field experiment, ammonia at 56 and 112 kg/ha reduced population den-

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TABLE 1. Selected amendments to soil studied for their activities against plant-parasitic nematodes.

Amendment	Nematode	Test plant	Reference
Oil-cakes			
Castor bean	<i>Heterodera schachtii</i> , <i>Meloidogyne javanica</i> , <i>Meloidogyne</i> spp. <i>Tylenchulus semipenetrans</i>	Tomato, sugarbeet	28
Karanj	<i>Meloidogyne</i> spp.	Citrus	30,33
Castor, linseed, mahua, margosa, sesame, peanut	<i>M. javanica</i>	Tomato, okra	58
Castor, mahua, margosa, mustard, sesame, peanut	<i>M. incognita</i>	Tomato, okra	58,61
Mustard, etc.	<i>Meloidogyne</i> spp.	Tomato	19,26
Fish	<i>M. hapla</i>	Tomato	20
Castor, neem, peanut	<i>Helicotylenchus erythrinae</i> , <i>H. indicus</i> , <i>M. incognita</i> , <i>Rotylenchulus reniformis</i> , <i>Tylenchorhynchus brassicae</i>	Sugarbeet	69
Neem	<i>Helicotylenchus</i> , <i>Pratylenchus</i>	Tomato, eggplant	25
Cotton seed, linseed, neem, mustard, peanut, sesame	<i>Helicotylenchus</i> , <i>Pratylenchus</i>	Maize, mung bean, wheat	50
Castor, mahua, neem, peanut	<i>Hirschmanniella oryzae</i>	Rice	34
Karanj, neem	<i>Aphelenchus avenae</i> , <i>Ditylenchus cyperi</i> , <i>M. incognita</i> , <i>T. brassicae</i>	Spinach	3
Cotton seed, mustard, sesame	<i>M. incognita</i>	Okra	13
Mustard, peanut	<i>M. incognita</i> , <i>Meloidogyne</i> spp.	(In vitro)	59
Manures and composts		Pepper	64
Farm yard manure, compost	<i>H. rostochiensis</i>	Potato	65
Farm yard manure	<i>Heterodera</i> spp.	Turf	21
Steer manure, chicken manure, liquid fish	<i>T. semipenetrans</i>	Citrus	33
Composted timothy hay	<i>P. penetrans</i> <i>Meloidogyne</i> spp., <i>T. semipenetrans</i>	Strawberry	42
Crotalaria, Kentucky blue grass, marigold	<i>M. hapla</i>	Citrus	30
Pressmud, farm yard manure	<i>M. incognita</i>	Sugarbeet	69
Chicken manure	<i>Meloidogyne</i> spp.	Okra	4
Chopped margosa, leaves, melia, sesbania, crotalaria	<i>M. incognita</i>	Several	8,12
Miscellaneous	<i>M. javanica</i>	Tomato, okra	60
Chitin	<i>M. incognita</i> <i>T. semipenetrans</i> <i>P. penetrans</i>	Tomato	31
Alfalfa, lespedeza, oat hays	<i>M. incognita</i>	Sweet orange	32
		Cucumber	39
		Tomato	24

sities of juveniles of *Heterodera glycines* in soil samples collected 14 days after planting. These field experiments also demonstrated that planting time applications of ethylene dibromide (4.7–18.6 liters/ha) together with anhydrous ammonia (56 or 112 kg N/ha) resulted in a soybean yield increase and accompanying control of *M. arenaria* and *H. glycines* superior to that ob-

tained when each chemical was applied singly. Similar results were also obtained with combinations of ammonia and 1,3-dichloropropene in other soybean field experiments for control of *M. arenaria* and *M. incognita* (55). Rodríguez-Kábana et al. (53) were in agreement with Vassalo (66) in attributing the nematicidal properties of anhydrous ammonia principally to its plas-

molysing effect in the immediate vicinity of its application point in the soil; however, their data on the effectiveness of ammonia against *H. glycines* also suggested other mechanisms were operating. They believed it possible that ammonia could exert a selective influence for microbial antagonists of *H. glycines*, particularly fungi (43,44,48,49). It was reasoned that since $\text{NH}_4^+\text{-N}$ is the preferred source of N for many soil fungi (10), some fungal parasites of *H. glycines* could have increased in numbers following applications of NH_3 to soil. Proliferation of such fungal parasites in turn could have resulted in the observed reductions in *H. glycines* juvenile populations.

Walker (68) studied organic—peptone, soybean meal, skim milk, urea—and inorganic— KNO_3 , $(\text{NH}_4)_2\text{SO}_4$, $(\text{NH}_4)_2\text{CO}_3$, NH_4OH —nitrogen sources and found that ammoniacal and organic nitrogen sources were more detrimental to nematodes than nitrate. Other common fertilizers also have been studied, and findings generally indicate that those containing ammoniacal nitrogen are more damaging to nematodes than those with nitrate nitrogen (6–8, 23,56).

Since ammoniacal nitrogen is detrimental to nematodes, urea has been studied as a nematicide. The compound is readily converted to ammonia by urease present in the soil, a necessary conversion if urea is to be effective both as a fertilizer and as a nematicide. Mojtahedi and Lownsbery (45) performed in vitro experiments in which urea was added to a mixture of nematodes with and without the addition of urease or urease-producing bacteria; nematodes were killed only in the presence of urease. Urea is a good nematicide when applied at levels in excess of 300 kg N/kg soil (22,52). Such high rates of urea result in significant accumulations of nitrate and ammoniacal N in soil and phytotoxicity (22). The phytotoxic effects of urea are due to the narrow C:N ratio of urea; there is insufficient available carbon in soil treated with nematicidal rates of urea alone to permit microbial utilization of all the available nitrogen. These detrimental accumulations of ammonia and nitrate can be overcome by supplementing urea amendments with additional available carbon.

Studies at Auburn University have shown that combinations of blackstrap molasses plus urea (52) or of hemicellulosic paper waste plus urea (22) are not phytotoxic and are as nematicidal as additions of urea alone. In addition, these combination treatments stimulate microbial activity resulting in marked increases not only in urease activity but also in other soil enzymatic activities associated with microbial metabolism. In all cases, soil receiving the combination treatments had much greater enzymatic activity than soil treated with urea alone. The observed increase in numbers of microbivorous nematodes relative to soil treated with urea only reflected the increased microbial activity in soil treated with the combination treatments. This was interpreted as resulting from the short life cycle of these nematodes and the availability of large bacterial populations in soil that received the combination treatments.

The superiority of ammonia-releasing nitrogen sources over nitrates for suppressing nematodes has been demonstrated in experiments with *Rotylenchulus reniformis* on olives (6), *Criconemoides xenoplax* on plum (45), and *Tylenchulus semipenetrans* on citrus (5,7).

Studies of the nematicidal properties of inorganic N fertilizers indicate that to be effective these materials must be applied at levels far in excess of those required for crop fertilization. This perhaps explains why in some studies (57,67) inorganic N fertilizers, even ammonia-releasing materials, when applied at fertilizer rates have been ineffective against plant parasitic nematodes. There is also evidence that different rates are required according to the nematode species present. Eguiguren et al. (14) observed no significant decreases in *Tylenchorhynchus* spp. but reported a suppression of species of *Criconemoides* and *Trichodorus* in response to the same rate of nitrogen fertilizer. Miller (38) found urea inhibited *Pratylenchus penetrans* and *Hoplolaimus* sp. but was ineffective against *Tylenchorhynchus* sp.

The high rates of N required for consistent nematicidal activity from ammoniacal fertilizers can be expected to result in significant phytotoxicity through the accumulation of metabolic byproducts in the soil. As was demonstrated for urea, how-

ever, this can be obviated by formulating the fertilizers with carriers containing sufficient available carbon to ensure adequate stimulation of microbial metabolic activity. It should be possible through careful choice of appropriate organic carriers to enhance the nematicidal properties of inorganic N fertilizers, avoid phytotoxic effects, and provide excellent plant nutrition.

Additions of nitrogenous organic manures to soil have often been reported to reduce population densities of plant parasitic nematodes. Most efficacious of these amendments are those with low C:N ratios that release ammonia in soil. Effective materials of this type are oil meals and cakes, composts and animal ordures, and green manures. Table 1 presents a list of the types of materials utilized for nematode control, the target nematodes, and the crop species on which they have been tried.

There is a direct relation between the amount of Kjeldahl-determined N in organic amendments and their effectiveness as nematode population suppressors (36). Most nematicidal amendments contain 2–7% (w:w) N; these materials are effective when incorporated at rates of 4–10 t/ha. Soil incorporation of these materials stimulates the soil microflora leading to the release of ammonia through the activity of proteolytic and deaminating enzymes. These amendments typically result in the enhancement of soil urease activity and the accumulation of ammoniacal and nitrate nitrogen (35,37,51). As with urea, these amendments can be phytotoxic if sufficient carbon is not available to support metabolism of the added nitrogen. This phenomenon was illustrated in a recent study with chicken litter and oil cakes of peanut and cotton for control of *M. arenaria* (35). All three materials were effective in suppressing the nematode; however, the oil cakes (C:N ratios of 7) were phytotoxic, whereas the chicken litter (C:N = 10) was not.

Whereas the nematicidal effects of ammoniacal inorganic fertilizers and high-N organic amendments can be attributed for the most part to microbial activities connected with the N cycle in soil, very little is known about the roles of individual microbial species in suppressing nematodes—specifically, which microorganisms are able to decompose or transform the

amendments in soil leading to the destruction of nematodes. Also, what, if any, toxins active against nematodes are released or synthesized through microbial activity during transformation of the nitrogenous amendments? Is there any relation between the proteolytic activity of the microflora and the ability of these microorganisms to destroy or parasitize nematodes? Are the enzymes needed to decompose the proteins of the amendments the same as those involved in the destruction of the nematode eggs, juveniles, or adults?

Some organic amendments are known to contain substances toxic to nematodes (1,2,4,5,28,61,62,63); thus, when added to the soil in sufficient quantity, they suppress nematode activity directly. Most interesting among nitrogenous amendments for control of nematodes are those containing chitin or similar mucopolysaccharides. Chitin is widely distributed in nature, being the second most common polysaccharide after cellulose (47). Crustacean chitin and chitinous materials of microbial origin (e.g., cell walls of some fungi) are readily available as waste products of the food and pharmaceutical industries. Chitin is a component of the middle layer of the tylenchoid egg shell (9). When chitin is added to soil it is depolymerized through chitinase activity in the soil (47,51). The end result of this process is the release of *N*-acetylglucosamine and presumably deamination of the sugar with consequent accumulation of ammoniacal N and nitrates in the soil (51). There is a particular microflora associated with the decomposition of chitin in soil (18,37,54). Chitin amendments are effective for control of *M. incognita* in tomato (31), reduction of the incidence of *Tylenchulus semipenetrans* on orange (32), and reduction of *Pratylenchus penetrans* and *Tylenchorhynchus dubius* on cucumber (39). Studies at Auburn University have shown that chitin amendments are also effective in the control of *H. glycines* (54) and *M. arenaria* (18,37). More important, with some exceptions an association has been established between the chitinolytic ability of fungi and their capacity to destroy nematode eggs (16–18,54). Several fungal species isolated from soil treated with chitin are able to decompose the polymer and are known parasites

of eggs of *Meloidogyne* spp. or *H. glycines*, or have been isolated from diseased eggs of these nematodes (18,54). As with other nitrogenous amendments, chitin amendments can be phytotoxic because of the relatively narrow (6.4) C:N ratio of the polymer; however, this problem can be eliminated with additional available carbon (11). There is also evidence that some of the phytotoxic effects caused by chitin amendments may be related to changes in soil pH (unpubl.).

Results from the chitin studies have demonstrated that it is possible to choose the composition of an amendment to be added to soil so as to stimulate the development of a microflora parasitic or destructive to nematodes. Conceivably, organic amendments could be developed to select for microorganisms capable of decomposing the proteins or other materials that make up nematode cuticles or other structures. Stimulation of a selected microflora could then be coupled with the addition to soil of compounds capable of rendering nematodes or their eggs susceptible to attack by the microorganisms.

LITERATURE CITED

1. Alam, M. M., M. Ahmad, and A. M. Khan. 1980. Effect of organic amendments on the growth and chemical composition of tomato, eggplant and chilli and their susceptibility to attack by *Meloidogyne incognita*. *Plant and Soil* 57:231-236.
2. Alam, M. M., A. M. Khan, and S. K. Saxena. 1978. Mechanism of control of plant parasitic nematodes as a result of the application of organic amendments to the soil. IV. Role of formaldehyde and acetone. *Indian Journal of Nematology* 8:172-174.
3. Alam, M. M., and A. M. Khan. 1974. Control of phytonematodes with oil-cake amendments in spinach fields. *Indian Journal of Nematology* 4:239-240.
4. Alam, M. M., A. M. Khan, and S. K. Saxena. 1979. Mechanism of control of plant parasitic nematodes as a result of the application of organic amendments. V. Role of phenolic compounds. *Indian Journal of Nematology* 9:136-142.
5. Badra, T., and D. M. Elgindi. 1979. The relationship between phenolic content and *Tylenchulus semipenetrans* populations in nitrogen-amended citrus plants. *Revue de Nematologie* 2:161-164.
6. Badra, T., and M. M. Khatatab. 1980. The effect of nitrogen fertilizers on the growth of olive and in relation to infestations of *Rotylenchulus reniformis*. *Nematologia Mediterranea* 8:67-72.
7. Badra, T., and M. F. Shafiee. 1979. Effects of nitrogen source and rate on the growth of lime seedlings and the control of *Tylenchulus semipenetrans*. *Nematologia Mediterranea* 7:191-194.
8. Badra, T., M. A. Saleh, and B. A. Oteifa. 1979. Nematicidal activity and composition of some organic fertilizers and amendments. *Revue de Nematologie* 2:29-36.
9. Bird, A. F., and M. A. McClure. 1976. The tylenchoid (Nematoda) egg shell: Structure, composition and permeability. *Parasitology* 72:19-28.
10. Cochrane, V. W. 1958. *Physiology of fungi*. New York: John Wiley.
11. Culbreath, A. K., R. Rodríguez-Kábana, and G. Morgan-Jones. 1985. The use of hemicellulosic waste matter for reduction of the phytotoxic effects of chitin and control of root-knot nematodes. *Nematropica* 15:49-75.
12. Derrico, F. P., and F. D. Maio. 1980. Effect of some organic materials on root-knot nematodes on tomato in field preliminary experiments. *Nematologia Mediterranea* 8:107-111.
13. Desai, M. V., H. M. Shah, S. N. Pilai, and A. S. Patel. 1979. Oil-cakes in control of root-knot nematodes. *Tobacco Research* 5:105-108.
14. Eguiguren, R., F. Torres, and G. Robalina. 1979. Influence of NPK on the population dynamics of several nematode genera on potato. *Nematropica* 9:16-22.
15. Eno, C. F., W. G. Blue, and J. M. Good. 1955. The effect of anhydrous ammonia on nematodes, fungi, bacteria, and nitrification in some Florida soils. *Proceedings Soil Science Society of America* 19:55-58.
16. Godoy, G. R., Rodríguez-Kábana, and G. Morgan-Jones. 1983. Fungal parasites of *Meloidogyne arenaria* in an Alabama soil. A mycological survey and greenhouse studies. *Nematropica* 13:201-213.
17. Godoy, G., R. Rodríguez-Kábana, and G. Morgan-Jones. 1982. Parasitism of eggs of *Heterodera glycines* and *Meloidogyne arenaria* by fungi isolated from cysts of *H. glycines*. *Nematropica* 12:111-119.
18. Godoy, G., R. Rodríguez-Kábana, R. A. Shelby, and G. Morgan-Jones. 1983. Chitin amendments for control of *Meloidogyne arenaria* in infested soil. II. Effects on microbial population. *Nematropica* 13:63-74.
19. Gowda, D. N., and K. G. H. Setty. 1973. Studies on comparative efficacy of various organic amendments on control of root-knot of tomato. *Mysore Agricultural Science* 7:419-423.
20. Hameed, S. F. 1970. Note on the effect of some organic additives on the incidence of root-knot nematodes in tomato (*Lycopersicon esculentum*). *Indian Agricultural Science* 40:207-210.
21. Heald, C. M., and G. W. Burton. 1968. Effect of organic and inorganic nitrogen on nematode populations feeding on turf. *Plant Disease Reporter* 52:46-48.
22. Huebner, R. A., R. Rodríguez-Kábana, and R. M. Patterson. 1983. Hemicellulosic waste and urea for control of plant parasitic nematodes: Effect on soil enzyme activities. *Nematropica* 13:37-54.
23. Johnson, L. F. 1962. Effect of the addition of organic amendments to soil on root-knot of tomatoes. II. Relation of soil temperature, moisture, and pH. *Phytopathology* 52:410-413.
24. Johnson, L. F., A. Y. Chambers, and H. E. Reed. 1967. Reduction of root-knot of tomatoes with crop residues amendment in field experiments. *Plant Disease Reporter* 51:219-222.
25. Khan, M. W., A. M. Khan, and S. K. Saxena.

1974. Rhizosphere fungi and nematodes of eggplant as influenced by oil-cake amendments. *Indian Phytopathology* 27:480-484.

26. Khan, M. W., A. M. Khan, and S. K. Saxena. 1973. Influence of certain oil-cake amendments on nematodes and fungi in tomato field. *Acta Botanica Indica* 1:49-51.

27. Kirmani, M. R., M. M. Alam, A. M. Khan, and S. K. Saxena. 1975. Effect of different carbon:nitrogen ratios on the population of nematodes and fungi and plant growth of cabbage. *Indian Journal of Mycology and Plant Pathology* 5:22.

28. Lear, B. 1959. Application of castor pomace and cropping of castor beans to soil to reduce nematode populations. *Plant Disease Reporter* 43:459-460.

29. Linford, M. B., F. Yap, and J. M. Oliveira. 1938. Reduction of soil populations of root-knot nematode during decomposition of organic matter. *Soil Science* 45:127-141.

30. Mankau, R. 1963. Effect of organic soil amendments on nematode populations. *Phytopathology* 53:881-882.

31. Mankau, R., and S. Das. 1969. The influence of chitin amendments on *Meloidogyne incognita*. *Journal of Nematology* 1:15-16.

32. Mankau, R., and S. Das. 1974. Effect of organic materials on nematode bionomics in citrus and root-knot nematode infested field soil. *Indian Journal of Nematology* 4:138-151.

33. Mankau, R., and R. J. Minter. 1962. Reduction of soil populations of the citrus nematode by the addition of organic matter. *Plant Disease Reporter* 46:375-378.

34. Mathur, J. K., and S. K. Prasad. 1974. Control of *Hirschmanniella oryzae* associated with paddy. *Indian Journal of Nematology* 4:54-60.

35. Mian, I. H., and R. Rodríguez-Kábana. 1982. Soil amendments with oil-cakes and chicken litter for control of *Meloidogyne arenaria*. *Nematropica* 12:205-220.

36. Mian, I. H., and R. Rodríguez-Kábana. 1982. Survey of the nematocidal properties of some organic materials available in Alabama as amendments to soil for control of *Meloidogyne arenaria*. *Nematropica* 12:235-246.

37. Mian, I. H., G. Godoy, R. A. Shelby, R. Rodríguez-Kábana, and G. Morgan-Jones. 1982. Chitin amendments for control of *Meloidogyne arenaria* in infested soil. *Nematropica* 12:71-84.

38. Miller, P. M. 1976. Effects of some nitrogenous materials and wetting agents on survival in soil of lesion, stilet, and lance nematodes. *Phytopathology* 66:798-800.

39. Miller, P. M., D. C. Sands, and S. Rich. 1973. Effect of industrial residues, wood fiber wastes and chitin on plant parasitic nematodes and some soil-borne diseases. *Plant Disease Reporter* 57:438-442.

40. Miller, P. M., G. S. Taylor, and S. E. Wahrheim. 1968. Effect of cellulosic soil amendments and fertilizers on *Heterodera tabacum*. *Plant Disease Reporter* 52:441-445.

41. Miller, P. M., and S. E. Wahrheim. 1966. Invasion of root by *Heterodera tabacum* reduced by cellulosic amendments or fertilizers in soil. *Phytopathology* 56:890.

42. Morgan, G. T., and W. B. Colins. 1964. The effect of organic treatments and crop rotation on soil populations of *Pratylenchus penetrans* in strawberry

culture. *Canadian Journal of Plant Science* 44:272-275.

43. Morgan-Jones, G., B. Ownley Gintis, and R. Rodríguez-Kábana. 1981. Fungal colonization of *Heterodera glycines* cysts in Arkansas, Florida, Mississippi, and Missouri soils. *Nematropica* 11:155-164.

44. Morgan-Jones, G., and R. Rodríguez-Kábana. 1981. Fungi associated with cysts of *Heterodera glycines* in an Alabama soil. *Nematropica* 11:69-77.

45. Mojtahedi, H., and B. F. Lownsbery. 1976. The effects of ammonia-generating fertilizer on *Criconeimoides xenoplax* on pot cultures. *Journal of Nematology* 8:306-309.

46. Muller, R., and P. S. Gooch. 1982. Organic amendments in nematode control. An examination of the literature. *Nematropica* 12:319-326.

47. Muzzarelli, R. A. 1977. Chitin. New York: Pergamon Press.

48. Ownley Gintis, B., G. Morgan-Jones, and R. Rodríguez-Kábana. 1983. Fungi associated with several developmental stages of *Heterodera glycines* from an Alabama soybean field soil. *Nematropica* 13:181-200.

49. Ownley Gintis, B., G. Morgan-Jones, and R. Rodríguez-Kábana. 1982. Mycoflora of young cysts of *Heterodera glycines* in North Carolina soils. *Nematropica* 12:295-303.

50. Prasad, S. K., S. D. Mishra, and A. C. Gaur. 1974. Effect of soil amendments on nematodes associated with wheat followed by mung and maize. *Indian Journal of Entomology* 34:307-311.

51. Rodríguez-Kábana, R., G. Godoy, G. Morgan-Jones, and R. A. Shelby. 1983. The determination of soil chitinase activity. Conditions for assay and ecological studies. *Plant and Soil* 75:95-106.

52. Rodríguez-Kábana, R., and P. S. King. 1980. Use of mixtures of urea and blackstrap molasses for control of root-knot nematodes in soil. *Nematropica* 10:38-44.

53. Rodríguez-Kábana, R., P. S. King, and M. H. Pope. 1981. Combinations of anhydrous ammonia and ethylene dibromide for control of nematodes parasitic of soybeans. *Nematropica* 11:27-41.

54. Rodríguez-Kábana, R., G. Morgan-Jones, and B. Ownley Gintis. 1984. Effects of chitin amendments to soil on *Heterodera glycines*, microbial populations, and colonization of cysts by fungi. *Nematropica* 14:10-25.

55. Rodríguez-Kábana, R., R. A. Shelby, P. S. King, and M. H. Pope. 1982. Combinations of anhydrous ammonia and 1,3-dichloropropenes for control of root-knot nematodes in soybean. *Nematropica* 12:61-69.

56. Scotto La Massesse, C., C. R. Vassy, and H. Zaouchi. 1973. Elimination de *Tylenchulus semipene-trans* par des apports azotes appliques a des clementinier greffes sur higardiens. *Nematologia Mediterranea* 1:15-21.

57. Sinclair, W. A. 1975. Plant-parasitic nematodes suppressed by urea fertilization in a forest nursery. *Plant Disease Reporter* 59:334-336.

58. Singh, R. S. 1965. Control of root-knot of tomato with organic amendments. U.N. Food and Agricultural Plant Protection Bulletin 13:35-37.

59. Singh, I., S. K. Sharma, and P. K. Sing. 1980. Effect of oil-cakes extract on the hatching of root-knot nematodes, *Meloidogyne incognita*. *Indian Journal of Mycology and Plant Pathology* 9:115-116.

60. Singh, R. S., and K. Sitaramaiah. 1967. Effect

of decomposing green leaves, sawdust and urea on the incidence of root-knot in okra and tomato. *Indian Phytopathology* 20:349-355.

61. Singh, R. S., and K. Sitaramaiah. 1973. Control of plant parasitic nematodes with organic amendments of soil. Final technical report. Effect of organic amendments, green manures, and inorganic fertilizers on root-knot of vegetable crops. Research Bulletin, Experiment Station and College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, India.

62. Sitaramaiah, K., and R. S. Singh. 1978. Effect of organic amendments on phenolic content of soil and plant and response of *Meloidogyne javanica* and its host to related compounds. *Plant and Soil* 50:671-679.

63. Srivastava, A. S., R. C. Pandey, and S. Ram. 1971. Application of organic amendment for the control of root-knot nematode, *Meloidogyne javanica*. (Trueb.). *Labdev Journal of Science and Technology* 9 B (319):203-205.

64. Trivedi, P. C., A. Bhatnagar, and B. Tiagi.

1978. Control of nematodes on *Capsicum annuum* by application of oil-cakes. *Indian Phytopathology* 31: 75-76.

65. Van der Laan, P. A. 1956. The influence of organic manuring on the development of the potato eelworm, *Heterodera rostochiensis*. *Nematologica* 1:112-115.

66. Vassalo, M. 1968. The nematicidal power of ammonia. *Compte Rendue 8th International Symposium of Nematology*. P. 128.

67. Villanueva, C. F., J. A. de Guerra, and E. E. Carbonell. 1978. Effect of nitrogen application rate on the population density of plant parasitic nematodes of sugarcane. *Saccharum* 6:72-85.

68. Walker, J. T. 1971. Populations of *Pratylenchus penetrans* relative to decomposing nitrogenous soil amendments. *Journal of Nematology* 3:43-49.

69. Yuhara, I. 1971. Effect of soil treatment with organic powder on the population of *Meloidogyne hapla* attacking sugarbeet. *Bulletin of Sugarbeet Research* 13(Suppl.):201-205.