Genetically-engineered resistance to potato nematodes

Validated RNRRS Output.

Potatoes that are genetically modified to resist nematodes are ready to use. Nematodes are parasites that cause huge crop losses—about US$125 billion a year—or enough to provide for 50 million people in Africa. Already accepted in Bolivia, Peru, India and China, nematode-resistant potatoes could boost potato harvests worldwide. People just need to be reassured that they are completely safe, both as food and for the environment. Breeding nematode resistance in potatoes by conventional methods takes ages—up to fifty years. Now, the gene technology makes it possible very quickly. So, the technology has a huge potential for crops that are important for reducing poverty but are neglected by profit-oriented plant breeders.

Project Ref: **PSP21:**
Topic: **1. Improving Farmers Livelihoods: Better Crops, Systems & Pest Management**
Lead Organisation: **University of Leeds, UK**
Source: **Plant Sciences Programme**

Document Contents:

Description, Validation, Current Situation, Current Promotion, Impacts On Poverty, Environmental Impact,

Research into Use
NR International
Park House
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ME20 6SN
UK

Geographical regions included:

Bolivia, China, India, Peru, Uganda,

Target Audiences for this content:

Crop farmers,

Description

PSP21

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.

#	Title of Dossier	Technology	ID Code	Lead person
21	Genetically engineered resistance to potato nematodes	Biosafety issues and policies relating to potatoes genetically modified to be resistant to nematodes	PSP0034	Prof H Atkinson

Working title

Resolving biosafety issues and defining policies underpinning donated plant biotechnology that benefits the poor using nematode resistance as an example

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

Plant Science Research Programme (ID code PSP0034).

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.

PSRP grants R6360, R7548 and R8031 plus EU INCO funding

Institutional partners on DFID PSRP grants
R8031
Prof. HJ Atkinson, Centre for Plant Sciences, University of Leeds. LEEDS LS2 9JT, tel 0113 3343 2900 e-mail h.j.atkinson@leeds.ac.uk
Dr Philippe Vain and **Prof. John Snape**, John Innes Centre, Colney Lane, Norwich. NR4 7UH, UK. Tel: +44 (0) 1603 450000 , Fax: +44 (0) 1603 450023, E-mail: philippe.vain@bbsrc.ac.uk & john.snape@bbsrc.ac.uk
Dr. Tushemereirwe, Kawanda Research Institute (KARI), NBRP/NARO, P.O. Box 7065, Kampala, Uganda
Current funding of the biotechnology but not its application to developing world includes BBSRC Agrifood committee AGXX/XXXX and Crop Science Initiative plus NERC Dorothy Hodgkin Studentship for crop environmental biosafety (Chinese national).

R7548
Dr Philippe Vain and **Prof. John Snape**, John Innes Centre, Colney Lane, Norwich. NR4 7UH, UK. Tel: +44 (0) 1603 450000 , Fax: +44 (0) 1603 450023, E-mail: philippe.vain@bbsrc.ac.uk & john.snape@bbsrc.ac.uk

R6830,
Prof. HJ Atkinson Centre for Plant Sciences, University of Leeds. LEEDS LS2 9JT, tel 0113 3343 2900 e-mail h.j.atkinson@leeds.ac.uk
Dr J. Franco, Fundacion para la Promocion e Inveatigacion de Producxtos Andinos
Av. Blanco Galindo Km 12.5,calle Prado w/n, Cochabmaba, Bolivia Tel 00-591-4-4360800 e-mail jfranco@proinpa.org

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.

Summary of issues
Development of polices and biosafe approaches for plant biotechnology for global, public goods that can benefit the poor. There is a needs to avoid all hazards and allay the apprehensions of some. This benefits need to be grounded in approaches for which clear demand and or need can be defined.

Grounding in RNRRS outputs
A suitable example trait is available from RNRRS Plant Sciences Research Programme. It controls nematodes in many crops. Potato is chosen as the initial example crop as that technology is ready for use. Nematode damage to crops is estimated to be $125 billion (US) each year. This represents sufficient calories lost in Africa to meet the annual need of 50 million people.

The project established that the approach is both effective and a biosafe (see references cited later).The protein is safe for human consumption but can be excluded from the crop yield. There are no identified risk to consumers or to non-target crop associates including soil organisms. The outputs of this project have a general value for developing world agriculture and has received considerable interest in many countries in Asia, Africa and S. America.

Biotechnology is required for several reasons:
Traditional breeding for nematode resistance is usually a long-term process lasting over 50 year to-date for potato in the UK. Slow progress resulted in CIP abandoning its nematode resistance programme.
A range of nematode can be controlled by the approach including *Meloidogyne* species (root-knot nematodes) which is the main nematode problem in Africa and S. Asia. Its control is a long established aim of DFID now achievable.

Example policy related issues that require development include:
i: Defining needs and benefits
Defining the direct and indirect benefits for a region/country and providing accurate information so national acceptance can be sought
ii: Apprehension
Provision of information that addresses all concerns and compares the approach with realistic alternatives
iii Environmental Safety
Initial focus at first on regions that are outside the centres of origin of the crop. It is important to ensure genetic isolation of the crop from other plants including cross-fertile relative species.
iv: Food safety
Assurance of food safety in relation to both margin of exposure for nutritionally stressed poor people and substantial equivalence. It will also consider elimination of antibiotics selectable markers (clean gene technology).

v: Underpinning national efforts
Appropriate policy development for three categories of countries ie a) enacted and deployed transgenic plants b) enacted by no history of deployment and c) no biosafety regulations. Product labelling and illiteracy
vi: Training needs
Biosafety training to cover current gaps in such provision at national and regional levels and todsicsse benfits as well as concerns.

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			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

The main commodity in which the approaches have been developed is potato plus some work on both rice and banana. The technology is applicable to all crops for which transformation has been achieved and for which nematodes cause considerable losses. It has particular potential for orphan crops that are unlikely to receive much attention from company-based plant breeders and biotechnologists. This is a particular issue for Africa and India were certain crops important for food security are not the focus for crop improvement by well resourced traditional or biotechnology based plant breeders.

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			

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			

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.

There have been a number of potato related RNNRSS projects. One groups emphases sustainable potato seed tuber management (R8435, R8104 and R7856). One aspect of biosafe deployment of biotechnology is assuring that growers are supplied with high quality seed able to take advantage of the new traits. It is also necessary to ensure that growers obtain the requested beneficial trait. A formal or semi-formal potato planting material distribution is beneficial. In addition in R 6830, we developed distinctive phenotypic markers (leaf shape or less favoured flower colour) to ensure illiterate growers can confirm they have the new cultivar (Green J., Atkinson H.J. et al. (2005) *Molecular Breeding* 16: 285-293). This will also allow social scientists to monitor uptake and secondary distribution through informal systems.

The approach developed in R6380 R7548 and R8031 has high potential to control *Meloidogyne* on potato and importantly, many other crops. There is advantage in deploying the approach within an IPM approach. We have shown that the technology we have developed is compatible with biocontrol. Therefore it could be integrated with *Meloidogyne* control (R8296) plus control of insect pests.

Much of the initial work on potato (R6380) was carried out in interaction with Dr J. Franco (PROINPA, Bolivia) and other work-funded was EU involved CIP. There is therefore the opportunity to link to outputs of R8443, R8044 (PROINPA) and R8485, R8182 (CIP) to ensure polices and practises associated with biosafety are compatible with all other advances. Nematode control in banana and rice (R6453 R6948 R7294 R8031) and banana (R6743 and R3081) would provide a basis for broadening the policy development issues to other crops of particular importance in S. Asia and Africa.

The work explored for rice the use of clean gene technology to remove selectable markers such as those based on antibiotic resitstance from the plants prior to their trials or deployment.

Validation

B. VALIDATION OF THE RESEARCH OUTPUT(S)

10. How were the output(s) validated and who validated them? *(max. 500 words)*.
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

Methods of Evaluation
The biosafety and efficacy of the approach were examined thoroughly and much of this work has been published in peer review journals including *Nature* and leading international journals for particular research fields. They include field trials in the UK and further work of this type is envisaged with further funding from BBSRC Agrifood committee plus its Crop Science initiative. This underpins research into use opportunities.

Who was involved?
Scientific evaluation: This varied to involve the most appropriate scientists to help validate the issue being studied. They included International scientists from PROINPA, CIP, Wageningen University, Lancaster U. and CSL plus a leading toxicology company (BIBRA). A list of main publications is given below.

Involvement of NARS: The next stage in evaluating the benefits beyond scientific publications involved NARS. Potato plants were provided to Chinese Academy of Agricultural Sciences, Institute of Vegetables and Flowers, Beijing for containment trial evaluation. It was also planned to trial potato in Argentina and also National Agricultural Research India. Ending of RNRRS curtailed these developments but a relationship with India is still being developed (see later). Biosafety issues have been developed further in Uganda using funding from Rothamsted Intentional Africa fellowship awards and from USAID PSP funding for training of a Ugandan scientists in food safety methodology here. Banana plants have been offered for trial in Uganda. Our constructs have also been donated and used in further transformation in Uganda. This is producing “home grown technology” which Uganda prefers. Consequently, trials may concentrate on these plants.

Evidence of demand:
Groups in target countries with interest in uptake within RiUP: A number of NARS and others active in target countries have expressed interest in involvement in reducing this research to use. They include NARO and IITA Uganda, Agbio, Zimbabwe, NARI, India and CAAS, China. There would also be high interest in PROINPA, Bolivia. Wider interest could be identified but it is inappropriate to do this until there is a real prospect of further funding for work of this type.
Demand for the approach:
The views of villagers were obtained via meeting and farmers Schools in Bolivia. They revealed that plant breeding provides them with real benefits. They welcome the new power of biotechnology and would like to judge the benefits. This pro-science and practical approach is likely to prevail among many developing world growers.
Publications organised by aspect of the technology
A, Gene flow in the environment, **B**, biosafety for non-target organisms, **C**, food safety and restricting unwanted plant expression, **D**, Efficacy of the approach, **E**, policy development.

A: Celis C., Atkinson H.J. *et al.* (2004) *Nature* 432, 222-225
A: Green J., Atkinson H.J. et al. (2005) *Molecular Breeding* 16: 285-293.
B: Cowgill, S. E. and Atkinson, H. J. (2003) *Transgenic Research* 12, 439-449.
B: Cowgill, Atkinson H.J. *et al.* (2002) *Journal of Applied Ecology* 39, 915-923.
B: Cowgill, S. E., Atkinson H.J. *et al.*. (2004) *Molecular Ecology* 13, 639-647.
B: Cowgill, Atkinson H.J. *et al.* (2002) *Molecular Ecology* 11, 821-827.
C: Atkinson H.J. *et al.* (2004). *Journal of Nutrition* 134, 431-434.
C: Lilley, C. J., Atkinson H.J. *et al.*. (2004). *Plant Biotechnology Journal* 2, 3-12.
D: Urwin, P. E., Atkinson H.J. *et al.* (2003). *Molecular Breeding* 12, 263-269.
D: Urwin, P. E., Atkinson H.J. *et al.* (2001). *Molecular Breeding* 8, 95-101.
E: Atkinson H.J. *et al.* 2005) *Aspects of Applied Biology* 75: 109-114.
E: Atkinson H.J. *et al.* (2001). *Trends in Biotechnology* 19, 91-96.

11. Where and when have the output(s) been validated? (max 300 words) *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.*

The biosafety issues have been validated for Bolivia (PROINPA), Peru (CIP) and are being extended to India (NARI), and China (CAS, CAAS). Progress in some of the countries has been halted by funding constraints. The approaches have been adapted to East African Highland Banana with USAID funding. The Ugandan National Biosafety Committee has moved forward rapidly partly due to the quantity of information supplied by an international team. It has granted containment field trial for banana biotechnology in less than 12 months. Crucial to this has been the lead taken by local scientists delivering comprehensive biosafety data collected by them and the international team. Dr Coyne (IITA Uganda) has expressed an interest in carrying out the necessary research into use for potato in Uganda and elsewhere in East Africa.

Current funding for collaboration in India (see response 16b for further details) and a developing relationship with The Indian biotechnology ministry may prove valuable. A visit is planned to India (23-30/10/06) part of which will explore the trial and deployment of the potatoes in India. India has a strong science base and a commitment to exploring biotechnology to enhance its future food security. It provides a source of information, which other developing countries trust. Following initial encouragement from Dr Rao from that Ministry in a brief visit to Leeds, this visit will also investigate the potential of collaboration with the Indian Biotechnology Ministry to ensure safe uptake of nematode resistant crops and other beneficial traits into Indian subsistence agriculture.

Current Situation

C. CURRENT SITUATION

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

Plant biotechnology is being widely used for insect control on cotton in India and China. The aim of the work in this proforma would be to underpin safe transition of other global and regional public goods already available in international research Institutes. This raises a number of issues not addressed by use of *cry* genes from *Bacillus thuringiensis* (Bt) to control insects. Such work is often distrusted because of the involvement of biotechnology companies in promoting the approach. There is also a narrowness of scope. For instance USAID BBI programme is not mandated to look beyond the macrofauna which there has been concern in relation to non-target Lepidoptera and Bt. Their mandate does not allow them to examine soil quality issues (H Quemada, manager BBI, personal communication).

UK is will placed to make this important contribution to public global goods rather than the biotechnology company influenced approaches of USA. The opportunity is to ensure a whole trench of benefits not achievable by other means can be adopted safety. Examples beyond insect and nematode control, involve other fungal diseases and tolerances to both drought and acid soils. The enormity of the potential gains justifies investment in ensuing a biosafe basis for uptake.

India has realised that biotechnology has an important role in its future food security. African countries (e.g. Uganda) are already actively pursuing the lessons learnt there. The UK can use its research and policy development strength to support these efforts and ensure the global public goods are biosafe. India could proof crucial to such effort. The UK's influence is at risk of being marginalized if it does contribute to the momentum now in India and China for plant biotechnology if that does lead to widespread uptakeof new traits.

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

The answer to this question repeats that to question 11 in that validation has occurred but uptake at the level of the individual farmers awaits the biosafety issue and polices envisaged in this profoma.

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

The ending of RNRRS has halted the process. Some biosafety activities have continued and plants have been provided to NARS (China for potato, Uganda for banana) with other requests (e.g. from Uganda, Zimbabwe, India, Argentina and Brazil) frozen without the funds to generate the initial planting material and other supporting resources and biosafety material. A key need is to set up research into use via formal seed systems.

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).

Key factors

a. a clear need has been identified. Demand exists but is limited in some area e.g. Africa by a lack of thought definition of the intensity of nematode induced loses on many subsistence crops (D. Coyne, IITA pers communication).
b. the biotechnology to be deployed should be shown to be fit for purpose and fully biosafe when expressed in potato or other target crop
c. benefits and future potential the technology should be clearly detailed to various stakeholders before uptake is progressed.
d. benefits must meet the needs of the resource poor with minimised negative impact on others. This requires careful and thorough analysis of the benefits as well as the apprehensions surrounding deployment of biotechnology.
e. a government that has a pro-biotechnology attitude is essential and a concern to facilitate substantial rather than incremental approaches to enhancing food production (e.g. India, Uganda, China)
f. a segment of the media willing to promote benefits when real as well as concerns amongst the opinion makers in the society.
g. a national biosafety committee/system seeking to be progressive while offering rigorous scrutiny of all relevant biosafety issues
h. a NARS willing to take on the translation research and having the appropriate resources and knowledge to assess benefits and identify substantial hazards not revealed by work elsewhere
i. an extension service/farmer school system able to explain the potential of biotechnology in fair balance with the concerns of some that surround its uptake.
j. a formal seed system able to multiply and deliver high quality planting material (e.g. potato).
k. social scientists willing to support the process, assess uptake and determine safe dispersal to the informal seed system so extending to the poorer sections of the grower community
l. lead growers eager to support scientific improvements whose successes favour diffusion to further growers.
m. Promotion of public goods within the country with its scientists leading the initiative ("home grown technology for home use") independent of overseas commercial interests.

Current Promotion

D. CURRENT PROMOTION/UPTAKE PATHWAYS

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

a. ***Uganda***. This country has an active and progressive national biosafety committee. It has recently agreed to a contained field trial of banana with transgenic traits being lead by NARO within a USAID biotechnology programme. Outputs from RNRRS are likely to feature in these field trials.
b. ***India:*** This country has become very committed to developing biotechnological products. Because of outputs from R8031, a relationship has developed with NARI, Delhi with two small grants from 1) The Indian Government 2) UK High Commission/ Government. Both provide training in Plant Biotechnology in relation to nematode control. The latter is from 3 years from October 2006. A planned visit for October will involve discussions with the Biotechnology Ministry of India to define biosafety needs for uptake by subsistence growers. Funding by DFID in this area would be timely.
c. ***China:*** A relationship has been forged with both The Chinese Academy of Science and Chinese Academy of Agricultural Sciences initially with funding provided by RNRRS. The first emphasis is on nematode resistant soybean and the latter on nematode resistant potato and vegetables. Progress has faltered with the end of funding until donors for biosafety work are identified. USAID is

interested only in macrofauna in relations to biosafety. Effort continues with a Chinese national holding a NSERC Dorothy Hodgkin's PhD training award.

17. What are the current barriers preventing or slowing the adoption of the output(s)? (max 200 words)

Cover here institutional issues, those relating to policy, marketing, infrastructure, social exclusion etc..

a. A demonstration is needed in different agro-ecological situations that the plants do prevent nematode losses and enhance yields when in the hands of the resource poor grower.

b. A range of biosafety issues must be addressed to lower apprehension over uptake. Resources are required to ensure benefits can be obtained safely.

c. The necessary emphasis on the biosafety of biotechnology is not being balanced with emphasis on the benefits that it can provide in much of Africa

d. The initial need is to concentrate on countries with fully enacted and functional biosafety regulations. They should be supported with all scientific resources required for translational research. They also require all biosafety issues appropriate for that country and region to be addressed. The demonstration of benefits without risk will ensure dissemination later from counties like Uganda and India to others in the region.

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).*

a. Demonstration that the approach has benefits in target countries using current local agricultural practises. This will provide the impetus to ensure all biosafety issues are addressed.
b. Establishment of partnerships with those willing to progress nematode resistant into other subsistence crops.
c. Complete resolution of outstanding issues relating to biosafety of the nematode traits so establishing a template for other traits to follow.
d. A full biosafety dossier addressing all hazards so that national biosafety committee can make informed consent and progress where this is a national priority.
e. Demonstration of successful uptake to encourage countries with less progressive biosafety policies. The aim is for them to progress and advance to capture full advantages from the opportunities.

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).

a. Demonstration of efficacy of the trait under the farming conditions of the poor
b. Biosafety legislation enacted and committed at the national levels to evaluate new opportunities rapidly
c. Scientists in NARS committed to the opportunity and well resourced to complete the translational research and so develop "home grown" technology
d. Effective farmers' schools or other approaches to engage with growers on the benefits and to allay apprehensions etc.
e. Local ownership of the biotechnology so the "home grown" approach can be developed
f. A positive environment for biotechnology from a range of stakeholders including politicians and media

87 words

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.

A main aspect of this proforma deals with establishing a biosafety and policy environment to widen the range of approaches taken up beyond the current range.

There have been both general considerations. Examples include:
Cohen JI (2005) Poorer nations turn to publicly developed GM crops, *Nature Biotechnology*, 23, 27-33.
De Groote H., Mugi, S., Bergvinson, D and Odhiambo, B (2004) Debunking the myths of GM crops for Africa: The case of Bt maize in Kenya.
http://www.biw.kuleuven.be/aee/clo/euwab_files/degroote2004.pdf
Thirtle, C, Beyers, L., Ismael, Y Piesse, J (2003) Can GM-Technologies Help the Poor? The Impact of Bt Cotton in Makhathini Flats, KwaZulu-Natal *World Development*, 31, 717–732
Lipton M. (2001), Reviving Global poverty reduction, what role for genetically modified plants, *Journal of International Development,* 13, 823-846.

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*

Benefits from nematode resistant potato

a. Increases in yield can exceed 50% for individual growers and are likely to be a miniimum of 12% for potato growing areas of the developing world.
b. Were potato is the main subsistence crop, it is possible to reduce the share of holding down to the crop annually. This provides opportunity to enhance nutrition with a fuller range of crops and to market surplus produce. This is well established for Bolivia (see Atkinson *et al*., 2001, reference above).
c. Reduction in use of hazardous of pesticides for nematode control in peri-urban situations. Extreme examples occur in South America (e.g. Ecuador and around Lima).
d. Beneficial trait around which to promote improved tuber distribution or true potato seed where ware tuber storage is a limiting factor.
e. Reduction of follow-on damage by *Meloidogyne* of other crops grown in close rotation with potato
f. Reduced risk of wilderness loss to slash and burn agriculture or important habitats e.g. rare indigenous forest in the Chapare area of Bolivia (see Atkinson *et al*., 2001, reference above)
g. Increase growth in potato production where that crop can out perform currently used stable

crops.

Benefits from nematode resistant crops

a. The above benefits can be multiplued many fold if the technology can be used in other crops soon.
b. The impact of *Meloidogyne* control in Africa and S. Asia would be considerable.
c. The rate that these benefits being achieved depends on the investment levels to distribute constructs and resources to a range of NARS etc.
d. It could also be dependent on an appropriate biosafe environment (see below).

Benefits from resolution of biosafety issues and policy development

a. Enhancement of the rate of adoption in countries such as India, China and Uganda willing deploy plants depends.
b. A resource for use by other countries following the example of the biotechnology pioneering countries above.
c. Allaying all scientifically based concerns about the approach will create an environment in which rapid uptake is favoured
d. Establishing a base for national scientists to adopt the technology underpinned by all necessary information and resources promote to "home grown for home use" deployment of public global goods such as nematode resistance.
e. Establishing favourable biosafety environment for policy development will enable uptake of further traits for food security (e.g. drought and acid soil tolerances, disease resistance, biofortified crops) that cannot be delivered in other ways to meet the longer-term global challenge of food security for all.

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.

a. There is a clear risk of loss of wilderness to agriculture through slash and burn approaches with nematodes being a known cause of crop failure supporting this erosion of biodiversity. The case has been made that intensive agriculture with land sparring is a better option for much wildlife than extensive production, as much of biodiversity cannot survive in a farmed landscape.
b. Some growers deploy nematicides in periurban situations. These pesticides are all WHO class 1a or 1b compounds. They all pose severe risks to agricultural workers. If misused, carbamates and organophosphate nematicides can be a health risk to the consumer.
c. All nematodes pose risk to the environment but the risk varies with the chemical compound. Many contaminate waterways, harm aquatic systems including, in extreme cases, inshore marine environments (e.g. coral reefs).
d. The risk from use nematicide is currently not substantial among the very poor as the cost of the compounds is usually beyond their means. The scale of nematode losses is often not fully appreciated. Studies establish that as development occurs, growers gain the resources to turn to pesticides to raise their yields further. International society need to provide them with alternatives to avoid this or severe outcomes may arise. These are already evident in some countries e.g. potato and banana cropping in Ecuador.
e. The environmental benefits from adoption of Bt cotton in China have been defined. The incidence of toxic episodes for agricultural workers from pesticides fell from 22% for those using conventional cultivars to just 4.7% of those cropping with Bt –expressing cultivars that required less frequent pesticide use (Huang, J. *et al.,* (2002) *Science*, 295, 674-677). The benefits from reduced use of other crop protection chemicals should be sought.

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

A primary aim for the proposed development of biosafe biotechnology and policies for their adoption is to ensure that there are no harmful impacts. An *apriori* case has made that is the case in our outputs from the RNRRS programme (see earlier).

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)

The outputs will enhance the ability of poor people to cope with droughts associated with climate change. The principal, direct consequence of nematode damage is to stunt root systems. This ensures plants are less able to obtain water and nutrients from soil. Common symptoms of attack are wilting and mineral deficiencies. This issue is very apparent for potato. It requires water to bulk its tubers. The effect is evident for other crops to which the plant technology could be applied later once biosafety is assured

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