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The Use of Botanicals in the Management of Plant Parasitic Nematodes

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Abstract:
Environmental hazards resulting from the use of synthetic chemicals is a major global concern. As such, investigators have risen to the challenge of finding more environmentally friendly alternatives and botanicals have been tested. Used as organic soil amendments, nematicidal activities of dried leaves, seed powders and cakes, tree fibres and green manures have been established. Their use as organic soil amendment is compatible with other cultural practices. Employed as extracts, they could be prepared as aqueous extracts, root extracts or exudates; or they could be extracted with chemical solvents including methanol, ethanol and acetone. They were applied as soil drench, root dip and in restricted cases, foliar. The botanicals are significant in modifying the soil ecosystem and if properly developed, may result in the long awaited ecological alternatives to synthetic nematicides. They may also be implicative in sex reversal in some species of nematodes and effective in manipulating the sex ratio in favour of more males than female nematodes. Consequently, nematode population declines with resultant reduction in damage to plants. Employing botanical nematicides in the control of plant parasitic nematodes would be cheap for the resource-poor subsistence farmer.

1. Introduction

Nematodes form one of the most important groups of micro-organisms inhabiting the soil environment of the roots of plants and they frequently play a vital role in their growth and production. Rarely is any crop free of their attacks, whether in the field, orchard, the home or the green house (Thorne, 1961). Financial losses attributed to crop damage by nematodes are difficult to assess and according to Radewald (1978), estimates place nematode cost to growers at more than four billion dollars annually in the United States of America. On a global basis, Sasser and Freckman (1987) proposed over 100billion dollars crop loss annually.

Research Nematologists tend to focus much effort on developing "management" schemes while the farmer's problems are more immediate and they want an effective and economical "control" tactic when nematode populations are large and must be rapidly reduced to prevent damage (Thomason and Caswell, 1987). Nematicides have, therefore, remained for some time, the most immediate practical solution to nematode problems. This is not merely due to the profitability of the use of chemicals, but the fact that the world has passed the point of no return, and cannot afford not to use them. The demand for food continually increases, yet there is no new land to colonize and cities, industrial plants, highways and other agencies (Thorne, 1961) spread themselves everywhere over the acreage; thus more food must come from the shrinking areas (Collingwood, 1965) or from marginal land. The world has a limited area of productive land from which food must come for n unyieldingly fast growing population. To increase their agricultural production, therefore, developing countries continue to use many off the most persistent organochlorine compounds because they were effective, long-lasting and cheap while the developed countries abandoned these for the less persistent but more immediately toxic compounds, though more expensive.

Nematicides have become less readily available in European countries because of governmental regulatory actions (Thomas and Caswell, 1987). In most developing countries, however, the non-readily availability of synthetic nematicides has resulted from their high cost which made them unaffordable by resource poor farmers. The economics of nematode control in developing countries have changed drastically since the oil crisis of 1974, which resulted in a marked increase in price of petroleum products (Thomason et al., 1983). Consequently, nematicides are now as ten times as expensive as they were 20 years ago (Thomason and Caswell, 1987).

On low value and perennial crops, nematicides have been insufficiently effective, too expensive, phytotoxic or they may leave undesirable residues when applied on the growing crop (Wallace, 1973). The decreasing efficiency of these compounds has culminated in efforts to find new and hopefully, better control methods (Lundholm and Stackerud, 1980). The deleterious effects of the common nematicides including occupational hazards, mammalian toxicity and the discovery of traces of synthetic nematicides in underground water are also issues of global concern. The environmental hazards accruing from the use of these synthetic chemicals have resulted in a clarion call for safer alternatives, which would be harmonious with the environment.

Environmental consideration in nematode control has lead to an increased interest for better information on the synchronism of the floral and fauna composition of the oil ecosystem. The knowledge of this has given rise to some basic control strategies (Thomason and Caswell, 1987). The search for alternatives to synthetic nematicides has led several workers into investigating the potentials of botanicals for such use. Biocides or botanical pesticides are plants that contain natural substances, which exhibit pesticidal properties. Biocides are receiving increasing attention because of their environmental friendliness and compatibility with other types of pesticides. Research efforts on the use of biocides for the control of insects have encouraged their applications with nematodes; for instance, laboratory and field bioassays have demonstrated the promise of botanicals in controlling insect pests.

Common botanicals have been bioassayed in the laboratory and field using different plant parts ranging from leaves, seeds, tree barks to roots of plants (Figure 1). Laboratory and field assessments have established the efficacy of extracts of plants like neem tree (Azadiractha indica), hot pepper (Capsicum sp.), coffee husk and wood ash (Ysenbrandt, 1996; Fogain and Ysenbrandt, 1998; Courrier du CRBP, 1999a, 1999b; Messiaen et al., 1998; Oni, 2011). Among other uses, the materials have been employed as organic soil amendments and as extracts. Various soil amendment strategies have been used to increase levels of biological control based on the principle of increasing biological diversity in the soil community (Cook and Baker, 1983). Addition of organic amendment to soil increases the organic matter content of the soil. Increasing the organic matter level of the soil will influence, among other properties, the pH, cation exchange capacity (CEC), moisture level and microbial populations of the soil, and these complexities must always be considered. There is also increasing evidence that soil organic matter is important in nematode ecology (Norton, 1978).

This work has summarized literatures on the use of botanicals as organic soil amendments and plant extracts in the control of plant parasitic nematodes and reported some interactions of these treatments with soil microflora. Reports considered in this review did not necessarily mean the best supportive information of any point. It has only made use of readily available information at the time of write-up in compiling this paper. Authors whose significant and worthy reports have not been duly acknowledged in this review should, therefore, not feel slighted.

2. Methods of Application of Botanicals

2.1. Organic Soil Amendments

Amending the soil with organic materials entails the incorporation of such into the soil. This type of treatment has been found promising and / or effective, in the control of several plant parasitic nematodes. Earlier reports on the use of organic soil amendments to control plant parasitic nematodes were not encouraged because of the inherent problems in their uses such as their bulkiness and slow activity.

2.1.1. Dried Leaves

The addition of dried leaves to soil for the control of plant parasitic nematodes has been extensively documented. Sharma and Tiagi (1989) studied the efficacy of certain leaf powders against root-knot nematodes on pea and reported enhanced plant growth and reduced galling by all leaf powders they used. Akhtar and Alam (1990) presented Calotropis procera as the most effective against freshly hatched juveniles of Meloidogyne incognita. It was better than Azadirachta indica (neem), Ricinus communis and a host of other plant leaves evaluated against root knot nematodes on tomato and chilli. Rao and Reddy (1992), however, reported their findings on incorporating into soil, leaves of Azadirachta indica and seven others at the rate of 80 g / kg soil. The authors found A. indica and two others to be comparable with carbofuran application at 2 kg a.i./ha for control of Meloidogyne incognita. Nadal and Bhatti (1990) reported inhibition of penetration of juveniles of M. javanica into host plant roots with the use of chopped and finely ground leaves of Calotropis procera, Datura stramonium, Ricinus communis and Xanthium strumarium. Penetration of the juveniles was reduced from 97% to 100% with the effect lasting for six weeks at all the doses they investigated. In amending soil with dried tea dregs (Camillia sinesis) at different rates of application. Montasser (1991) observed significant increase in length and fresh weight of both shoot and root of sunflower (Helianthus annus) at lower application rates of 10, 15 and 20 g / soil with corresponding reduction in root gall formation. At higher application rates (39 and 40 g /kg), however, phytotoxicity of the dregs seems to have marred the resultant higher effectiveness against nematode invasion. Reddy et al. (1993) did not observe significant difference in the efficacy of chopped leaves of 10 plants including marigold (Tagetes spp.) and neem in reducing root galling on their host plant. Olaniyi et al. (2005) applied dried leaves of Azadirachta indica, Cymbopogon citratus, Acacia alata, Ocimum gratissimum and Acalypha ciliata in the control of the root knot nematode, Meloidogyne incognita on tomato in the screen house. The striking observation was that A. ciliata and C. citratus supported higher production of males than female nematodes, revealing that there were substances deleterious to the development of the nematodes. Moreover, damage potential of the nematode is reduced as the male nematodes do not feed.

2.1.2. Seed Powders and Cakes

Chattopadhyay and Mukhopadhyaya (1989) made comparative studies on the nematicidal properties of Typhonium trilobatum and Melia azedarach corm and powders respectively. They found T. trilobatum at a dose of 0.75 g / kg soil to control 18% more nematodes than M. azedarach in pre-plant application. The effects of seed cakes on root-knot nematodes were also documented. Suppression of nematode population (Borah and Phukan, 1992; Dwivedi and Pandey, 1992), improved plant yield (Murthy and Rao, 1992), reduction in total number of egg masses (Borah and Phukan, 1992; Dwivedi and Pandey, 1992), males and females per plant (Dwivedi and Pandey, 1992) were among the effects recorded. Singh et al. (1988) reported castor, mustard, neem mahua and groundnut seed cakes to have exhibited suppressive activity on the Meloidogyne spp. used in their investigation. Maximum reduction in the number of root-knot nematode was also recorded from neem cake-amended soil in Pandey and Singh's (1990) study.

2.1.3. Tree Fibres and Other Crop Wastes

Conifer arks have been investigated for their nematicidal potentials. MacGrady and Cotter (1989) evaluated the effect of fresh and aged conifer arks on galling by M. incognita on tomato roots. From their investigation, fresh bark exhibited significant nematicidal activity when used as medium component (50 or 70%) with sand. Singh and Singh (1991) amended soil with 1,2 and 3% powdered Terminalia arjuna bark in a pot experiment and found significant reduction in the number of cysts, eggs and the number of males of Heterodera cajani. They also reported significant increase in plant growth and correlation of nematicidal activity with concentration of the powder. In a field study (Rotimi, 1998), wood chips mixture of Dactyladenia barteri, Cacia spectabilis, Alconia cordiflora and Anruagana spp. were applied as mulch under plantain (Musa spp. AAB-sugroup) after first applying grass mulch composed predominantly of Panicum maximum, and others such as Paspalum orbiculae and Cyperus spp. The mulch treatment improved vegetative growth and alleviated nematode stress on plant growth, while also lowering the population densities of Radopholus similis, Helicotylenchus multicinctus, H. dihystera, Hoplolaimus pararobustus and Meloidogyne recovered from the root of plantain. In related studies, Rotimi et al. (1999) and Rotimi et al. (2004 a & b) reported that oil palm bunch refuse used as mulch repressed the multiplication and establishment of sedentary and migratory endoparasitic nematodes on plantain. The mulch additionally improved vegetative growth and plantation longevity of the plantain (Rotimi et al., 1999; Rotimi, 2004a; Olaniyi, 2006; Coyne et al., 2005).

2.1.4. Green Manure

The use of green manure in suppressing the population of Meloidogyne spp. has also been reported. Motjahedi et al., (1991) obtained greatest reduction in M. chitwoodi population density by cropping rapeseed (Brassica rapa) for two months and then incorporating it into the soil as green manure. Motjahedi et al. (1993) went ahead to support this earlier finding and also reported wheat green manure to be inferior to the rapeseed green manure treatment. However, Johnson et al. (1992) could not support this report this report when they observed that incorporating 30-60 t / ha green biomass of rapeseed into the soil six months after planting did not affect the population densities of M. incognita and M. javanica.

2.2. Compatibility of Organic Soil Amendments with Other Cultural Practices

There are reports to support the recommendation of organic soil amendments with other cultural practices. Akhtar and Alam (1991) presented results indicating that combining organic amendments with inter-cropping in integrated method gave better control than either treatment singly. Greco *et al.* (1992) also reported synergistic results in applying different rates of wheat straw in combination with soil solarization and fumigant nematicides.

2.3. Plant Extracts

Literature is replete on the nematicidal efficacy of plants and plant products. Extracts obtained from plant parts such as leaves (Egunjobi and Afolami, 1976; Nadal and Bhatti, 1986; Chandravadana et al.,1994; Sasanelli and D'Addabbo, 1990), seeds (Salam and Sinha, 1990; Nidiry et al., 1993), roots (Sweelam, 1989; Sasanelli and D'Addabbo, 1990), bark (Salam and Sinha, 1990), latex (Siddiqi and Alam, 1990) and tarpenoids (Al-Obaedi et al., 1987; Duke, 1991), seeds (Khurma and Singh, 1997) were documented. However, Khurma and Singh (1997) observed that seed extracts of some plants, including Acacia eburnea, Azadirachta indica, Cassia spp., Melia azedarach, among others against M. incognita and M. javanica juveniles were less effective against egg hatch as compared to mortality of emerged juveniles and that seeds that rated high in suppressing egg hatch were related to high juvenile mortality.

Different extraction methods have been employed by investigators and their effects on egg hatching and freshly hatched juveniles were extensively documented. Different modes of application were also employed by different investigators.

2.3.1. Nematicidal Activities of Plant Extracts

2.3.1.1. Aqueous Extracts

The influence of aqueous extracts on egg hatch and juveniles of Meloidogyne spp. have been reported. Mojumder and Mishra (1991) obtained reduced hatching of juveniles of M. incognita from egg masses kept in aqueous extracts of seed cakes by Azadiarachta indica (neem) and Brassica rapa (rapeseed). The extracts also inhibited penetration of juveniles into Vigna radiata after soaking the seeds in the aqueous extracts. Gupta and Sharma (1993) tested aqueous bulb extract of Allium sativum (garlic) against M. incognita and reported toxicity of juveniles at 0.05% concentration. Dipping the eggs in the extracts for 10 days before transferring them to distilled water reduced egg hatch significantly. However, Chattopadhyay and Mukhopadhyaya (1989) reported reduced hatching after 24, 48 and 71 hours of exposure. According to the authors, longer exposure time could improve the activity of the extracts.

Whapman et al. (1994) observed the influence Maxicrop original, a seed weed (Ascophyllum nodosus) extract formulation on the migration of infective juveniles of Meloidogyne javanica. There was between 95% and 50% inhibition of migration of the juveniles in Maxicrop original (1%) treated sand columns.

Kirshnamurthy and Murthy (1993) studied the influence of dilution of the standard solution of their water extracts on its nematicidal activity. They found dilution levels of 1:10 to show higher nematicidal effects against M. javanica than 1:100 and 1:1,000. At 5% and 1% concentrations, Gupta and Sharma (1993) obtained approximately 88% and 21% mortality respectively of the juveniles in aqueous extracts of garlic bulbs after 24 hour exposure.

2.3.1.2. Root Extracts and Exudates

Aqueous root extracts singly or in combination with the leaf extracts of Tagetes erecta, Cineraria maritima and Ruta graveolens have been shown to exhibit nematicidal activity against M. arenaria, M. hapla and M. javanica but not against M. incognita (Sasanelli and D'Addabo, 1990). The experiments also showed non significant differences between hatch in all leaf extracts (3-7% concentrations), root extracts of C. maritima (2% concentration) and combination of C. maritima (5% concentration) and R. graveolens (4% concentration) for M. arenaria. Pandey and Haseeb (1988) observed strong nematicidal activity with all extracts they exploited in their study against M. incognita. They obtained highest mortality (100%) with their standard concentration of root extracts of Aloe barbadensis, Gloriosa superba and Scillia indica after 12hour exposure of the juveniles to the extracts. Sweelam (1989) also investigated the potentials of some ornamental plants for nematode control in Egypt. Using M. javanica in a pot experiment, he obtained reduction of nematode populations by 88, 70, 65 and 55% with fenamiphos, marigold, Aloe and lemon grass. The reduction in egg masses was recorded as 91, 83, 69 and 57% for fenamiphos, Aloe, marigold and lemon grass respectively. Treating pared plantain suckers in red acalypha leaf extract for 5-15 mins effectively reduced root and rhizome damage by parasitic nematodes and population densities of the nematode species (Olaniyi, 2012, 2014). These treatments reportedly displayed liming effect on the soil, which merits further investigations. However, pre-plant dip of pared suckers in red acalypha leaf extract for 20 mins was phytotoxic, encouraged high nematode density build up and concomitant parasitism.

2.3.1.3. Chemical Extraction

Different laboratory chemicals have been exploited as solvents in the extraction of active principles of plant materials. Al-Obaedi et al. (1987) suspended powdered samples of plant spp. in 80% aqueous ethyl acetate for 24 hours; the suspensions were filtered and the filtrates concentrated in a rotary vacuum evaporator. The authors tested their products against freshly hatched juveniles of M. javanica and obtained best effect when the extracts were used as pre-plant application for tomato pants compared with planting and post-planting applications.

Sarosh et al. (1989) got a higher inhibitory effect on egg hatching of M. incognita with aqueous extracts than with ethyl acetate extracts. Verma et al. (1989) demonstrated the toxicity of methanol extracts of Ricinus communis, Calotropis procera and Nerium oleander against M. javanica, Anguina tritici and Tylenchulus semipenetrans. The authors reported the irreversible nematicidal activity of the extracts. Gotke et al. (1990) extracted products from Myristica fragrans using acetone and tested the extracts against M. incognita. N-hexane extract of marigold hairy roots induced by infection with Agrobacterium rhizogenes showed nematicidal activity against Caeanorhabditis elegans and Pratylenchus penetrans (Kyo et al., 1990).

Qamar et al. (1989) in their screening of 30 plant spp. for possible nematicidal properties prepared extracts from leaves using ethanol. The investigators reported Nicotiana tabacum, Trachyspermum copticum, Ricinus communis and Azadirachta indica as the most effective, respectively causing 100, 95, 90 and 56% mortality of Cephalobus litoralis. Ethanol extracts of funicles of Acacia auriculiformis have been demonstrated by Badu et al. (1992) to exhibit nematicidal activity against M. incognita in vitro and in vivo. The authors also presented the extracts as non-phytotoxic on the test plant Vigna catjang. Acetone extracts of Euphorbia pulcherrima (leaf), Ricinus communis (seed), Spigelia anthelmia (leaf) and Calotropis procera (root bark) showed promise in the control of Heterodera sacchari. When used either singly or in combination, varying levels of suppression of cyst development were recorded (Salawu, 1992a). Abid et al. (1997) obtained 100 % mortality of M. javanica juveniles after 72hr exposure to ethanol extracts of Annona squamosa, Cocculus pendulus, Datura fastuosa and Solanum surattens.

2.3.2. Mode of Application

2.3.2.1. Soil Drench

Egunjobi and Afolami (1976) applied water extracts of neem leaves as soil drench and they obtained effective control of Pratylenchus zeae on maize. In an investigation of the influence of seaweed concentrates (Kelpak 66) on the reproduction of Pratylenchus zeae on maize, De Waele et al. (1988) applied different concentrations of the product as a soil drench. Result obtained showed 47-60% suppression in reproduction of P. zeae compared with the control. In view of this report, Whapman et al. (1994) investigated the role of seaweed extracts, Ascophyllum nodosum in the reduction of fecundity of M. javanica and applied their dilutions as a soil drench. They obtained reduction in the infestation of tomato roots by the nematodes compared with the untreated control.

2.3.2.2. Root Dip

Nisar and Husain (1989) reported all root-dip treatments that they investigated using Helianthus annus and Vicia sativa extracts to retard the development o root-knot nematodes in brinjal roots. Bare root dip in castor and mustard oil cake and neem leaf extracts effectively controlled M. javanica on tomato and eggplant (Abid and Maqbool, 1991). Akhtar et al. (1992) documented the reduction in the development of root-knot on tomato caused by M. incognita, with bare root dip in leaf extracts of Persian lilac (Melia azedarach) and Calotropis procera. According to Owino and Waudo (1992), root dip of okra in extracts of Datura metel, Ricinus communis and Galium aparinoides significantly reduced infection by M. incognita and the effect was comparable with the soil amendment treatments using the same plants. Akhtar and Mahmood (1993) studied the control of plant parasitic nematodes with "nimin" (a commercial product from neem) and some plant oils by in the bare root dip treatment. The authors obtained inhibition in root -knot development caused by M. incognita on tomato plants with their treatments. On plants like plantain, the efficacy of rhizome dip in extracts of leaves of Acalypha wilkesiana and Gmelina aborea, and seeds of Gmelina aborea in enhancing health of root system and managing nematode related damage to the system was tested with promising results in the screen house (Olaniyi, 2006). Olaniyi (2012, 2014) further investigated the effects of rhizome dip of pared plantain in crude water extracts of Acalypha wilkesiana leaves and at different duration of exposure in comparison with the conventional hot water dip, in protecting against nematode damage under field conditions. The most effective treatment in terms of reduction in nematode population density and related damage was obtained with 15 mins exposure to the extract on the field (Olaniyi, 2012, 2014).

2.3.2.3. Foliar Application

Literature is restrictive on the foliar application use of the extracts from botanicals. Ajayi et al. (1993) compared among other applications, the foliar application and soil drench when they tested Vernonia amygdalina (bitter leaf) leaf extract in the control of M. incognita. Their results showed that foliar application did not show phytotoxicity on the soybean test plant, but soil drench treatments were phytotoxic on the test plants. When they compared their extract treatments with the recommended dose of carbofuran, they observed that carbofuran reduced the egg hatch of M. incognita while the bitter leaf extract treatments completely suppressed egg hatch of the nematode.

2.4. Interaction of Organic Soil Amendments and Plant Extracts with Microorganisms

2.4.1. Soil Amendment

Investigators have shown that the activity of organic soil amendments is likely to be enhanced by the influence of microorganisms. Goswani and Bhattacharya (1989) found fungal populations in their pot experiment to increase markedly during decomposition of neem (A. indica) and groundnut (Arachis hypogaea) oil cakes. From their results, predominance of Aspergillus spp. was correlated with neem-amended soil plantings while groundnut amended soil showed more of Trichoderma viridae. Pandey and Singh (1990) registered the maximum number of Azotobacter spp. on neem. They also recorded maximum soil fungal colonies and the best growth of chickpea from plots amended with neem cake followed by mahua cake (Madhuca longifolia). The effect of filtrates from culture of 13 fungi isolated from neem cake amended soil was investigated by Singh et al. (1991). Their results showed Aspergillus niger and Penicillium citrinum to cause 100% mortality of Heterodera cajani juveniles at their standard concentrations. The authors also observed the culture filtrates of P. citrinum to completely inhibit emergence of juveniles from cysts and were also effective at lower concentrations.

Owino et al. (1993) obtained stimulated egg parasitism of M. javanica by a Kenyan isolate of Verticillium chlamydosporium from soil amended with marigold (Tagetes patula) and neem (A. indica), though from the same study, extracts from soil-decomposed mustard (at least 16days) significantly inhibited fungal growth and egg parasitism.

2.4.2. Plant Extracts

Owino (1992) obtained inhibition of fungal parasitism of M. incognita and M. javanica eggs with leaf extract of marigold at high concentrations. At the lowest concentration investigated, significantly higher fungal parasitism of M. javanica eggs was observed. However, Owino and Sikora (1992) obtained significantly more egg parasitism by Fusarium spp. in marigold leaf-extract-amended soil than in non-amended soil. Tagetes minuta and Datura stramonium were observed to have significant inhibition on fungal parasitism of eggs of M. incognita and M. javanica in vitro, while leaf extracts of Ricinus communis had no effect. An unidentified fungal isolate, however, appeared to be more parasitic than the two Fusarium spp.tested (Makhatsa et al., 1993). Rotimi and Moens (2005) reported fungal contaminants consistently in the extracts of red acalypha and A. indica in their ovicidal study while others were clean. The investigators suggested that the extracts could improve soil biodiversity hence increasing the level of parasitism on egg-masses of Meloidogyne.

3. Discussion

Nematode problems are not easily detected early enough and the nematode continues to accumulate in the field over the years. This often results in epidemics, which warrant quick and effective control measures. Nematicide use is always a great relief in such a situation. Additionally, nematicides are always handy as complementary treatments or as the last resort when other methods of control fail especially in high priced crops. The need for better yet quick alternative has prompted the agitation for natural pesticide and information available has shown that plant show promise as source of natural pesticides.

A major problem in the use of synthetic nematicides apart from their mammalian toxicity had been their recent discovery in underground water (Babatola, 1992). These ominous environmental hazards are good reasons to condemn their use by environmentalists, which lead to ardor for more ecological means of control. Use of organic soil amendment has shown promise in this regard. However, there are a lot of arguments against the large- scale use of organic soil amendments. The major ones being the bulkiness of the materials need to apply it in large quantities and the slow activities. These should not be points against the development of this promising approach; rather technologies should be developed to ameliorate these ardent problems and make the approach more attractive. For instance, the lower efficacy of amendments in contrast to synthetic nematicides is overcome by their cheapness and relative availability. Moreover, maximum benefit of the use of organic matter will be by small farmers or horticulturists who have limited financial resources, but have access to locally produced wastes (Muller and Gooch, 1983; Rotimi et al., 1999).

Organic soil amendment and plant extracts would alter the complex soil ecosystem and it is possible for otherwise unknown antagonists of plant parasitic nematodes to be amenable to these treatments thereby increasing to population levels, which would suppress the nematode populations. In their natural environment, plant parasitic nematodes are attacked by numerous and varied soil organisms, including fungi, bacteria, protozoa, other nematodes and invertebrates (Russel, 1973; Sayre, 1980; Misari, 1992). Several bacteria and fungi tested for the control of specific plant parasitic nematodes showed promise but little is still known about their activities under natural conditions. Liming effect of extracts of a plant like Acalypha wilkesiana (Olaniyi, 2014) is an added advantage that merits further investigation.

Generally in entomology, biological control strategies, that present the most desirable characteristics of natural enemies were: mobility and ability to search out prey, adaptability to the environment, host specificity, synchronization with the host and the ability to survive in the absence of the host. Biotic antagonists are believed to give temporary control, be slow action, erratic and may never completely suppress pest populations to economically effective levels obtained with nematicides (Misari, 1992). This should be an explanation for the slow activity of organic soil amendments since such materials are full of litter microbes, which are gradually decomposing the litter and may prey on parasitic nematodes in the soil. The use of these materials as extracts rather than amendments is an attractive solution to the slow acting quality of the organic soil amendments. The extracts act faster and are often more effective. This probably shows that some active chemical principles are likely to be removed into the extracts. Extracts are also easy to apply. The nematotoxicity of the extracts may even better still, be due to toxic chemicals produced from microbial degradation of extracts (Tomerlin, 1969; Alam et al., 1980; Salawu, 1992b). An attractive advantage in the use of plant extracts is their purported environmental safety in view of mammalian toxicity. This should make them attractive to environmentalists.

The activity exhibited by extracts may be related to the method of extraction employed and the activity expressed on the nematode varied from ovicidal, nematostatic, to nematicidal. The action of the extracts on the nematodes is also influenced to a large extent by the type of plant and the plant parts from which the extract was prepared.

The influence of toxic material on sex expression was demonstrated in a few studies with extract of red acalypha and amendment with red acalypha and lemon grass leaves. These treatments gave extract gave more males of Meloidogyne incognita than females. Since males of plant parasitic nematodes do not feed, it is a promising intervention if treatments with botanicals would enhance sex reversal, thereby reducing nematode damage and ultimately reducing the number of females and possibly fecundity.

4. Conclusion

In conclusion, since there is a need for the development of new chemicals, which would be harmonious with the environment, the proposal of biological nematicides is not out of place and their development should be encouraged. There is also a great need for better understanding of soil microbial ecology and more systematic approach in biocontrol by nematologists. Information is additionally needed on the type of influence that the treatments would exert on the soil community structure. The knowledge of interaction between nematode and their natural enemies in the natural habitat would help in the development of better control strategies. This knowledge will help in better developing the use of organic material in the control of plant-parasitic nematodes so that this promising idea would not be aborted on flimsy grounds. The idea should be given time to incubate and bring forth an attractive solution. It could even be a better and effective alternative to synthetic nematicides on the long run. The use of organic materials, either as soil amendments or in the extract form presents an attractive way of alleviating the environmental problems accruing from the use of synthetic nematicides.

The employment of organic materials as extracts look promising as a model biological alternative to synthetic nematicides if properly developed. However, more field trials need to be carried out on these materials to test their efficacy under natural conditions. The significance of foliar application of the extracts should be a choice of proper investigation as this might reveal basipetally (downwardly) translocated systemic compounds, which would be of great attraction in developing new nematicides.

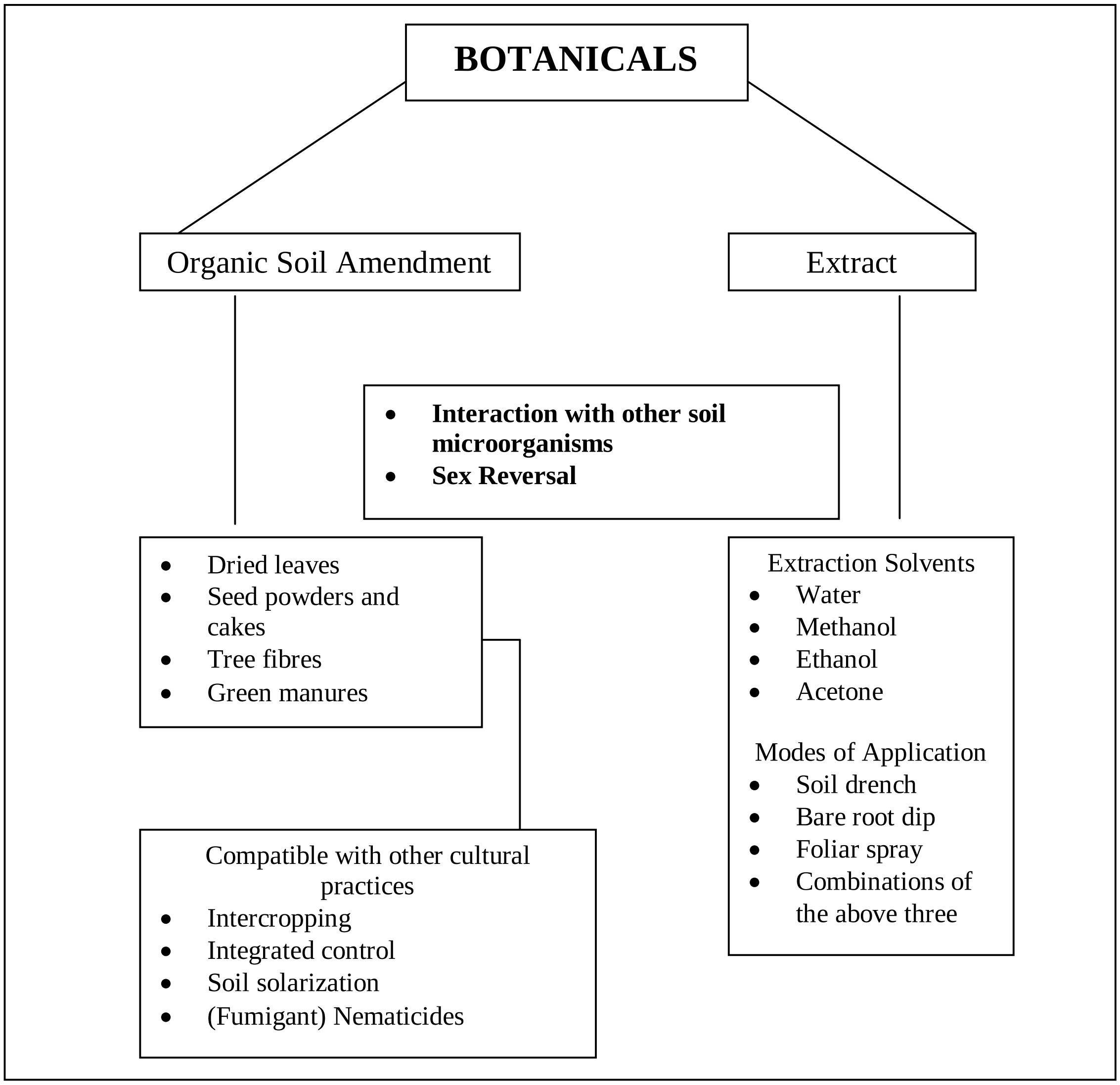

Figure 1: Summary of the use of Botanicals in the control of plant parasitic nematodes

5. Challenges for Improving the Use of Botanicals

Literature is replete on the activities of botanicals in the control of plant parasitic nematodes while only limited information is available on the active components of these materials. Efforts should be directed at identifying active components with the aim to formulating new environmentally friendly nematicides from them.

Mode of application of botanicals needs to be harmonized while the application rate should be established. A way forward would be to first standardize procedures in order to allow comparison of results.

Domestication of some of these plants would be necessary as several of them are only in the wild while others are given less attention since they are not food crops.

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