Biological controls to combat root-knot nematodes

Validated RNRRS Output.

In East Africa, a combination of biological controls, cultural practices and new pest-resistant varieties helps reduce damage to valuable tomato export crops. Root-knot nematodes are a chronic problem for vegetable growers. Crops do not thrive on land that's severely affected, so it's often abandoned. Export markets for vegetables from East Africa are booming. But growers must make sure their produce meets the safety standards set by importing countries. This means they can't use harmful pesticides. Many smallholders in western Kenya, Tanzania and Uganda now practice safe production, using biological controls and resistant varieties. A small company in Kenya already produces 40 kilogrammes a week of a biological fungicide. And Kenya has amended its registration system to include biopesticides. So, there's a huge potential.

Project Ref: **CPP50:**
Topic: **1. Improving Farmers Livelihoods: Better Crops, Systems & Pest Management**
Lead Organisation: **University of Reading, UK**
Source: **Crop Protection Programme**

Document Contents:

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Geographical regions included:

Kenya, Tanzania, Uganda,

Target Audiences for this content:

Crop farmers,

Description

CPP50

A. Description of the research output(s)

1. Working title of output or cluster of outputs.
In addition, you are free to suggest a shorter more imaginative working title/acronym of 20 words or less.

Biocontrol of root-knot nematodes

2. Name of relevant RNRRS Programme(s) commissioning supporting research and also indicate other funding sources, if applicable.
Crop protection Programme

3. Provide relevant R numbers (and/or programme development/dissemination reference numbers covering supporting research) along with the institutional partners (with individual contact persons (if appropriate)) involved in the project activities. As with the question above, this is primarily to allow for the legacy of the RNRRS to be acknowledged during the RIUP activities.

R8296 R7472 The University of Reading, Rothamsted Research; Prof. Brian Kerry, Kenya Agricultural Research Institute (KARI); Dr Gilbert Kibata, CABI Africa Regional Centre; Dr Daniel Karanja

R8218 (Production of *Pasteuria penetrans* to control root-knot nematodes) Lead Institute Dudutech Kenya Ltd, Dr L Rovesti and Dr Roma Gwynn The University of Reading; S R Gowen/B. Pembroke

4. Describe the RNRRS output or cluster of outputs being proposed and when was it produced? ***(max. 400 words)****. This requires a clear and concise description of the output(s) and the problem the output(s) aimed to address. Please incorporate and highlight (in bold) key words that would/could be used to select your output when held in a database.*

The project aimed to verify and promote sustainable approaches to the management of **root-knot nematodes**, (***Meloidogyne*** spp.) through the use of micro-organisms, cultural techniques and **plant resistance**. Through research participation smallholders have been acquainted with the production constraint and of potential ways of its allieviation. The novelty has been the inclusion of the naturally occurring **biological control** organisms within the cropping system preferred by (or acceptable to) the farmers. This will become an accepted practice when the national regulatory authority approves the use of "**biopesticides**", when organisations have the capability to mass produce these products at an acceptable price and when there are appropriate channels to deliver them to the smallholder grower community. Progress has been achieved with each of these stages which will ensure the long-term benefit to all sectors of the Kenyan vegetable-producing community.

The amendments to the **Kenya** pesticide legislation to include those defined as "biopesticides" such as ***Pochonia chlamydosporia*** and ***Pasteuria penetrans*** have been drafted and await final legislative ratification. This will then enable companies to produce and market these products.

Dudutech have refined the production of *P. chlamydosporia* and are producing 40 kg of formulated product per week; this can be scaled up to 100 kg /week when required. There is no loss of pathogenicity in sequential batches of fungus. This was achieved after the technology had been developed in a collaboration between Rothamsted Research and the Centro Nacional de Sanidad Agropecuaria, Havana, Cuba. The work was funded by a DFID small grants project,which led to the establishment of a pilot production plant and the registration of KlamiC based on *P. chlamydosporia* as a biocontrol product. Colleagues from Cuba spent 3 months establishing the technologies in Dudutech under a confidentiality agreement.

Methods of scaling-up the *in vivo* system of mass-producing *P. penetrans* are being investigated but as yet no consistent process has yet been developed because of the dependence on uniformly warm temperatures and large supplies of nematode hosts on which to produce the parasite. Spore yields of 3.26 – 5.6 x 10^6 per g of dried tomato root have been achieved.

P. chlamydosporia was applied through a drip system spores were not evenly delivered along the line of the drippers. This could be a technical problem relating to formulation because of the size of chlamydospores. Distribution of spores of another biocontrol fungus, *Paecilomyces lilacinus,* through such a system is better, probably because spores of this fungus are smaller and consistent in size.

Farmers' perceptions and preferences of some different tomato varieties shows that a "new" variety with **root-knot nematode resistance** was ranked best (of four) including the standard cultivar Cal J which is nematode susceptible.

Thirty five farmers from Kibirigwi (rainfed), 26 Kibirigwi (irrigated) and 36 at Mwea participated in evaluations on field days.

5. What is the type of output(s) being described here?
Please tick one or more of the following options.

Product	***Technology***	***Service***	***Process or Methodology***	***Policy***	***Other Please specify***
X	*X*				

6. What is the main commodity (ies) upon which the output(s) focussed? Could this output be applied to other commodities, if so, please comment:

Vegetables.

The outputs of this work have application for many other crops including some tropical fruits (annual and perennial), yams, some fibres, legumes and flowers.

7. What production system(s) does/could the output(s) focus upon?
Please tick one or more of the following options. Leave blank if not applicable

Semi-Arid	***High potential***	***Hillsides***	***Forest-Agriculture***	***Peri-urban***	***Land water***	***Tropical moist forest***	***Cross-cutting***
	X		*X*	*X*			*X*

8. What farming system(s) does the output(s) focus upon?
Please tick one or more of the following options (see Annex B for definitions).
Leave blank if not applicable

Smallholder rainfed humid	***Irrigated***	***Wetland rice based***	***Smallholder rainfed highland***	***Smallholder rainfed dry/cold***	***Dualistic***	***Coastal artisanal fishing***
X	*X*		*X*	*X*		

*9. How could value be added to the output or additional constraints faced by poor people addressed by clustering this output with research outputs from other sources (RNRRS and non RNRRS)? (**max. 300 words***
Please specify what other outputs your output(s) could be clustered. At this point you should make reference to the circulated list of RNRRS outputs for which proformas are currently being prepared.

Root-knot nematodes are a chronic problem wherever vegetables are grown continuously. Nematodes are one of several pest and disease problems that can debilitate a crop or lead to the abandonment of land for intensive vegetable production. Generally, farmers are unaware of nematodes because the diagnostic symptoms are on the roots. The above-ground symptoms cannot be separated from those caused by other pest, disease or abiotic constraints. Until the seriousness of the nematode problem is recognised farmers are unlikely to invest time or resources in implementing management strategies. Added value can be obtained by clustering the outputs of this project with:

R8341 Promoting the adoption of IPM in vegetable production
R8299 Accelerated uptake and impact of CPP research outputs in Kenya
R8281 Linking demand for and supply of agricultural information in Uganda.

Validation

B. Validation of the research output(s)

*10. **How** were the output(s) validated and **who** validated them?*
*Please provide brief description of method(s) used and consider application, replication, adaptation and/or adoption in the context of any partner organisation and user groups involved. In addressing the "who" component detail which group(s) did the validation e.g. end users, intermediary organisation, government department, aid organisation, private company etc... This section should also be used to detail, if applicable, to which social group, gender, income category the validation was applied and any increases in productivity observed during validation **(max. 500 words)**.*

Experimental results showed improved yields with nematode resistant varieties
Varieties were tested on-farm by four groups of organic farmers. The nematode resistant variety Monyala yielded approx 45 t/ha compared to the widely grown nematode susceptible variety Cal J which yielded 11 t/ha. Participating farmers were satisfied with the new variety 87% preferring this to the traditional variety. Of the farmers in these groups 47% were also keen on adopting biopesticides.

The interest in bionematicides and nematode resistant crop cultivars extends throughout the vegetable producing communities throughout the world. Products such as *Paecilomyces lilacinus* and *Pochonia chlamydosporia* have been registered for use on vegetables in other developed and developing countries eg USA, Mexico, www.prophyta.com and South Africa and are also being produced and used by smallhoders in Cuba.

The use of nematode resistant tomato varieties has been limited by absence of promotion (in developing countries) relatively higher cost of seed and poor fruit quality/flavour. In Kenya the new varieties are being marketed by Regina Seeds and Nirit Seeds (http://www.seedquest.com). In the on-farm work in Kenya 60% of the farmers (organic and non-organic) considered the price of seed of the resistant varieties to be high. However in terms of yield and acceptability the introduced varieties were preferred to the standard Cal J variety.

The organic and non-organic farmers participating in the biopesticide and nematode resistance study were growing tomatoes for commercial purposes. Male farmers were more likely to try the new technologies but more men are involved in commercial farming.

The research generated a number of scientific papers that have been published in international journals following peer-review to validate the quality of the science, which underpinned the strategies being promoted to local growers and entrepreneurs.

*11. **Where and when** have the output(s) been validated?*

*Please indicate the places(s) and country(ies), any particular social group targeted and also indicate in which production system and farming system, using the options provided in questions 7 and 8 respectively, above **(max 300 words)**.*

The use of nematode resistance in tomato has been validated widely particularly in the large producing countries such as the USA. Their adoption in developing countries has been slow because of poor promotion, limited appreciation of the importance of nematodes and the relative cost of new varieties many of which are hybrids (and relatively expensive).

Similarly, use of biopesticides has become a standard practice in developed countries, driven by the need for lower pesticide inputs in all intensive vegetable production systems. Bio-nematicides have recently been registered for use in some countries (see above) but because they are relatively new, their efficacy has not been widely proven under full commercial conditions.

The target groups for the new varieties and biopesticides in poorer countries such as Kenya will be those organic and organic commercial farmers supplying local markets.

Current Situation

C. Current situation

*12. **How and by whom** are the outputs currently being used? Please give a brief description **(max. 250 words)**.*

Widespread dissemination was not a part of the original project. Dr Karanja (CABI ARC) has contacted farmers who participated in the on-farm trials. Few (<10%) are planting the cultivar Monyala. The major constraint according to them has been the high cost of the seed. The seed companies, they are still selling the seeds but their main clients are farmers with large commercial farms, particularly in Eldoret, Kitale and Nakuru. These seeds are produced outside the country, hence the high cost. If there could be a regional programme to breed &/or multiply seeds of nematode-resistant varieties (with other characteristics preferred by the farmers, as identified in the study), these would enhance their access to the resource-poor farmers in Kenya. The seed companies are interested in such a programme. Root-knot nematode is still a pest of concern among tomato farmers in Kenya. Currently the participating farmers are still practicing seedbed management strategies as well as crop rotation, to reduce the impact of nematode damage.

All producers supplying international markets are adopting biopesticide strategies because of the EUREP-GAP regulations. Dudutech K Ltd has the responsibility for developing nematodes biocontrol agents for its parent company HomeGrown. The Real IPM company (http://www.realipm.com) is also developing biopesticides for the general producers in Kenya and is providing training programmes in use of biopesticides and in helping producers become compliant with regulations governing produce for export.

*13. **Where** are the outputs currently being used? As with Question 11 please indicate place(s) and countries where the outputs are being used **(max. 250 words).***

Bio control agents in general are in demand in all vegetable and flower producing enterprises (worldwide). The issues of mass production, formulation and efficacy are still important and limit the development of biocontrol agents such as *Paecilomyces lilacinus* , *Pochonia chlamydosporia* and *Pasteuria penetrans.*

*14. What is the scale of current use? Indicating how quickly use was established and whether usage is still spreading **(max 250 words).***

Resistant varieties are being used by some commercial farmers. Although the tomato varieties have proven to be popular the is a continuing problem with cost of the seed. (see Q 17)
Biopesticides for nematodes (see above)

*15. In your experience what programmes, platforms, policy, institutional structures exist that have assisted with the promotion and/or adoption of the output(s) proposed here and in terms of capacity strengthening what do you see as the key facts of success? **(max 350 words).***

The development of IPM systems is the universally accepted option for all production systems in all ecological zones. The work with biopesticides and crop resistance has been fundamental to the clusters of vegetable projects in East Africa in which there has been scientific collaboration between NARS, NGOs (such as KIOF), farmers' groups (organic and otherwise), commercial companies (Dudutech K Ltd), International centres (ICIPE, AVRDC, CABI Africa Regional Centre) with funding support from various agencies and International donors (USAID, Rockefeller Foundation, IDRC, The Gatsby Charitable Foundation and its associated regional trusts).

The relatively new concept of developing biopesticides has been furthered with the initiatives leading to the preparation of legislation enabling their use in Kenya. The opportunities for introducing biopesticides from countries where their use is well established (India, S Africa) can now be exploited.

Because there is an increasing export market of vegetables and flowers from the east African region, producers have to meet the regulations set down by the European importing countries through EUREPGAP (http://www.eurepgap.org).
The use of safer production techniques with reduced use of pesticides is extending to the many smallholder out-growers.

Promotional materials (posters & leaflets) produced on project R 8296 are being used by farmers and various Farmer Field Schools particularly from western Kenya have been requesting more. Over 1000 copies were disseminated during the 1-year extension (2005-06) of the Accelerated Uptake project in western Kenya (R8041). There has been an increasing demand for the leaflets from Tanzania (Agricultural Research Institute – Uyole under their vegetable extension programme with INADES-Formation) and about 50 copies were sent to NARO-Namulonge, Uganda. The posters and brochures will be used during a farmer's training on production of quality seed (which includes some aspects of pest management of seed crop), in Rift valley and western Kenya later this year, under an SDC-funded Good Seed Initiative, which CABI is implementing in collaboration with KEPHIS. Currently the training is focused on contract farmers who produce vegetable seeds for East Africa Seed Company & Kenya Seed Company.

Key staff have developed capacity through training experience on project include two PhDs, technical personnel from commercial vegetable and flower producing enterprises (50 staff at two courses on nematodes and nematode biocontrol agents) and training of two technicians in use of biocontrol agents at Reading University. In addition, a 5 year Gatsby project is funding a capacity-building project linking nematologists in the region (Kenya, Uganda, Tanzania, Malawi, Zimbabwe).

These training initiatives have raised the profile of nematodes as key pests of vegetables and flower crops.

Current Promotion

D. Current promotion/uptake pathways

*16. **Where** is promotion currently taking place? Please indicate for each country specified detail what promotion is taking place, by whom and indicate the scale of current promotion **(max 200 words).***

The main clients of the seed companies in Kenya (see above) are farmers with large commercial farms, particularly in Eldoret, Kitale and Nakuru. Because the seed of the nematode resistant tomato varieties are produced outside the country they are relatively costly and are only being adopted by the large commercial growers.

Similarly, biological control agents (including bio-nematicides) are being promoted by companies (from India and South Africa) but to the larger Kenyan producers growing crops commercially for export and for urban markets.

Real IPM was established to provide consultancies and biological control agents to clients in Kenya and in the region producing company. Training of staff of vegetable and flower producers is a component of their activity and is benefiting the region by increasing skills at all levels of production.

*17. What are the current barriers preventing or slowing the adoption of the output(s)? Cover here institutional issues, those relating to policy, marketing, infrastructure, social exclusion etc. **(max 200 words)**.*

Creating awareness of the seriousness of the damage caused by root-knot nematodes is a continuing challenge particularly for the poorer farmers. Among the commercial growers in the project study areas, >80% appreciated that nematodes are important pests.

Resistant varieties
Although there have been root-knot nematode resistant tomato varieties available for 50 years they have been slow to be adopted in the developing countries. The reasons for this are many:

- varieties developed in temperate and Mediterranean climates are not adapted for tropical conditions
- fruit size, colour, flavour may be unsatisfactory
- limited promotion, tomato has not been a priority crop of seed companies in the tropics

other serious diseases increase risk of crop failure and so there is unwillingness to invest in expensive seed

It is noteworthy that the nematode resistant tomato varieties used in trials were liked for their general attributes as well as resistance (see above).

Methods are required for making seed available to the smaller growers. This could be done by linking this work to other projects in Kenya and Tanzania where platforms exist for promotion and distribution of good quality seed

Biopesticides
Companies still have problem of producing products at levels which are economically attractive/viable. Companies are still focussing on the home growers (large scale commercial rather than the smaller independent (and poorer) farmers.
Issues of packaging delivery and shelf life of products (for smallholders) still need addressing.

Overall there has been a lack of awareness of the farmers needs; more on-farm demonstrations are required, lack of collaboration between seed companies and extension services (farmers groups, Govt and NGOs KIOF) is shrouded by the overriding problem of production costs and lack of availability.

18. What changes are needed to remove/reduce these barriers to adoption? This section could be used to identify perceived capacity related issues ***(max 200 words).***

The basis for future work:

1. More on-farm demonstrations; collaborative programmes with the same stakeholders (Government and international scientists, NGOs, farmers groups, KIOF, seed suppliers and or companies).
2. Rapid study of seed supply and availability to identify the bottlenecks and limitations to ensure widespread availability Cross reference to other seed projects but which may not have looked at tomato. Followed by activities to address the bottlenecks
3. A regional collaboration in breeding and or selection of nematode (and other disease) resistant crop varieties
4. Training of staff to achieve above
5. Address seed cost issues through farmers groups bulk buying and using group savings schemes
6. Biopesticide companies still faced with some costs to fine-tune the production processes
7. Farmers and organic farmers may have opportunities for bulk buying and forward ordering. This includes the issue of meeting demand from farmers' groups ie in Mwea who would all be needing product at planting time. Unless companies have prior knowledge supply would be difficult

19. What lessons have you learnt about the best ways to get the outputs used by the largest number of poor people? ***(max 300 words).***

The project had success with addressing institutional constraints ie legislation on pesticides. The newly drafted pesticide legislation in Kenya should be a model for other countries to adopt.

This has enabled biopesticides to become more generally available in Kenya and it is to be expected that commercial suppliers will become more active in the promotion of biopesticides. However, in this case the targets for promotion of these new technologies are likely to be the larger wealthier producers rather than the most poor. The non-commercial platform members such as NGOs and farmers groups will have the responsibility of demonstrating and promoting new technologies including biopesticides. Some of these organisations like KIOF that have large membership and new messages can be promoted efficiently.

There is potential to link these outputs to farmer field schools and other initiatives with farmers groups

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Impacts On Poverty

E. Impacts on poverty to date

20. Where have impact studies on poverty in relation to this output or cluster of outputs taken place? This should include any formal poverty impact studies (and it is appreciated that these will not be commonplace) and any less formal studies including any poverty mapping-type or monitoring work which allow for some analysis on impact on poverty to be made. Details of any cost-benefit analyses may also be detailed at this point. Please list studies here.

No independent impact studies have been done

21. Based on the evidence in the studies listed above, for each country detail how the poor have benefited from the application and/or adoption of the output(s) ***(max. 500 words):***

- *What positive impacts on livelihoods have been recorded and over what time period have these impacts been observed? These impacts should be recorded against the capital assets (human, social, natural, physical and, financial) of the livelihoods framework;*
- *For whom i.e. which type of person (gender, poverty group (see glossary for definitions) has there been a positive impact;*
- *Indicate the number of people who have realised a positive impact on their livelihood;*
- *Using whatever appropriate indicator was used detail what was the average percentage increase recorded*

Environmental Impact

H. Environmental impact

24. What are the direct and indirect environmental benefits related to the output(s) and their outcome(s)? ***(max 300 words)***

This could include direct benefits from the application of the technology or policy action with local governments or multinational agencies to create environmentally sound policies or programmes. Any supporting and appropriate evidence can be provided in the form of an annex.

The movement toward lower use of pesticides in the commercial vegetable and flower sector is undoubtedly driven by environmental concerns. In Kenya these benefits will be large as there is widespread concern about reported deteriorating conditions in the areas where there is intensive production (such as Naivasha).
There is also a human health factor in that there is less risk to workers (and consumers) when pest management is done biologically.
In the poorer smallholder sector where current pesticide use is small there may be little direct benefit from the introduction and adoption of biopesticides.

The successful application and uptake of the technology developed will increase crop yields and reduce dependence on nematicides used by growers that produce flowers and vegetables for export. Increased yields will enable growers to diversify their production and/or reduce the spread of horticulture into marginal land.

25. Are there any adverse environmental impacts related to the output(s) and their outcome(s)? ***(max 100 words)***

No. *Pochonia chlamydosporia* and *Pasteuria penetrans* occur in natural habitats and in agricultural soils at similar levels to those achieved through the application of these organisms as biocontrol agents. *Pochonia chlamydosporia* has been tested extensively to EPA standards for registration purposes and no environmental impacts have been detected

26. Do the outputs increase the capacity of poor people to cope with the effects of climate change, reduce the risks of natural disasters and increase their resilience? ***(max 200 words)***

Plant parasitic nematodes have major impacts on root architecture and the efficiency with which infested plants take up water and nutrients. Water use efficiency is a key issue in a changed climate and will greatly affect the resilience of crops to cope with biotic stresses such as nematodes. Most scenarios indicate that predicted changes in the climate of sub-saharan Africa will reduce plant tolerance to nematode attack and reduce food security, especially for the poor that have reduced access to control measures, fertilisers and water.
