ACP Science
and Technology II Programme

OPTIONs — Optimisation of pesticidal-plants: technology innovation, outreach & networks

Lead farmers show other farmers how to propagate pesticidal plants in homemade screen house, Moshi, Tanzania (October 2016).

SUMMARY OF RESULTS

Scientific, technological and application capacity of agricultural stakeholders to exploit pesticidal plants and optimise their use for smallholders was strengthened. Protocols and methodologies were designed and used for testing plants against target pest organisms in laboratory and field trials and for the propagation of eight key pesticidal plant species to guarantee supply. Thousands of trees and pesticidal shrubs have been planted in communities in Kenya and Tanzania. In Eastern and Southern Africa, existing partnerships with various stakeholders were consolidated, and commercial ventures established on small and large scale. Commercial opportunities for pesticidal plants, particularly Pyrethrum, have been established with major producers and policy makers in Kenya, and are being further developed in light of their environmental and economic benefits.

BACKGROUND

The expected world population of 9 billion by 2050 and associated food demands places increasing pressure on global food production. Demand for land area to produce adequate food sustainably while reducing inputs is high and pest damage to crops is a major challenge to food and nutritional security and disproportionately affects poor farmers and low-input agriculture. Africa experiences this acutely due to 80% of food being produced by smallholders who farm marginal and degraded land areas of <2 ha, with little mechanisation or effective inputs (Sibhatu et al., 2015). Pest control is often overlooked because of the prohibitive financial outlay among many smallholders, but higher production rates are dependent on pest management. Current practices are reliant on agrochemical inputs, which have negative impacts on the health of both users and consumers, as well as on ecosystem services such as pollinators and natural pest regulation.

While food production and storage are limited by numerous constraints, insect pests are a manageable challenge for even the poorest of farmers who can exert control with low cost interventions. Furthermore, if left unmanaged, insects will invariably cause further, often severe damage. Pesticidal plants are a viable alternative approach to pest control and are widely used. However, greater knowledge is required about the optimisation of this organic intervention to enable farmers to benefit from their natural and more environmentally benign pest control properties.

The main problem addressed by the project was to maximise the opportunities for smallholders to use pesticidal plants to control pests in an economically viable, environmentally benign and effective way that improved crop production sustainably. The project also provided knowledge and tools to improve plant propagation permitting farmers to produce their own materials and potentially develop towards self-sufficiency and commercial production.

The main users of the outcomes were farmers, nursery growers, small enterprises commercialising indigenous plants for pest control, and government and non-government agricultural extension staff. Other beneficiaries included researchers from universities and the National Agricultural Research System (NARS) who learned new approaches to addressing scientific problems and conducting robust publishable scientific research.

PROJECT IMPLEMENTATION PERIOD
January 2014 - June 2017

CONSORTIUM
- Natural Resources Institute (NRI) - University of Greenwich, UK
- Royal Botanic Gardens, UK
- University of Zimbabwe, Zimbabwe
- Mzuzu University, Malawi
- Sokoine University of Agriculture, Tanzania
- World Agroforestry Centre (ICRAF), Kenya
- Sustainable Global Gardens, UK
- National Museums of Kenya, Kenya

Associated partners:
- Centre For International Forestry Research (CIFOR), Indonesia
- Ministry of Agriculture, Irrigation and Water Development, Malawi
- Egerton University, Kenya
- Community Initiatives For Rural Development, Kenya
- Community Sustainable Development Empowerment Programme (COSDEP), Kenya
- Kenya Organic Agriculture Network, Kenya
- Indigenous Knowledge Centre (IKC), Malawi
- Environment Africa, Zimbabwe
- Pyrethrum Growers Association, Kenya

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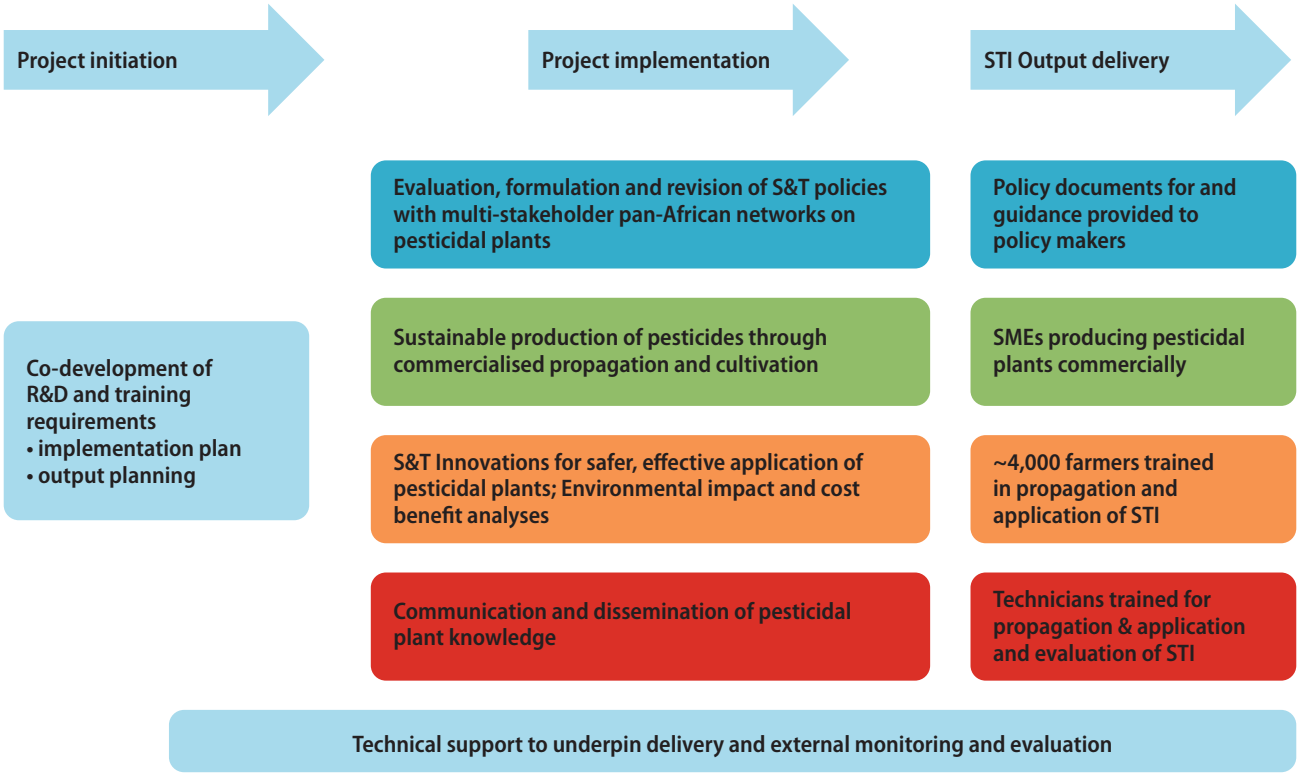
PROJECT WEBSITE
http://projects.nri.org/options

METHODOLOGY



Evaluation, formulation and revision of Science and Technology policies with multi-stakeholder pan-African networks on pesticidal plants.

Engagement with policy makers took place to draw on their support for existing and new initiatives and to promote the use of plants as environmentally benign pesticides. The policy environment and current status of the pesticidal plants sector were assessed for their suitablity for commerical production and documented in policy papers outlining opportunities and hurdles to up-scaling the use of pesticidal plant technologies for crop pests and livestock ectoparasites. Work has continued with policy makers at the highest level in East Africa, including the Governor of Nyandarua and Deputy Governor of Nakuru in Kenya, to support the revival of the botanicals sector.

Sustainable production of pesticides through commercialised propagation and cultivation.

>50 scientists / nursery growers per country - in three countries - were trained in propagation or innovative application protocols of at least four indigenous pesticidal trees and shrubs per country. A total of 10 local training workshops and one national training workshop per country were held. 40,000 trees were planted by 4,000 farmers located across three countries enabling a participatory approach to learning and upscaling. Harvesting protocols and optimised preparations for at least

Laboratory training for technicians and agricutural scientists working on pesticidal plants in Nairobi, Kenya, June 2015.

eight pesticidal plant species were developed through chemical and biological studies. Project partners and trainees were informed about the UN's Convention on Biological Diversity and intellectual property issues relating to indigenous materials to ensure appropriate access and benefit sharing.

Science and Technology Innovations for safer and more effective application of pesticidal plants along with environmental impact and cost benefit analyses.

STIs were developed and promoted to farmers. Elite pesticidal plant materials were identified for 10 species through chemical analysis and biological study in laboratory and field trials. Application technologies for four plant species for control of cattle ticks on livestock were developed and promoted to farmers. Safe handling methodologies and improved application protocols were developed for use of pesticidal plants on stored food products and knowledge transferred to farmers. Parameter profiles for four pesticidal plant species were determined to understand climate sensitive variables.

Communication and dissemination platform for pesticidal plant knowledge.

The OPTIONS network was established for communication among partners and to the wider community of stakehlders through stakeholder appropriate outputs, a website and public speaking and training events. Scientific research papers describing results and outcomes were published in high impact international refereed journals. An international conference was hosted to consolidate the African pesticidal plants network and provide a dissemination platform for new knowledge to the wider stakeholder community.

Using pesticidal plants means farmers need not invest in costly and environmentally harmful synthetic pesticides. Cost-benefit analyses proved their economic value even when harvesting and preparation time was factored in. This economic assessment was published in two peer reviewed scientific papers (Blankson et al., 2014 Crop Protection and Mkenda et al., 2015 *PLoS One*).

RESULTS

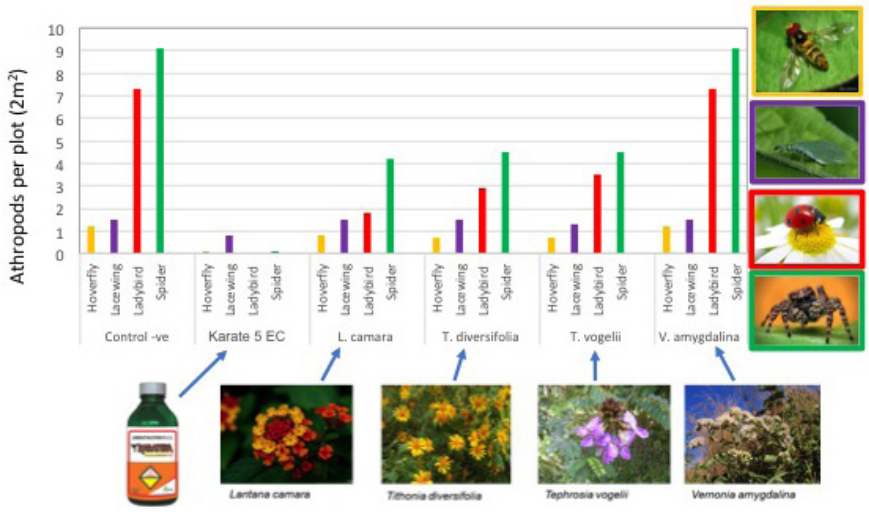
Outputs

Capacity building

- >20 local training workshops in Kenya, Tanzania, Malawi and Zimbabwe.
- Hundreds of farmers trained in optimised use of pesticidal plants (~40% female, especially for legume cropping systems).
- >90 scientists and nursery growers (~30% female) trained on the propagation of 4 indigenous species; additional training and knowledge transfer about other effective species including Tephrosia.
- >90 graduate students and scientists trained in scientific techniques about validation of biological activity and in the propagation and use of pesticidal plants.

Plant material

- Elite pesticidal plant materials identified for 10 species.
- Application technologies for 4 plant species for control of cattle ticks on livestock.



Pesticidal plants had lower negative effects on beneficial insects in field trials providing farmers a pest control option that works with the ecosystem rather than against it (Data published in Mkenda et al., PLoS One, 2015).

Technologies

- Simple methods to maximise the efficacy of pesticidal plants using, e.g., liquid soaps to maximise extraction efficiency and novel approaches to propagate the plant species most at risk of overuse such as Securidaca and Bobgunnia (important and indigenous tree species).

Training material

- Handbook on 'Pesticidal Plants' (English and French).
- Leaflet on the propagation of Securidaca longepedunculata.
- Proceedings of a training workshop on Optimisation of Pesticidal plants: Technology Innovation, Outreach & Networks (OPTIONs).
- 12 pesticidal plant information sheets (in English, French and Kiswahili): *Aloe ferox, Chenopodium* (syn. Dysphania) *ambrosioides, Euphorbia tirucalli, Lippia javanica, Securidaca longepedunculata, Solanum incanum, Strychnos spinosa, Tagetes minuta, Tephrosia vogelii, Tithonia diversifolia, Vernonia amygdalina,* and *Zanthoxylum holtzianum.*
- Guidelines for the 'Sustainable harvesting of traditional medicinal plants'.

Facilities

- Analytical chemical facility established at Mzuzu University to provide technical support for further research in pesticidal plants.

Policy papers

- 3 policy papers published as reports in an internationally reviewed journal (Food Security) and a widely read magazine.

Visibility

- Project website.
- International conference held with 80 abstracts / presentations and >120 scientists participating.
- >5 public media narratives including TV and radio.
- Leaflets.

Publications

- Stevenson P.C. *et al.*, 2016. Pesticidal plants in African agriculture: Local uses and global perspectives. Outlooks on Pest Management. 27(5): 226-230.
- Arnold S.E.J. et al., 2016. Shades of yellow: interactive effects of visual and odour cues in a pest beetle. PeerJ. 4:e2219.
- Stevenson P.C. *et al.*, 2016. Nor-Hopanes explain pest control activity of Zanha africana root bark. Phytochemistry, 123, 25-32.
- Nyahangare E.T. *et al.*, 2016. Acute oral mammalian toxicity and effect of solvents on efficacy of *Maerua edulis* (Gilg. & Ben.) De Wolf against Rhipicephalus (Boophilus) decoloratus Koch, 1844 (Acarina: Ixodidae), Tick Larvae. BioMed Research International. 8.
- Mkenda P. *et al.*, 2015. Extracts from field margin weeds provide economically viable and environmentally benign pest control compared to synthetic pesticides. Plos ONE. 10(11), e0143530.
- Arnold S.E.J. *et al.*, 2015. Responses to colour and host odour cues in three cereal pest species, in the context of ecology and control. Bulletin of Entomological Research, 1–9.
- Mkenda P.A. *et al.*, 2015. Contact and fumigant toxicity of five pesticidal plants against *Callosobruchus maculatus* (Coleoptera: Chrysomelidae) in stored cowpea (Vigna unguiculata). International Journal of Tropical Insect Science. 35(4): 172-184.
- Sola P. *et al.*, 2014. Botanical pesticide production, trade and regulatory mechanisms in sub-Saharan Africa: making a case for plant-based pesticidal products. Food Security. 6(3): 369-384.
- Tembo Y. *et al.*, 2018. Pesticidal plant extracts improve yield and reduce insect pests on legume crops without harming beneficial arthropods. Frontiers in Plant Science, 10, 01425.
- Stevenson P.C. et al., 2014. Pesticidal plants for stored product pests on small-holder farms in Africa. In: Advances in Plant Biopesticides (ed. Dwijendra Singh), Springer India, pp. 149-172.
- Grzywacz D. *et al.*, 2014. The use of indigenous ecological resources for pest control in Africa. Food Security, 6 (1). pp. 71-86.
- Amoabeng B.W. *et al.*, 2014. Cost-benefit analysis of botanical insecticide use in cabbage: implications for smallholder farmers in developing countries. Crop Protection. 57, 71-76.
- Anjarwalla P. *et al.*, 2016. Handbook on Pesticidal Plants. World Agroforestry Centre (ICRAF), Nairobi, Kenya.
- Anjarwalla P. *et al.*, 2013. Proceedings of a training workshop on sustainable production, harvesting and conservation of botanical pesticides. World Agroforestry Centre (ICRAF), Nairobi, Kenya. 61pp.

RESULTS

Outcomes

- New knowledge on harvesting and usage of pesticidal plants to control pests and improve yields
- Awareness of pesticidal plants as economic and environmentally benign alternatives to synthetic pesticides for use in field and storage.
- Small and medium sized enterprises engaged to commercialise pesticidal plant products.
- Pesticidal plants had lower negative impacts on beneficial insects in the fields such as pollinators and natural predaotors.
- Farmers in West Kenya stimulated to propagate and sell their own pesticidal plants.
- Policy makers in Zimbabwe, Malawi and Kenya aware of scope for more effective and sustainable pest management in field crops and stored products using plant-based pesticides.
- Capacity of scientists enhanced to conduct research more effectively using robust methodologies and statistical analysis to ensure scientifically sound evidence.

Impacts

Usage

- c.4,000 farmers in Kenya, Tanzania, Malawi and Zimbabwe are propagating trees, and >40,000 trees have been planted.
- A manufacturer in Kenya is setting up commercial production of pesticidal plants, specifically Pyrethrum, for export to reinvigorate this Kenyan manufacturing sector. Further support is being sought, for instance with direct contacts with County Governors, and predictions indicate that the African botanical insecticides sector will redevelop into a major industry on both domestic and international markets.
- Farmers generating new income streams by growing and selling pesticidal plants in local fora and for local uses will develop the outreach and uptake of these plants through a desire to increase their own wealth; and the benefits of these technologies will underpin commercial success and further adoption.

Policy implications

- It was determined that the use of pesticidal plants by smallholder farmers also supported agro-ecological intensification. These studies provide strong evidence to inform policy that pesticidal plants are a sustainable alternative to synthetic pesticides.
- Policy environment has been informed through policy assessments and policy papers, and policy briefs were published and distributed widely. Policy documents published in the scientific literature have been cited frequently by other scientists.

Sustainability

- Through the McKnight Foundation network that supports a variety of research activities on legume production systems in Southern and Eastern Africa, our botanicals research has supplemented R&D projects because they suffered from pest issues and have since used pesticidal plants to resolve the problem effectively and thus promoted a wider uptake in their use.
- Further research funding was obtained through: the McKnight Foundation Farmer Research Network to evaluate sustainable agro-ecological crop protection using pesticidal plants; and the Darwin Initiative to look at wider benefits of pesticidal plants in supporting beneficial insects in natural landscapes adjacent to farm land.
- Contributions were made to a new project funded through the UK's Global Challenges Research Fund to understand how field margin diversity supports both beneficial insects and botanical insecticides and underpins recovery of beneficial populations.
- The regional research capacity through the analytical chemistry facility in Mzuzu University and expertise in conducting field and laboratory studies on the bioactivity of plant materials will be further exploited.

TESTIMONIALS

Emmanuel T. Nyahangare, University of Zimbabwe, Zimbabwe

"The project provided an excellent opportunity to grow both as a researcher and PhD scholar. This has helped me carve a small niche in the research and development of acaricidal plants that can be used against ticks in developing countries like Zimbabwe. I enjoyed setting up both in vitro and in vivo efficacy experiments while the network of other senior scientists working around the same area gave invaluable advice on the development of protocols and other soft and hard skills. I now have internationally peer-reviewed publications and presented the project work at various conferences."

Dr. John F. Kamanula, Mzuzu University, Malawi

"The project has made a significant contribution to our Department of Chemistry, through capacity building in analytical and natural products chemistry, bioassays, proposal and manuscript writing, but also with a high performance liquid chromatograph (HPLC) for the characterisation of bioactive compounds in pesticidal plants. The equipment is still being widely used for teaching and research. Furthermore, smallholder farmers who use pesticidal plants in northern Malawi benefitted from the project through training in processing, application and sustainable harvesting of pesticidal plants."

ACP-EU Co-Operation Programmes in the fields of Higher Education and Science, Technology and Research

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