Biological Control of Plant Parasitic Nematodes: Prospects and Challenges for the Poor Africa Farmer

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Abstract

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Africa contains a larger part of world's developing countries with their associated problems of food security and healthy environment. Pollution and its grave consequences are among the greatest challenges of the tropics and affect the choice of management strategies in agriculture. Biocontrol as an integral part of management is an attractive option for plant parasitic nematodes that should be pursued besides the cultural practices of crop rotation and organic amendment to include the use of microorganisms isolated, cultured and packaged in the tropics for tropical farmers. Exploring biocontrol in nematode management is yet unattainable for the tropical farmer, not until research and manpower development in this area are encouraged by both governments and donor agencies.

Keywords: nematodes; food security; Africa

Scientists all over the world do not have a uniform concept of what biological control is. However, in the course of years a broad concept proposed by Cook (1987) has found acceptance among the community of scientists involved in biocontrol research. Biological control is defined broadly as the use of natural or modified organisms, gene products to reduce the effects of undesirable organisms and support desirable beneficial organisms such as crops, trees, animals, and beneficial insects. It is simply the use of one or more organisms to maintain or to check the population of another pest at a level where it ceases to be a problem (Cobraz 1990; Kroschelk 2001; Nekouam 2004). It depends on the knowledge of biological interactions at the ecosystem, organism, cellular and molecular levels and is often a more complicated management strategy than physical and chemical methods. It is less spectacular than most physical or chemical controls but it is usually more stable, longer-lasting and environmentally friendly. Biological control describes the normal state of affairs in natural undisturbed ecosystems, where populations of organisms exist in a dynamic equilibrium and species or individuals unable to compete or find ecological niche are replaced by those that can (more aggressive ones). The knowledge of the ecosystem can be manipulated to favour the host rather than the pest. However, biocontrol like other approaches in management has its constraints. The use of micro pesticides in nematode management requires skill, is labour intensive, non-systemic and subject to rapid inactivation by varied environmental factors in comparison with other synthetic products.

Africa has most of the world's developing countries. With poor technologies coupled with rapid urbanisation and industrialization, pollution is becoming one of the greatest challenges of the tropics. However, the rich ecological diversity of Africa is a natural endowment that can be harnessed in pest management without exacerbating the already growing environmental pollution. The challenges of biocontrol not withstanding, its importance cannot be contested in the tropics. The issue is not whether to pursue it, but how best to do so. Africa cannot afford a control approach that will topple the already delicate balance of a clean and healthy environment. Reducing pollutants in the environment becomes a major issue and a guide in the choice of control approach. This paper discusses the challenges of biocontrol as it affects the poor African farmer.

Challenges of biological control:

In the most developed parts of the world where attempts have been made at commercial production of biocontrol agents, its use is not without challenges. Growers do not generally use biocontrol products due to lack of rapid and adequate control (Felde *et al.* 2006). Inconsistent performance of applied biocontrol agents has been reported as a primary obstacle in exploring this mode of management. This inconsistency is due to abiotic and biotic factors. Biotic factors include interactions with non-target organisms, damage caused by non-target pathogens and pests, degree of rhizosphere and/or soil colonisation by a biocontrol agent, initial population levels of the target organisms, susceptibility of the host plant species and host plant cultivar. Abiotic factors include climate, and physical and chemical composition of the rhizosphere (Meyer & Roberts 2002; Sikora & Hoffmann-Hergarten 1993). These factors mitigating the performance of beneficial microbes explain their differential performance in various soil environments.

The use of biocontrol organisms such as endophytes is important where nematicides are prohibited like in organic farming and in areas where low nematode densities were recorded over time (Felde *et al.* 2006). Microbial pesticides do not generally reduce the population of targets below the necessary economic threshold (Flexner & Belnavis 2000). Furthermore, biocontrol is not presently considered an acceptable alternative for pesticides. It lacks a broad-spectrum activity in addition to its inconsistency. The hurdles between identifying and development of large-scale *in vitro* rearing systems are enormous. Formulations that will allow for adequate shelf-life and infectivity in the field are a problem. Microbial pesticides are generally slow-acting, lacking persistence and systemic ability in the field. They are readily inactivated by environmental factors such as sunlight, rain and wind and, therefore, remain infective for a short while (Thacker 2002). The numerous set-back of microbial pesticide in management makes its use more laborious when compared to the synthetic products.

The suppressive activity of two or more bioagents has been explored by researchers as a means of overcoming the problem of inconsistency. Advantages accruing from the consistent use of such combinations include extensive colonisation of rhizosphere and higher expression of beneficial traits (Table 1) under a broad range of soil conditions (Meyer & Roberts 2002). Multiple modes of action against the target nematode with effect at different stages of their life cycle are a possibility. Adaptation of this approach depends on positive research findings from combining biocontrol agents in nematode management. These findings include an increase in plant vigour or yield, reduction of nematode populations or penetration into roots, compared with individual applications of biocontrol agents. These recorded successes are indicative of the relevance of this approach

Table 1. Effect of single and combined inoculations of endophytic fungi on the number and density of *Radopholus similis* in banana roots

Treatment	Number of *R. similis* in whole root system	Reduction (%)	Density of *R. similis* (number/g of roots)	Reduction (%)
Trichoderma atroviride	2327	49	473	73
Fusarium oxysporum	1964	57	469	73
T. atroviride & *F. oxysporum*	1600	65	245	86
Control	4582	–	1721	–

Adapted from Felde *et al.* (2006)

to nematode management. Successful biocontrol combinations have been recorded against root-knot nematodes. The combination of the bacterium *Bacillus subtilis* and the fungus *Paecilomyces lilacinus* suppressed nematode populations beyond the individual application of the agents (Gautam *et al*. 1995). A similar synergistic effect was recorded for the use of the combination of the bacterium *Pasteuria penetrans* and the fungus *Verticillium chlamydosporium* on tomato. An increased effect at suppressing more than one plant disease was observed for the combined use of *P. lilacinus* and *Trichoderma harzianum* on root-knot disease and *Fusarium* wilt of papaya.

Another school of thought opines that such combinations of agents may not always be beneficial as antagonism can occur between biocontrol agents. This will ultimately lead to unchanged control levels (Zaki & Maqbool 1999; Viaene & Abawi 2000). Biocontrol interactions leading to disease suppression are mediated through antibiosis, induced resistance and competition for resources (Siddiqui & Mahmood 1999). Therefore, the positive responses observed in such combinations are a product of synergy or additive effect. In the same manner similar mechanisms directed against a companion biocontrol agent will lead to the unchanged control level of pathogens with corresponding suppression of biocontrol agents. Meyer and Roberts (2002) clearly showed that microbes in biocontrol preparations are potentially antagonistic to each other through parasitism and antibiosis. Compatibility of microbial agents combined in a biocontrol preparation is advocated by researchers. The success of such compatibility in nematode control was elucidated by Felde *et al.* (2006) and Khan *et al.* (2006) in their work. This will further compound the problem of research in biocontrol. This means that besides the identification of an agent, its compatible mate has to be identified for effectiveness when used in combination.

Biocontrol in the tropical Africa – the journey so far

The major approach that has been very acceptable to the local farmer is the manipulation of the soil environment to increase the activity of microbes through the incorporation of organic amendment. Walker (1969) earlier demonstrated the involvement of soil microbes in the decline of plant parasitic nematodes during the degradation of complex organic materials and nitrogenous compounds. Poultry manure, cow dung, green manure, and crop residues have found wide acceptability among small-scale farmers. These amendments serve the dual purpose of improving soil fertility and reducing the nematode population through the increase of soil microfauna (Poswal & Akpa 1991; Agbenin 2004). In Nigeria, success in nematode disease management was recorded using poultry manure, cow dung and sawdust (Babalola 1982; Chindo *et al.* 1991). In Egypt, Korayem *et al.* (2008) reported the effectiveness of chitins and abamectin in reducing the root-knot problem in oil seed rape in the field. The use of organic amendment in nematode control has gained much acceptability in most developing nations. Reports from India and the region of Pakistan have shown the organic amendment of soil using dried poultry faeces, municipal refuse, cakes of groundnut, neem, mustard and chitin to be effective in the management of plant parasitic nematodes (Siddiqui *et al*. 1976; Alam *et al.* 1980). In India, neem-based products Achook and Suneem G separately and in combination with urea and compost manure proved effective in suppressing a plant parasitic nematode population in *Cajanus cajan* (Akhtar 1998).

The use of plant extract has become an acceptable alternative to synthetic pesticides in nematode management in most African countries and developing nations of the world. Although in itself it is not a component of biocontrol, it enjoys wide acceptability by small-scale farmers who consider it an alternative. Extracts of plants such as *Azadirachta indica*, *Acacia alatta*, *Borrelia* spp., *Acalypha cilliata* and garlic bulbs have been identified to have nematicidal properties (Egunjobi & Onayemi 1981; Agbenin *et al.* 2005; Rotimi & Moen 2002). In India extracts of *Calendula officinalis, Enhydra fluctans* and *Solanum khasianum*, chilli pepper and garlic were all effective against the root-knot nematode (Goswami & Vijayalakshmi 1986; Sukul, 1992). Plant extracts are applied either as soil drench, root dip or foliar spray. However, sometimes these are crude extracts with the known phytochemical constitution. Research efforts in the use of plant extracts in nematode management worldwide have largely been basic and descriptive (Chitwood 2002). Identification of the specific phytochemicals in these extracts is a plus given the large ecosystem

Table 2. Biocontrol methods in use in tropical Africa

Type of bio-control agent	Target organism	Reference
Organic amendment		
Leaves of Neem, *Parkia biglobosa*, Crotalaria	Plant Parasitic Nematode (PPN)	Fatoki and Oyedumade (1996)
Cassava peelings (partially decayed)	*Pratylenchus* spp.	Egunjobi and Ekundare (1981)
Neem seed powder	*Meloidogyne* spp.	Agbenin *et al.* (2004)
Green manure/crop residue	PPN	Poswal and Akpa (1991)
Cow dung/poultry manure	*Meloidogyne* spp. PPN	Poswal and Akpa (1991)
Bio-pesticides		
Pasteuria penetrans	PPN	Babalola (1982), Chindo *et al.* (1991)
Pochonia chlamydosporia	PPN	www.researchintouse.com/nrk/RNinfo/PF/CPP50
Paeciliomyces lilacinus	PPN	Sikora *et al.* (2006)

diversity of tropical Africa. These compounds can be developed for use as nematicides or they can serve as model compounds for the development of chemically synthesised derivatives with enhanced activity or environmental friendliness (Chitwood 2002).

In East Africa a combination of biocontrol, cultural and resistant cultivars is in use. In Kenya, Tanzania and Uganda many small holders practise safe production using biocontrol and resistant cultivars. Pesticide legislations are being amended in some countries to include biopesticides. Biopesticides such as *Pasteuia penetrans*, *Pochonia chlamydosporia* are finding acceptance among vegetable growers in developing nations such as Kenya, Tanzania, South Africa, and Cuba (Table 2). However, most of the few works on the use of fungal endophytes involve the use of nonpathogenic strains of *Fusarium oxysporum* and to a lesser extent *Trichoderma* species (Sikora *et al.* 2006).

Besides the general challenges of biocontrol, the tropical farmer is faced with peculiar conditions. It is established that the efficiency of biocontrol agents varies with soil type; therefore, for microbial agents to be very effective they have to be those isolated from the tropical environment. Research in this area in most developing countries including tropical Africa is very minimal, if not absent (Sikora *et al.* 2006). Identification of biocontrol agents largely involves the manipulation of naturally occurring microbial organisms rather than the introduction of identified and researched agents. Besides the issue of identification, is the compatibility of more than one organism whose synergy effect is exploited as a tool towards solving the problem of inconsistency. A high degree of precision in the fine details of research is needed. Sometimes the available human resources lack the expertise and even when the personnel are there for these forms of research, the facilities are not often available. The inconsistent field performance of biocontrol agents makes it essential that the potential microorganism be identified within a given ecological region.

CONCLUSIONS

Giving the existing scenario in the tropics the prognosis for the tropical farmer assessing biocontrol as a part of nematode disease management is very poor. However, there is no alternative to this environmental friendly management procedure. Developing an indigenous technology to cater for the need of the tropical farmer in the context of his environment is a necessity. Government and other research funding bodies must be committed to investing in manpower development and funding of research in this area.

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