SOIL AMENDMENTS WITH OIL CAKES AND CHICKEN LITTER FOR CONTROL OF *MELOIDOGYNE ARENARIA*.

I.H. Mian and R. Rodríguez-Kábana

Department of Botany, Plant Pathology, and Microbiology, Auburn University, Agricultural Experiment Station, Auburn, AL 36849, U.S.A.

Accepted:
18.X.1982
Aceptado:

ABSTRACT

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.

The effect of soil amendments with cotton (*Gossypium hirsutum* L.) seed oil cake, peanut (*Arachis hypogaea* L.) oil cake and chicken litter on *Meloidogyne arenaria* (Neal) Chitwood was studied in greenhouse experiments with squash (*Cucurbita pepo* L.). The amendments reduced root galling caused by the nematode and stimulated plant growth. The degree of nematode control was dependent on the amount of material added; oil cake amendments of 0.4% or more practically eliminated root galling. Nematode control with chicken litter was directly proportional to the amount of the litter added within the range of 0-5%; however, this material was not as nematicidal as the oil cakes since even the 5% rate failed to completely eliminate root galling. The use of oil cakes at rates of 0.4% or higher caused significant phytotoxicity. All treatments with chicken litter were nonphytotoxic. Soils treated with high levels (1.0% or more) of the amendments contained more nitrate nitrogen, and had higher urease activity and pH than untreated soils.

Additional key words: ammonia, biological control, C/N ratio, cultural practices, organic manures, nematode control, root-knot nematodes, soil enzymes, waste management.

RESUMEN

Mian, I.H. y R. Rodríguez-Kábana. 1982. Enmiendas al suelo con tortas de aceites y con estiércol de gallina para combatir *Meloidogyne arenaria*. Nematrópica 12:205-220.

Se estudió con tres experimentos de invernadero con calabacín (*Cucurbita pepo* L.) el efecto sobre *Meloidogyne arenaria* (Neal) Chitwood de enmiendas al suelo con tortas de aceites de algodón (*Gossypium hirsutum* L.) y de maní (*Arachis hypogaea* L.) así como el de enmiendas con estiércol de gallina. Las enmiendas redujeron el agallamiento de las raíces causado por el nematodo y estimularon el crecimiento de las plantas. El nivel de redución del agallamiento, sin embargo, dependió de la cantidad de material añadido; las enmiendas con tortas a niveles de 0.4% (w/w) o más, eliminaron practicamente el agallamiento. El grado de

control del nematodo obtenido con el estiércol de gallina estuvo relacionado de manera linear y directa con la cantidad de estiércol añadido al suelo entre los niveles de 0-5%; este material sin embargo, no fue tan nematicida como las tortas de aceites ya que aún cuando se le añadio al suelo al 5% no resultó en la eliminación total del agallamiento. Las enmiendas con tortas de aceite a niveles de 0.4% o más causaron fitotoxicidad. El estiércol de gallina, por el contrario, no mostró ser fitotóxico en todas las concentraciones del estudio. Todos los suelos tratados con altos niveles de las enmiendas (1.0% o más) contuvieron más nitrato y mostraron niveles más altos de actividad de la ureasa, y pH más alto, que los suelos sin enmiendas.
Palabras claves adicionales: amoniaco, control biológico, abonos orgánicos, nematodos noduladores, proporción C/N, combate de nematodos, enzimas del suelo, manejo de desperdicios, prácticas culturales.

INTRODUCTION

The addition of organic matter to soil for control of plant parasitic nematodes is an old concept. A review of the literature on this method of nematode control reveals that the type of material used in the amendments determines the success of the application; most effective are materials with narrow C/N. Among this type of materials oil cakes and poultry manures are abundant in supply and available in most areas of the world. Various kinds of oil cakes are effective for control of many economically important phytonematodes (1,3,7,8,9,10,17,18,19,24,31,32,33,34,35,37). Similarly, the beneficial effects of chicken manure amendments as nematicides is well documented (2,3,5,6,8,20,21,30). Most of the research on the use of soil amendments for control of nematodes has been done outside the U.S.A.; the availability of synthetic nematicides and the relatively large quantities of organic materials required to obtain effective nematode control has limited their use in the U.S.A. While these limitations apply to row crops, they may not apply for their use in home gardens where currently the number of synthetic nematicides registered for that use is very limited.

Information on the mode of action of soil organic amendments with narrow C/N against nematodes is limited. Several investigators have suggested a number of probable mechanisms (3,16,30,33). Badra *et al* (3) believed that fatty acids, phenols, gases, etc., produced during decomposition of oil cakes and chicken manure were nematicidal. Khan *et al* (16) thought that ammonia released during decomposition of the amendments was toxic to plant parasitic nematodes. Mian and associates (25) were of the opinion that ammonia was partially involved in controlling *Meloidogyne arenaria* (Neal) Chitwood in chitin amended soils; these investigators showed that a specific mycoflora antagonistic to the nematode developed in soils treated with chitin.

The present study was performed to: assess the efficacy against *M. arenaria* of three organic amendments with narrow C/N commonly available in the U.S.A., and to determine the effect of these materials on several variables important in the soil nitrogen cycle.

MATERIALS AND METHODS

The effect of three organic amendments with low C/N ratios on *M. arenaria* was studied in three separate greenhouse experiments. One experiment was with cotton (*Gossypium hirsutum* L.) seed oil cake, another with peanut (*Arachis hypogaea* L.) oil cake, and the third with chicken litter. The elemental composition of these materials determined by standard methods of analysis (13) is presented in Table 1. Soil for the experiments was a sandy loam [pH 6.0, org. matter content $< 1\%$ (w/w)] from an infested peanut field. Moist soil [60% field capacity (FC)] was screened (1 mm mesh) and apportioned in 1 kg quantities in 4-L capacity plastic bags. In experiments with oil cakes dry ground (0.2 mm mesh) material was added to the bags with the soil to have concentrations of 0.0, 0.1, 0.2, 0.4, 0.6, 0.8, and 1.0% (w/w). Dry ground (0.2 mm mesh) chicken litter was added at rates of 0.0, 0.5, 1.0, 2.0, 3.0, 4.0, and 5.0% (w/w). After thorough mixing, the amended soils were transferred to a 1-L capacity plastic pots which were placed in the greenhouse and maintained moist (60% FC) to allow decomposition of the materials. After 3 weeks the pots were planted with 5 summer crookneck squash seeds (*Cucurbita pepo L.*). The resulting plants were allowed to grow for 6 weeks when the number of surviving plants per pot was determined and the plants were removed from the soil. The number of galls per root system, the fresh weights of roots and shoots, and shoot heights were determined. In addition, the degree of galling of the roots was assessed using a scale of 0-10 where 0 represented roots with no galls and 10 those with maximal degree of galling (38).

Soil from each pot was spread on alumninum foil and allowed to dry at approximately 25C. The dry soil was stored in the dark at 4C until analyzed. Soil pH was determined electrometrically in a suspension of 10 gm of dry soil in 10 ml of water which had been shaken for 30 min on a mechanical shaker. After determination of pH 10 ml of water was added to the suspension and 10 ml of the diluted mixture was centrifuged (4000 g, 20 min). Conductivity of the clear supernatant was determined with an Industrial Instruments Conductivity Bridge fitted with a cell (K = 1.0). The amount of nitrate nitrogen in 2 ml of the clear supernatant was determined with the phenyldisulphonic acid method (14).

Microbial activity in the soil was assessed by determining urease activity with the method of Rodríguez-Kábana and King (26).

In every experiment each concentration of amendment was represented by 8 replications (pots) arranged in a randomized complete block design. All data were analyzed following standard procedures for analysis of variance and differences between means were evaluated for significance with a modified Duncan's multiple range test (36). Unless otherwise stated differences

Table 1. Elemental composition of 2 oil cakes and chicken litter tested as amendments to control *Meloidogyne arenaria* in infested soil.

	Percent (w/w) of dry weight							µg/gm of dry weight			
	C	N	P	K	Ca	Mg	S	Cu	Fe	Mn	Zn
Chicken litter	31.90	3.059	1.60	3.31	2.47	0.50	0.49	32	558	364	188
Cotton oil cake	44.72	6.331	0.99	1.56	0.11	0.50	0.45	8	20	22	28
Peanut oil cake	43.06	6.121	0.66	1.48	0.09	0.31	0.24	10	62	42	22

referred to in the text were significant at the 5% or lower level of probability. Linear correlation coefficients and regression equations were also calculated following standard statistical procedures (36).

RESULTS

1. *Cotton seed oil cake.* Data from this experiment are presented in Tables 2 and 3. The addition of cotton seed oil cake at rates of 0.2% or higher reduced the number of galls per gm of root. Differences in numbers of galls in roots of plants from the soil treated with 0.2% or higher of the cake were not significant. Gall indices followed a similar pattern to that for gall numbers; however, only the indices for treatments with 0.4% or higher concentration were lower than those for other treatments of the experiments.

Addition of the cake to soil at rates of 0.2, 0.4, and 0.6% resulted in heavier shoots and roots than unamended soil; those from other amended soils did not differ in weight from the control. Shoot height was lowest for plants from the 1% treatment and highest for those from soils that received 0.2% or less of the amendment.

Treatments with 0.2% or less of the amendment did not affect germination and seedling survival; however, higher amounts of the cake reduced the number of surviving plants per pot with the lowest number corresponding to the highest amendment level.

Values for pH of soils that received 0.2% or less of the cake were not different, but those corresponding to soils treated with 0.4% or more of the amendment were higher than those of unamended soils. Highest pH values were those of soils with the 3 highest concentrations of the cake.

Changes in conductivity of the soil water extract followed a trend similar to that for soil pH; the highest value was that of soils with the 1% treatment and the lowest that of soils that received 0.4% or less of the amendment. The 1.0% treatment was the only one that resulted in significant accumulation of nitrate nitrogen in the soil.

Urease activity was highest in soils treated with 0.8 and 1.0% of the amendment; differences between soils from all other treatments were not significant.

2. *Peanut oil-cake.* Data from this experiment are presented in Tables 4 and 5. Peanut oil-cake amendments of 0.4% or higher virtually eliminated galls from the roots of squash plants. The addition of the cake at the 0.1% rate resulted in increased numbers of galls per gm of root, and roots from soils with the 0.2% treatment had as many galls as those from unamended soil. Galling indices followed a pattern similar to that described for gall numbers. No differences in shoot or root weights were detected between plants from soils that received 0.4% or less of the amendment; however, shoots and roots of plants from the 0.8 and 1% treatments were heavier than those from untreated soil. Shoots of plants from pots with 0.1, 0.2, 0.4% and 0.6% of the cake were taller than those from control soil. The addition of peanut oil cake at rates of 0.4% or higher reduced the number of surviving plants; the lowest

Table 2. Effect of cotton seed oil cake as a soil amendment on growth of squash plants and development of *Meloidogyne arenaria*.[x]

Amount Added (% w/w)	Percent (w/w) Nitrogen Added	No. Plants per pot	Shoot Height (cm)	Fresh Shoot Weight (gm)	Fresh Root Weight (gm)	Galls per gm root	Gall[y] Index
0.0	0.000	5.0 A	21.1 A	2.14 C	0.40 C	33.8 A	3.2 A
0.1	0.006	4.8 AB	22.3 A	3.16 ABC	0.56 BC	29.9 AB	2.8 A
0.2	0.013	4.4 ABC	21.5 AB	3.37 AB	0.78 A	14.2 BC	1.8 B
0.4	0.025	4.1 BC	19.2 B	3.58 AB	0.74 AB	0.7 C	0.2 C
0.6	0.038	3.9 C	18.5 B	3.93 A	0.95 A	0.0 C	0.0 C
0.8	0.051	3.8 C	18.3 B	2.84 ABC	0.54 BC	0.0 C	0.0 C
1.0	0.063	1.4 D	13.6 C	2.42 BC	0.42 C	0.0 C	0.0 C

[x] Values are the averages of 8 replications; those within the same column with a common letter are not statistically different (P=0.05).

[y] Based on a scale of 0-10 where a value of 0 represented roots with no galls and 10 roots with the greatest number of galls (37).

Table 3. Effect of cotton seed oil-cake on pH and other variables related to the decomposition of nitrogenous amendments in soil.[x]

Amount Added (% w/w)	Percent (w/w) Nitrogen Added	Soil pH	Conductivity (micromohms)	Nitrate Nitrogen (μg/gm soil)	Urease Activity[y]
0.0	0.000	5.8 D	24.43 C	0.06 B	0.00 B
0.1	0.006	5.8 D	26.31 C	0.13 B	0.00 B
0.2	0.013	5.8 D	26.37 C	0.40 B	0.00 B
0.4	0.025	5.9 C	42.75 BC	1.88 B	1.82 B
0.6	0.038	6.0 B	50.68 B	1.27 B	7.96 B
0.8	0.051	6.1 A	56.25 B	0.98 B	13.48 A
1.0	0.063	6.1 A	112.56 A	5.40 A	13.70 A

[x] Values are the averages of 8 replications; those within the same column with a common letter are not statistically different (P=0.05).

[y] Expressed as μg of ammoniacal nitrogen released per hour per gm of soil.

Table 4. Effect of peanut oil-cake as a soil amendment on growth of squash plants and development of *Meloidogyne arenaria*.[x]

Amount Added (% w/w)	Percent (w/w) Nitrogen Added	No. Plants per pot	Shoot Height (cm)	Fresh Shoot Weight (gm)	Fresh Root Weight (gm)	Galls per gm root	Gall[y] Index
0.0	0.000	5.0 A	15.0 C	1.81 C	0.41 B	19.6 B	2.4 B
0.1	0.006	5.0 A	22.0 A	1.88 C	0.41 B	41.6 A	4.0 A
0.2	0.012	4.9 A	21.0 A	2.84 BC	0.38 B	28.9 B	3.7 AB
0.4	0.024	4.1 B	17.0 B	2.88 BC	0.27 B	0.2 C	0.1 C
0.6	0.038	2.9 C	18.0 B	3.06 AB	0.57 AB	0.0 C	0.0 C
0.8	0.049	2.9 C	15.0 C	3.11 A	0.75 A	0.0 C	0.0 C
1.0	0.061	1.6 D	15.0 C	4.08 A	0.79 A	0.0 C	0.0 C

[x] Values are the averages of 8 replications; those within the same column with a common letter are not statistically different (P=0.05).

[y] Based on a scale of 0-10 where a value of 0 represented roots with no galls and 10 roots with the greatest number of galls (37).

Table 5. Effect of peanut oil-cake on pH and other variables related to the decomposition of nitrogenous amendments in soil.[x]

Amount Added (% w/w)	Percent (w/w) Nitrogen Added	Soil pH	Conductivity (micromohms)	Nitrate Nitrogen (μg/gm soil)	Urease Activity[y]
0.0	0.000	5.8 B	22.50 CD	0.22 B	0.00 C
0.1	0.006	5.8 B	19.37 D	0.00 B	0.00 C
0.2	0.012	5.8 B	23.12 CD	0.37 B	0.00 C
0.4	0.023	5.8 B	44.93 BC	1.30 B	0.12 C
0.6	0.038	5.7 BC	71.25 A	4.91 B	0.38 C
0.8	0.049	5.9 B	79.25 A	9.49 A	0.89 B
1.0	0.061	6.1 A	68.00 A	7.09 A	2.62 A

[x] Values are the averages of 8 replications; those within the same column with a common letter are not statistically different (P=0.05).

[y] Expressed as μg of ammoniacal nitrogen released per hour per gm of soil.

Table 6. Effect of chicken litter as a soil amendment on growth of squash plants and development of *Meloidogyne arenaria*.[x]

Amount Added (% w/w)	Percent (w/w) Nitrogen Added	No. Plants per pot	Shoot Height (cm)	Fresh Shoot Weight (gm)	Fresh Root Weight (gm)	Galls per gm root	Gall[y] Index
0.0	0.000	5.0 A	19.1 D	1.27 E	0.33 C	122.7 A	6.8 A
0.5	0.015	4.3 A	26.1 BC	5.93 CD	0.77 AB	132.0 A	7.3 A
1.0	0.031	4.4 A	24.9 C	5.58 C	0.69 AB	82.8 B	4.6 B
2.0	0.061	4.4 A	28.2 A	8.15 AB	0.68 AB	69.9 BC	4.3 B
3.0	0.092	4.9 A	30.1 A	9.07 A	0.78 A	41.0 CD	3.3 B
4.0	0.122	4.6 A	26.8 BC	7.76 ABC	0.86 A	18.9 DE	1.3 C
5.0	0.152	4.8 A	24.1 C	6.50 BCD	0.62 B	6.18 E	0.4 C

[x] Values are the averages of 8 replications; those within the same column with a common letter are not statistically different (P = 0.05).

[y] Based on a scale of 0-10 where a value of 0 represented roots with no galls and 10 roots with the greatest number of galls (37).

Table 7. Effect of chicken litter on pH and other variables related to the decomposition of nitrogenous amendments in soil.[x]

Amount Added (%w/w)	Percent (w/w) Nitrogen Added	Soil pH	Conductivity (micromohs)	Nitrate Nitrogen (μg/gm soil)	Urease Activity.[y]
0.0	0.000	6.8 CD	13.12 F	0.00 D	0.00 E
0.5	0.015	6.6 D	44.38 EF	0.47 D	7.63 D
1.0	0.031	6.9 C	61,11 E	0.44 D	19.02 D
2.0	0.061	7.0 BC	127.71 D	1.03 CD	35.86 C
3.0	0.092	7.0 BC	193.87 BC	1.79 BC	46.83 BC
4.0	0.122	7.3 A	305.18 B	2.89 B	49.99 B
5.0	0.152	7.2 AB	397.87 A	5.67 A	71.13 A

[x] Values are the averages of 8 replications; those within the same column with a common letter are not statistically different ($P = 0.05$).

[y] Expressed as μg of ammoniacal nitrogen released per hour per gm of soil.

number of plants per pot corresponded to the 1.0% treatment.

Urease activity of soils treated with 0.8 or 1.0% peanut cake was higher than that of all other soil amendments in the experiment. Soils with the 2 highest amounts of cake contained more nitrate nitrogen than those that received less of the cake. Conductivity values of the soil water extract were greatest in soils with 0.6% or higher amounts of the cake; values for the other amended soils did not differ from those for control soils. Differences in pH values between soils with 0.8% or less of the cake were not significant; however, the 1.0% treatment resulted in higher pH values than those for all other soils in the experiment.

3. *Chicken litter.* Data from this experiment are presented in Tables 6 and 7. Chicken litter at rates of 1.0% or higher resulted in reductions in the numbers of galls per gm of root and in galling indices; the 0.5% treatment was ineffective in reducing nematode development. Greatest suppression of nematode development was obtained with the 4.0 and 5.0% treatments. The relation between the number of galls per gm of root and the amount of chicken litter added to soil was linear and inverse and could be described by the equation: $Y = 124.68 - 25.60X$, where Y represented gall number and X the percent of litter added to the soil.

All treatments with chicken litter resulted in taller plants with heavier shoots and roots than those from unamended soil. Chicken litter amendments had no effect on the number of plants surviving per pot. Shoot and root weights were linearly correlated ($r = 0.85$) and the relation could be described by the equation $Y_s = -2.28 + 12.73X_r$, where Ys represented shoot weights and Xr root weights; however, the two variables were not correlated with the number of galls per gm of root.

Urease activity was higher in soils with chicken litter than in control soils. The relation between soil urease activity and the amount of chicken litter added to soil was linear and could be represented by: $Yu = 6.47 + 12.58X$, where Yu was urease activity. Soil urease activity was correlated linearly ($r = -0.938$) with the number of galls per gm of root as described by $Y = 132.98 - 1.90Xu$ in which Xu represented urease activity. Similarly, soil urease activity was also correlated ($r = -0.926$) with values for the galling index.

Soils that received chicken litter at rates of 3.0% or higher contained more nitrate nitrogen than those amended with lower amounts of the material. Nitrate accumulation was directly related to the amount of litter added to the soil as described by $Yn = -0.45 + 0.99X$, where Yn was μg of nitrate nitrogen per gm soil. Soil urease activity was correlated ($r = 0.92$) with the amount of nitrate nitrogen (Xn) in the soil as $Yu \doteq 14.77 + 11.14Xn$.

The highest conductivity values of the soil water extract was recorded in soil with the 5.0% treatment and the lowest in those that received 0.5% of the litter. Conductivity values maintained a positive linear relation with the amount of litter incorporated into the soil which was expressed as: $Yc = -6.16 + 76.49X$, Yc representing conductivity in micromohs. Conductivity values were correlated ($r = 0.966$) with the amount of nitrate nitrogen (Xn) as described by Yc = 39.89 + 70.24Xn.

Soil pH values were higher than those for the other two experiments of the study. Soils with chicken litter treatments of 1.0% or higher had higher pH values than those that received less litter. A direct increase in soil pH value was observed in response to chicken litter addition; the relation was expressed as: Yh = 6.68 + 0.13X, Yh representing soil pH.

DISCUSSION

Results indicated that the three amendments controlled *M. arenaria* which agrees with other findings that these amendments are effective against other plant parasitic nematodes (2, 3, 5, 6, 7, 9, 10, 20, 21, 23, 34, 35).

The amendments used in this study had narrow C/N ratios varying from 7 for the cakes to 10 for chicken litter. This indicates that their action against nematodes was due to released ammoniacal nitrogen from these materials with consequent stimulation of the soil microflora. The release of ammoniacal nitrogen from these materials can be expected to be mediated through the action of proteolytic and deaminating enzymes produced by microorganisms in soil. The observed increases in urease activity in response to the amendments is thus the result of microbial stimulation (4). Released ammoniacal nitrogen in soil results in increased soil pH and accumulation of nitrates through the process of nitrification; however, the conversion of ammoniacal nitrogen to nitrates can lead to the accumulation of NH_3 and nitrites which are toxic to plants (29). Accumulation of these materials is dependent on pH and the rate at which ammoniacal nitrogen is released from the amendments. Data indicate that the effect of oil cake amendments on squash and on the chemical composition of soils differed from those of chicken litter amendments. Oil cake amendments resulted in phytotoxicity when applied at rates of 0.2% or higher, whereas no treatment with chicken litter reduced the number of squash plants/pot. We interpret this difference as due to the accumulation of NH_3 and possibly nitrites in cake-amended soils. Chicken litter contained considerably more carbon than the cakes and it is possible that the additional carbon in the litter permitted assimilation of available ammoniacal nitrogen by microorganisms preventing accumulation of NH_3 and nitrites. This interpretation agrees with the significant correlations obtained in the chicken litter experiment between gall numbers, urease activity, nitrate nitrogen, conductivity values and pH. Also, the lack of correlation between any of these variables in the oil cake experiments suggests that the process of nitrification was impeded with the probable accumulation of NH_3 and nitrites, and phytotoxicity to squash. Other studies have shown (26) that it is possible to eliminate phytotoxic effects of urea (C/N = 0.4) amendments to soil by the inclusion of a carbon source (blackstrap molasses) in the amendment. A similar result might be expected if such carbon source were combined with the oil cake amendments.

Although NH_3 (or nitrites) from the oil-cake-amended soils can be expected to be toxic to nematodes (27), this cannot explain entirely the mode of action of nitrogenous amendments against nematodes in this study. In the case of the chicken litter experiment and the 0.2% rate of cotton seed oil cake no significant phytotoxicity was observed even though significant reductions in gall numbers were noted. These nonphytotoxic but nematicidal treatments may stimulate development of populations of microorganisms directly antagonistic to *M. arenaria* (22,25,30) or may cause proliferation of microbial species capable of producing substances (other than NH_3 and nitrites) toxic to the nematode (3, 11, 12, 15, 28). In other studies (25) we have shown that the addition of chitin to soil stimulates the development of a specific mycoflora parasitic of eggs of *M. arenaria* and of *Heterodera glycines* Ichinohe. We made no attempt in the present study to quantitate or characterize the microflora of the amended soils for species parasitic or antagonistic to *M. arenaria*. This is clearly an aspect that will require further study.

The highest amounts of amendments added to soil in this study were equivalent (broadcast basis) to 22 MT/ha for the oil cakes and 112 MT/ha for chicken litter. While field applications of these quantities may be a problem, we believe that these levels are practical for use by home gardeners. This is particularly so since effective nematode suppression was obtained in the range of 4-9 MT/ha for the cakes and 22-44 MT/ha for the litter. Home gardeners can apply these quantities or may even reduce the amounts required for nematodes control by treating only those areas where the plants will be grown. The amendments are attractive for use since they are generally available, and in addition to controlling nematodes they provide plant nutrients eliminating or reducing the need to apply fertilizers.

LITERATURE CITED

1. ALAM, A.M. and A.M. KHAN. 1974. Control of phytonematodes with oil-cake amendments in spinach field. Indian J. Nematol. 4(2):239-240.
2. BADRA, T. and N.A.H. ELBARY. 1978. Comparative efficacy of different levels of nitrogen and phosphorus supplemented with organic amendments on tomato growth and associated *Rotylenchulus reniformis*. Indian J. Nematol. 8:110-115.
3 BADRA, T., M.A. SAHEL and B.A. OTEIFA. 1979. Nematicidal activity and composition of some organic fertilizers and amendments. Revue Nematol. 2(1):29-36.
4. BREMNER, J.M. and R.L. MULVANEY. 1978. Urease activity on soils. p. 149-196. In R.G. Burns (ed): Soil Enzymes. Academic Press, New York, N.Y. 380 pp.
5. CASTILLO, M.B., M.S. ALEJA and R.R. HARDWOOD. 1976. Nematodes in cropping patterns and cultural practices. Phyllipines Agric. 59(18):295-312
6. DERRICO, F.P. and F.D. MARIO. 1980. Effect of some organic mate-

rials on root-knot nematodes on tomato in field preliminary experiments. Nematol. Med. 8(1):107-111.

7. DESAI, M.V., H.M. SHAH, S.N. PILLAI and A.S. PATEL. 1979. Oil-cakes in control of root-knot nematodes. Tob Res. 5(1):105-108.
8. GOWDA, D.N. 1972. Studies on comparative efficacy of oil-cakes on control of root-knot nematode, *Meloidogyne incognita* Chitwood on tomato. Myssore Agric. Sci. 6(4):524-525.
9. GOWDA, D.N. and K.G.H. SETTY. 1973. Studies on comparative efficacy of various organic amendments on control of root-knot nematode of tomato. Myssore Agric. Sci. 7(3):419-423.
10. GOWAMI, B.K. and G.S. SWARUP. 1972. Effect of oil-cake amended soil on the growth of tomato and root-knot nematode population. Indian Phytopathol. 24(3);491-494.
11. HOLLIS, J.P. and R. RODRIGUEZ-KABANA. 1966. Rapid kill of nematodes in flooded soil. Phytopathology. 56:1015-1019.
12. HOLLIS, J.P. and R. RODRIGUEZ-KABANA. 1967. Fatty acids in Louisiana rice fields. Phytopathology. 57:841-847.
13. HUE, N.V. and C.E. EVANS. 1979. Procedures used by the Auburn University soil testing laboratory. Agron. and Soil Dept., Auburn University Dept. Ser. No. 16 (revised). Auburn, AL., 13 pp.
14. JACKSON, M.L. 1958. Soil chemical analysis. Prentice Hall, Englewood Cliffs, N.J. 498 pp.
15. JOHNSTON, T.M. 1959. Effect of fatty acid mixtures on the rice stylet nematode (*Tylenchorhynchus martini* Fielding, 1956). Nature. 183:1392.
16. KHAN, A.M., M.M. ALAM and R. AHMAD. 1974. Mechanism of control of plant parasitic nematodes as a result of the application of oil-cakes to the soil. Indian J. Nematol. 4:93-96.
17. 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 Bota. Indica. 1:49-51.
18. KHAN, M.W., A.M. KHAN and S.K. SAXENA. 1974. Rhizosphere fungi and nematodes of eggplant as influenced by oil-cake amendments. Indian Phytopathol. 27:480-484.
19. MAMMEN, K.V. 1972. Effect of root galls and yield of Bhindi in nematode infested soil. Agric. Res. J. Kerala. 10:186-187.
20. MANKAU, R. 1962. The effect of some organic additives upon soil nematode population and associated natural enemies. Nematologica. 7:65-73.
21. MANKAU, R. 1963. Effect of organic soil amendments on nematode populations. Phytopathology. 53:881-882.
22. MANKAU, R. 1980. Biocontrol: Fungi as nematode control agents. J. Nematol. 12(4):244-252.
23. MANKAU, R. and R.J. MINTEER. 1962. Reduction of soil populations of the citrus nematode by the addition of organic materials. Plant Dis. Rep. 46:375-378.

24. MATHUR, J.K. and S.K. PRASAD. 1974. Control of *Hirschmanniella oryzae* associated with paddy. J. Nematol. 3:54-60.
25. MIAN, I.H., G. GODOY, R.A. SHELBY, R. RODRIGUEZ-KABANA and G. MORGAN-JONES. 1982. Chitin amendments for control of *Meloidogyne arenaria* in infested soil. Nematropica. 12(1): 71-84
26. RODRIGUEZ-KABANA, R., and P.S. KING. 1980. Use of mixture of urea and blackstrap molasses for control of root-knot nematodes in soil. Nematropica 10:38-44.
27. RODRIGUEZ-KABANA, R., P.S. KING and M.H. POPE. 1981. Combinations of anhydrous ammonia and ethylene dibromide for control of nematodes parasitic of soybean. Nematropica 11:27-41
28. RODRIGUEZ-KABANA, R., J.W. JORDAN and J.P. HOLLIS. 1965. Nematode: biological control in rice field, role of hydrogen sulfide. Science. 148:523-524.
29. RUSSELL, E.W. 1961. Soil conditions and plant growth. John Willey & Sons, Ltd. New York, N.Y. 688 pp.
30. SAYRE, R.M. 1980. Promising organisms for biocontrol of nematodes. Plant Dis. 64(6):526-532.
31. SINGH, I., S.K. SHARMA and P.K. SING. 1980. Effect of oil-cakes extract on the hatching of root-knot nematode, *Meloidogyne incognita*. Indian J. Mycol. Plant Pathol. 9(1):115-116.
32. SINGH, R.S. and K. SITARAMAIAH. 1966. Incidence of root-knot of okra and tomato in oil-cake amended soil. Plant Dis. Repr. 50(9):668-672.
33. SINGH, R.S. and K. SITARAMAIAH. 1970. Control of plant parasitic nematodes with organic soil amendments. PANS. 16(2):287-297.
34. 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. Res. Bull. Expt. Stn. and Coll. Agric. G.B. Plant Univ. Agric. Tech., Pantanagar. 6.289 pp.
35. SRIVASTAVA, A.S., R.C. PANDEY and S. RAM. 1971. Application of organic amendment for the control of root-knot nematode, *Meloidogyne javanica*. Treub. Labdev J. Sci. Tech. 9 B (319):203-205.
36. STEEL, R.G.D. and J.D. TORRIE. 1980. Principles and procedures of statistics. McGraw-Hill Book Co., New York, N.Y. 481 pp.
37. TRIVEDI, P.C., A. BHATNAGAR and B. TIAGI. 1978. Control of nematodes on *Capsicum annuum* by application of oil-cakes. Indian Phytopathol. 31(1):75-76.
38. ZECHT, M.W. 1971. A rating scheme for field evaluation of root-knot nematode infestations. Pflazenchutz-Nacht. 24:141-144.

Received for publication:

9.VIII.1982

Recibido para publicar: