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THE NEMATICIDAL EFFECT OF ORGANIC AMENDMENTS: A REVIEW OF THE LITERATURE, 1982-1994

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Summary. Literature on organic amendments was reviewed from 1982 up to 1994. A total number of 221 papers was found, confirming the interest of research in this nematode control method. Most of work was still concentrated in developing countries. Organic materials, crops and nematode species involved in trials were examined. Oil cakes were the most frequently used and efficaceous amendments, but also green manures and agro–industrial wastes were largely experimented. An increasing attention was dedicated to the mechanisms of the nematicidal action of these materials.

The addition of organic materials to soil infested with plant parasitic nematodes has been clearly demonstrated as a satisfactory control method against many phytoparasitic nematodes, particularly in developing countries because of the cheapness and easy availability of materials. Various mechanisms are involved in this nematicidal action (Stirling, 1991). Some materials release compounds toxic to nematodes, preformed like phenols, tannin, azadirachtin, ricinin (Mian and Rodriguez-Kabana, 1982; Rossner and Zebitz, 1987; Rich *et al.*, 1989) or derived from the decomposition process in the soil, like ammonia, nitrites, hydrogen sulphide (Rodriguez-Kabana, 1986). Amendments may also provide a favourable substrate for the sustenance of soil microfauna and microflora (Linford, 1937; Linford *et al.*, 1938), which can include direct predators (micro-arthropods) or parasites (fungi, bacteria) of nematodes, or which suppress soil nematode population indirectly through the production of enzymes (Rodriguez-Kabana *et al.*, 1983; Galper *et al.*, 1990) or toxic metabolites, such as antibiotic of bacterial origin. Moreover the addition of organic materials usually improves soil structure and consequently the capacity of the soil to hold water and exchange ions that, together with the nutrients released by the organic matter, positively effect on plant growth.

An extensive literature on soil amendments has accumulated in past decades (Singh and Sitaramaiah, 1973; Müller and Gooch, 1982). Müller and Gooch (1982) summarized the research on amendments carried out in the decade 1971-1981; considerable research has been undertaken in the following years and this is reviewed up to 1994 in this paper.

Abstracts from *Helminthological Abstracts, Series B, Plant Nematology (Nematological Abstracts* from 1992) were the source of information used in the review. Examination was extended to every kind of organic material incorporated into the soil, including plants containing nematicidal principles if used as green manure, but excluding experiments with extracts from these plants, as their large number suggested a specific examination.

TABLE I - *Geographic distribution of papers on organic amendments in literature 1982-1994.*

Origin	No. of papers	%
India	126	56.3
USA	32	14.3
Latin America	18	8.0
Other Asian countries	17	7.6
Africa	14	6.3
Europa	14	6.3
Australia	3	1.3

A total number of 224 papers was reviewed, confirming the increasing interest in this possible control method during the 1980s. However, the geographic distribution of the literature remained substantially the same as in the previous decade (Table I). Many of the papers were from India (56.3%) and, more generally, from developing countries; USA and Europe produced only 20% of the papers. Research was differently orientated in the various geographic areas: experiments from developing countries generally tested the nematicidal effect of many organic materials added to soil, whereas research in USA and Europe investigated especially the mechanisms of action of amendments and the interaction with soil microflora and microfauna. As in the previous decade there was a prevalence of experiments on *Meloidogyne* species, in particular *M. incognita* (Table II). This is related to the economic importance of root-knot nematodes in developing countries. Genera such as *Tylenchorhynchus*, *Hoplolaimus*, *Helicotylenchus* were also well represented in trials in India and Asia. However, the effect of soil amendments on cyst nematodes has not been much investigated, despite the economic importance of these species. As noted by Müller and Gooch (1982), many authors were not precise about the identity of nematode species, indicating a generic "soil nematodes".

Many of the trials with *Meloidogyne* species

TABLE II - *Nematode species tested in trials on organic amendments reported in literature 1982-1994.*

Species	No. of trials	Species	No. of trials
Meloidogyne spp.	17	*Rotylenchus reniformis*	15
M. incognita	99	*Tylenchorhynchus* spp.	2
M. javanica	22	*T. brassicae*	6
M. arenaria	14	*T. vulgaris*	2
M. hapla	4	*T. claytoni*	1
M. chitwoodi	2	*Hoplolaimus indicus*	7
M. acrita	1	*H. galeatus*	2
M. exigua	1	*Tylenchus* spp.	1
Helicotylenchus spp.	6	*T. filiformis*	4
H. indicus	5	*Globodera rostochiensis*	3
H. dihystera	4	*Heterodera schachtii*	2
H. incisus	1	*H. cajani*	2
Pratylenchus spp.	3	*H. avenae*	1
P. zeae	5	*H. glycines*	1
P. brachyurus	3	other Tylenchids	18
P. penetrans	3	Longidorids	3
P. vulnus	1	soil nematodes	15

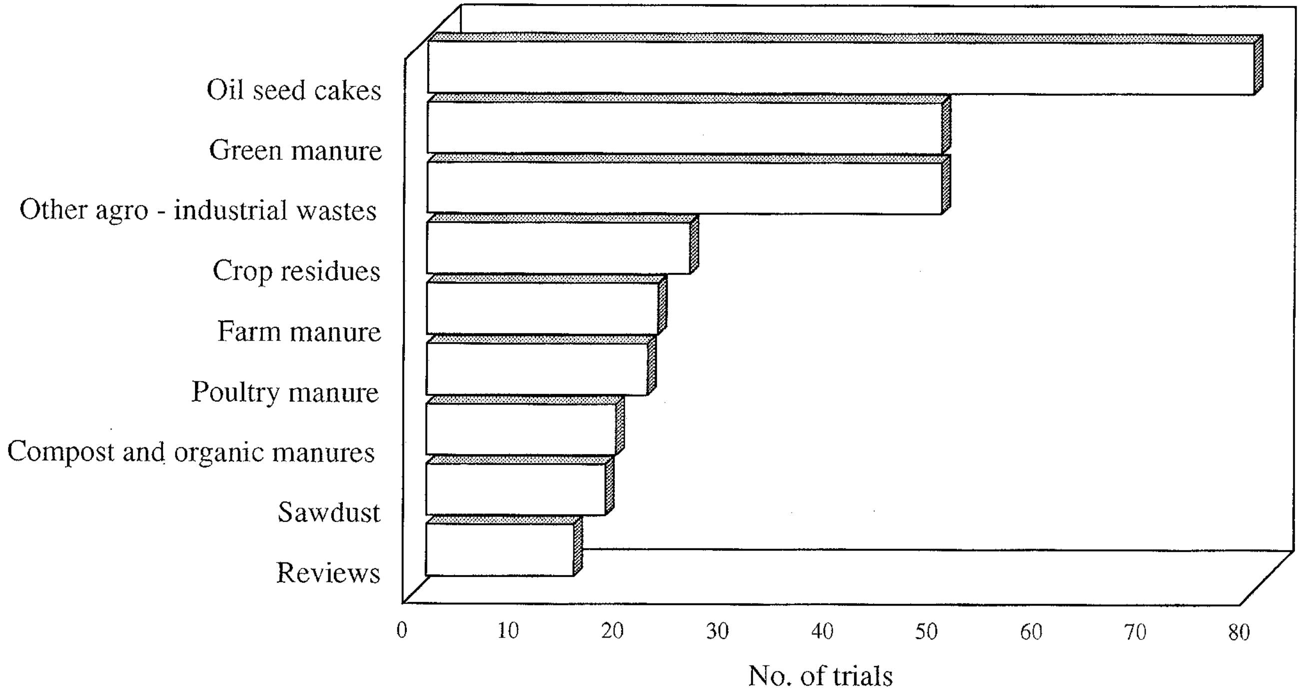

Fig. 1 - Classification of organic amendments present in literature 1982-1994.

used tomato and vegetables as the test crops (Table III). Field crops were prevalent in work undertaken in USA and Europe.

Amendments were classified according to Müller and Gooch (1982) (Fig. 1): the number of references of the different materials did not correspond to the number of publications, as in many of these more than one amendment, alone or in a mixture, was used. A prevalence of oil seed cakes was still found, although not so large as in 1971-81 experiments. In field trials rates of application of these materials varied from 1 to 5 t/ha. Neem (*Azadirachta indica* A. Juss) cake was the most frequently used and gave satisfactory nematode control, often comparable to that obtained with chemicals. In a comparative study on the nematicidal efficacy of neem oil cakes and aldicarb against *M. incognita* on tomato, Bhattacharya and Goswami (1987) found a significant improvement of plant growth for neem treatment over the nematicide, although the lowest root penetration was in aldicarb. Also, mustard, castor, groundnut and mahua cakes generally gave good results, but sometimes with problems of phytotoxicity at high dosages. Mustard and karanj cakes, when compared with carbofuran, showed the same plant growth response and the same efficacy in inhibiting penetration of *M. incognita* juveniles in tomato roots (Goswami and Meshram, 1991).

TABLE III - *Distribution of crops used in trials on organic amendments in literature 1982-1994.*

Origin	No. of papers	%
Vegetables	78	34.5
Tomato	64	28.3
Field crops	40	17.7
Plantation crops	20	8.8
Other crops	3	0.9
Soil and in vitro	22	9.7

Green manures were tested in a number of experiments: a wide range of materials were grouped under this definition, from green residues of crops to shoots, leaves, floral parts or latexes of ornamental plants or weeds containing nematicidal principles (Table IV). A large variability was found in doses used in field trials (1-40 t/ha), according to the material, or more specifically to the concentration of nematode principles in each plant species. Incorporation of subabool (*Leucaena leucocephala* L.) and neem leaves in soil infested by *M. javanica* significantly increased the growth of tomato and reduced nematode population (Walia *et al.*, 1994). Mojtahedi *et al.* (1991) found a significant reduction in numbers of *Meloidogyne chitwoodi* on potato after amendment of the soil with rapeseed (*Brassica campestris* L. DC.) shoots and a similar result was obtained by Owino *et al.* (1993) with *M. javanica*.

TABLE IV - *Plant species used as green manures (in literature 1982-1994).*

Plant species	Parts of plant used	Plant species	Parts of plant used
Amaranthus sp.	crop residues	*Gliciridia sepium* H. B. & K.	leaves
Andrographis paniculata Nees	crop residues	*Helianthus annuus* L.	crop residues
Anetum graveolens L.	leaves	*Ipomoea fistulosa* Mart.	leaves
Annona squamosa L.	dried leaves	*Iresine herbstii* Hook.	floral parts
Argemone mexicana L.	shoots	*Lantana camara* L.	leaves
Artemisia scoparia L.	leaves	*Lantana indica* Wall.	leaves
Artocarpus heterofilla L.	shoots	*Leucaena leucocephala* Benth.	leaves and seeds
Azadirachta indica A. Juss	leaves, shoots, seeds	*Mangifera indica* L.	crop residues
Brassica campestris L. DC.	crop residues	*Mentha viridis* L.	leaves
Calendula officinalis L.	crop residues	*Nerium odorum* Soland	leaves and latex
Calophyllum inophyllum L.	crop residues	*Nerium oleander* L.	leaves and latex
Calotropis gigantea Dryand.	shoots and leaves	*Phyllanthus niruri* L.	dried extracts
Calotropis procera Dryand.	shoots and leaves	*Polyalthia longifolia* Benth. & Hook.	dried leaves
Camelia sinensis L.	crop residues	*Ricinus communis* L.	shoots, leaves, flowers
Cannabis sativa L.	leaves	*Solanum khasianum* C. B. Clarke	shoots and leaves
Carica papaya L.	shoots	*Solanum xanthocarpum* Schrad. & Wendl.	shoots and leaves
Cassia fistula L.	shoots	*Syzygium cyminiferum* Presl.	floral parts
Chenopodium amaranticolor L.	crop residues	*Tabernaemontana coronaria* Willd.	shoots
Clerodendron interme R. Br.	leaves	*Tagetes erecta* L.	crop residues
Cordia mixa Forsk.	leaves	*Tagetes lucida* Cav.	crop residues
Croton bonplandianus Baill.	dried leaves	*Tagetes minuta* L.	crop residues
Datura metel L.	crop residues	*Tagetes tenuifolia* Cav.	crop residues
Eclipta alba Hassk.	stems and leaves	*Tephrosia purpurea* Pers.	leaves
Eichornia crassipes Solms	leaves, flowers	*Terminelia arjuna* Wight & Arn.	powdered bark
Enhydra fluctuans Lour.	crop residues	*Thuya orientalis* L.	leaves
Eucalyptus citriodora Hook.	fresh and dried leaves	*Tridax procumbens* L.	dried leaves
Eucalyptus tereticornis Smith	fresh and dried leaves	*Verbesina encelioides* Benth. & Hook.	leaves
Euphorbia hirta L.	dried leaves, latex	*Vinca rosea L.*	shoots and leaves
Ficus carica L.	leaves, shoots, latex	*Xanthium strumarium* L.	dried leaves
Ficus elastica Roxb.	shoots		

A large number of experiments was performed with compost and organic manures, in particular farm and poultry manures, and sawdust. In 1982-1994 these confirmed the suppressive effect of poultry manure and sawdust on soil nematodes, but with phytotoxicity at high dosages. In an experiment on the effect of five different manures, Gonzalez and Canto-Saenz (1993) found that chicken or horse manure reduced the number of cysts and multiplication rate of *Globodera pallida* by 96% and 35%, respectively, while all the manures increased significantly potato yield compared to the control. Chicken litter was also found to reduce the number of *M. arenaria* penetrating the roots of tomato and to enhance plant growth at 10-45 t/ha rates, while at higher dosages it was phytotoxic (Kaplan and Noe, 1993).

Trials with agro-industrial wastes increased remarkably in comparison with the previous decade: incorporation of these residues in the soil represents at the same time a possible nematode control method and a satisfying answer to the problem of their disposal without environmental pollution. Materials included in this group were various and of both vegetal and animal origin, from paper industry cellulosic wastes to fish or bone meal (Table V). Consequently, the rates at which they were incorporated in the soil show a large variability. However, the interest in these materials was locally limited, as industries from which they derived were always related to crops of specific geographic areas.

Particular attention has been paid to chitin and chitinous wastes, as this amendment has been shown to have a high nematicidal action (Mian *et al.*, 1982; Culbreath *et al.*, 1986). Mechanisms of this action are more than one and still not clear, so a number of studies have been designed to investigate this aspect (Spiegel *et al.*, 1987; Gooday, 1990). To avoid phytotoxicity caused by chitin at concentrations of more than 1% and due to a too narrow C/N ratio (Rodriguez-Kabana, 1986), studies have been undertaken on the effect of mixing chitinous materials with a source of available carbon such as meal or hemicellulosic wastes, that immobilize excess nitrogen stimulating microbial activity (Huebner *et al.*, 1983; Spiegel *et al.*, 1987; Rodriguez-Kabana *et al.*, 1990).

More generally, there have been investigations on the possibility of enhancing the suppressive action of amendments, based on their mechanism of action, by the addition of mineral fertilizer or of reduced dosages of nematicides.

TABLE V - *Organic amendments employed in trials (from literature 1982-1994), except oil cakes and green manures.*

Crop residues	
Bark and wood chips	Kolanut pods
Cassava peelings	Rice hulls
Coir pith	Wheat, rice, coffee straw
Dry tobacco broken stalks	Wood ash
Husks of bajira, cocoa pods, locust bean, paddy, *Parkia*, rice, tobacco seeds	
Manures	
Cattle gas manure	Pine shaving bedding
Cow, sheep, horse dung	Poultry manure
Farmyard manure	
Compost and organic manures	
Burnt township wastes	Peat moss
Compost	Pressmud
Dried municipal sludge	Sewage sludge compost
Leafmould	Tank silt
Agro-industrial wastes	
Anhydrous dextrose	Fish meal
Bone meal	Fruit canning factory wastes
Cassava flour industry wastes	Hemicellulosic wastes
Cellulose powder	Oil seed cakes
Chitin	Raw crab wastes
Citrus wastes	Shrimp shells
Collagen	Starch
Decaffeinated tea wastes	Sugarcane bagasse
Decomposed coffee pulp	Sugarcane filtercake
Egg yolk protein	Sugarcane molasses

Huebner *et al.*, (1983) found that a combination of hemicellulosic waste with urea significantly reduced populations of plant parasitic nematodes on soybean (*Glicine max* L.), enhancing the limited nematicidal action of hemicellulosic materials without the problems of phytotoxicity caused by the urea when used alone. In another experiment, a significant reduction of populations of *Meloidogyne chitwoodi* on potato and *Pratylenchus vulnus* on walnut (*Juglans hindsii* Sarg.) was obtained with a chitin–urea soil amendment (Westerdahl *et al.*, 1992). Results from these trials confirmed that most of the soil amendments, although not as effective as chemicals, could have a synergic action with low doses of nematicides.

In the last decade a large and increasing attention has been given to the effects of the addition of organic materials on soil microrganisms. Twenty eight papers were concerned with the investigation of variations caused by amendments in populations of nematode parasitic fungi, or in the level of enzymes in the soil produced by fungi, such as proteolitic and chitinolitic enzymes, attacking the cuticle or egg shells of nematodes. Zaki and Bhatti (1990) found that a combination of castor leaves and the nematode egg parasitic fungus, *Paecilomyces lilacinus* (Thom.) Samson, gave 86, 100 and 86% reduction, respectively, of gall index, second stage juveniles and eggs of *M. javanica* infecting tomato. A significant increase in conidial density of the endoparasitic nematophagous fungus *Drechmeria coniospora* (Drechsler) Gams *et* Jansson and a suppression of the soil nematode population was observed by Van Den Boogert *et al.* (1994) in a alfalfa meal amended soil. Chitin, chicken manure and oil cake amendments were also found to stimulate nematode parasitic fungi such as *Verticillium chlamidosporium* Goddard, *Hirsutella rhossiliensis* Minter *et* Brady, *P. lilacinus* (Godoy *et al.*, 1983; Patel *et al.*, 1991; Jaffee *et al.*, 1994).

The effects of amendments can be enhanced by soil saprophytic fungi which although not directly parasitic to nematodes, produce enzymes that destroy the nematode body structures. Galper *et al.* (1991) found that addition to the soil of 0.1% w/w collagen, supplemented with the collagenolytic fungus *Cunninghamella elegans* Lendner, reduced by 90% the root–galling index of *M. javanica* infested tomato and reduced motility of *Rotylenchus reniformis* and *Xiphinema index*. Nematode suppression was due to enzymes produced by the fungus, namely chitinase, collagenase, kerastase and elastase which disintegrate nematode cuticle.

In conclusion, research on soil amendments in the last 13 years has followed the same research pathways as the previous decade, but with an increasing attention to investigation of the mechanisms of the nematicidal action, the effect on other soil micro-organisms and the interaction among these and phytoparasitic nematodes. Also, environmental pollution caused by nematicides is making this practice increasingly interesting for countries with a well developed agriculture but only if integrated with chemicals. In developing countries it can be substitute for nematicides, but cost–benefit analysis indicates that in any case amendments could be competitive with nematicides only if they are available at low or zero cost, e. g. if there are locally produced residues. Consequently research should be directed to specific materials and to the agrosystems of each country.

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