Institution: University of Greenwich

Unit of Assessment: (UoA 6) – Agriculture, Veterinary and Food Science

Title of case study: Better pest control in Africa and Asia through biological pesticides and insect resistant crops

1. Summary of the impact

Research and knowledge dissemination led by Greenwich on biological pesticides has made a major contribution to the introduction of novel safe commercial pesticides based on insect viruses to help farmers overcome the problems of chemical resistance in major crop pests in Asia and Africa. Research at Greenwich identified effective virus strains, methods of production and formulation which were then developed and evaluated with in country research collaborators before being transferred to local SMEs to start up production in India, Thailand, Kenya and Tanzania. Greenwich advised governments on adopting suitable regulation to support the registration and sale of these novel pesticides.

2. Underpinning research

Insecticide-resistant crop pest species such as diamondback moth (*Plutella xylostella*), cotton bollworm (*Helicoverpa armigera*) and armyworms (*Spodoptera* species) each cost an estimated billion or more dollars annually in damage to crops and control measures. They are especially difficult to control in tropical Asia and Africa where pesticide resistance is most widespread. From subsistence farmers and their governments who cannot afford chemical insecticides, to the exporters of horticultural crops who must meet demanding EU pesticide residue standards banning many chemicals, populations in developing countries need alternative control methods.

Research from 1994-2004 on baculoviruses pathogenic to these pests, led by David Grzywacz, Principal Scientist at Greenwich, has generated key knowledge that has underpinned the development of new commercial insecticides. A research programme has collected, genetically characterised and evaluated the baculoviruses of *Spodoptera exigua, S. littoralis, S. litura, S. exempta, H. armigera* and *P. xylostella* through a long term programme of collaborative research with India, Thailand, Nepal, Kenya, Tanzania, Benin and Ghana. The research (1994-2004) developed efficient production and quality control systems suitable for production in developing countries, as well as studying efficacy and persistence of different formulations on target crops [3.1-3.3]. Fieldwork in India (1998-2004) also identified the issue of limited persistence of baculoviruses on some legume crops. This has been shown to be due to the plants' secretion of isoflavenoid phytochemicals that directly inactivates the insect baculoviruses [3.4]: the first published record of such a host-pathogen interaction.

Grzywacz was invited to join a private-public research partnership, the Collaboration on Insect Management for Brassicas for Africa and Asia (CIMBAA) [3.5] because of his research on diamondback moth. This €10 million collaboration between the universities of Greenwich, Cornell and Melbourne, and Bayer Crop Science, successfully developed GM insect-resistant brassicas, based on two previously unused Bt genes, CryICa4 and Cry1Ba2, as a more sustainable brassica pest solution during 2004-10. The University of Greenwich, under Derek Russell, Principal Scientist (1994-2012) and Grzywacz, led the public sector partners in the project, and the field research that selected and demonstrated the efficacy of the new GM cabbage and cauliflower for controlling DBM and other major pests of cabbage and cauliflower in India [3.6]. In 2012 Russell left the University of Greenwich to lead a new Australian $2.9 million project to deploy this technology in Asia, Africa and Australasia.

The university led the research (1996-2005) on control of African armyworm which identified, developed and evaluated the armyworm nucleopolyhedrovirus as an effective control [3.2]. This involved laboratory research to identify best virus strain and formulation for control, followed by extensive field trials in different application systems in Tanzania from 1999 to 2005. A second research project, funded by BBSRC-DFID (BB/F004311/1, 2008-11) on the ecology of African armyworm nucleopolyhedrovirus, gave key insights into armyworm population ecology and enabled the completion of an armyworm database that has been transferred to pest forecasters in the government of Tanzania to assist in outbreak forecasting. It also enabled the development of the community-based armyworm forecasting system (CBAF) adopted in Tanzania and Kenya.

3. References to the research (REF1 submitted staff in **bold**, **REF2 Output)

3.1 Cherry, A. J., Rabindra, R. J., Parnell, M. A., Geetha, N., Kennedy, J. S., & **Grzywacz, D.** (2000). Field evaluation of *Helicoverpa armigera* nucleopolyhedrovirus formulations for control of the chickpea pod-borer, *H. armigera* (Hubn.), on chickpea (*Cicer arietinum* var. Shoba) in southern India. *Crop Protection*, *19*(1), 51–60. http://dx.doi.org/10.1016/S0261-2194(99)00089-7

3.2 **Grzywacz, D.**, Mushobozi, W. L., Parnell, M., Jolliffe, F., & Wilson, K. (2008). Evaluation of *Spodoptera exempta* nucleopolyhedrovirus (SpexNPV) for the field control of African armyworm (Spodoptera exempta) in Tanzania. *Crop Protection*, *27*(1), 17–24. http://dx.doi.org/10.1016/j.cropro.2007.04.005

3.3 Cherry, A. J., Parnell, M. A., **Grzywacz, D.**, & Jones, K. A. (1997). The Optimization of in Vivo Nuclear Polyhedrosis Virus Production in *Spodoptera exempta* (Walker) and *Spodoptera exigua* (Hübner). *Journal of Invertebrate Pathology*, *70*(1), 50–58. http://dx.doi.org/10.1006/jipa.1997.4664

3.4 **Stevenson, P. C., D'Cunha, R. F., & **Grzywacz, D.** (2010). Inactivation of Baculovirus by Isoflavonoids on Chickpea (*Cicer arietinum*) Leaf Surfaces Reduces the Efficacy of Nucleopolyhedrovirus Against *Helicoverpa armigera*. *Journal of chemical ecology*, *36*(2), 227–235. http://dx.doi.org/10.1007/s10886-010-9748-8

3.5 **Grzywacz, D.**, Rossbach, A., Rauf, A., Russell, D. A., Srinivasan, R., & Shelton, A. M. (2010). Current control methods for diamondback moth and other brassica insect pests and the prospects for improved management with lepidopteran-resistant Bt vegetable brassicas in Asia and Africa. *Crop Protection*, *29*(1), 68–79. http://dx.doi.org/10.1016/j.cropro.2009.08.009

3.6 Kaliaperumal R, R., Russell, D.A., Gujar, G.T., Behere, G., Dutt, S., Krishna, G.K., Mordhorst, A., **Grzywacz, D.** (2011). The efficacy and sustainability of the CIMBAA transgenic Cry1B/Cry1C Bt cabbage and cauliflower plants for control of Lepidopteran pests, in R. Srinivasan, A. M. Shelton, & H. L. Collins (Eds.), *Proceedings of the Sixth International Workshop on Management of the Diamondback Moth and Other Crucifer Insect Pests*, 21-25 March 2011, Kasetsart University, Nakhon Pathom, Thailand. AVRDC pp 305-311 – The World Vegetable Center, Publication No. 11:755.

Key grants:

3a D. Grzywacz. *Safe and Affordable Armyworm Control Tools (SAACO - Tools) for poor farmers in East Africa*. DFID – Research Into Use grant. 2010-2012. £297,000.

3b D. Grzywacz. *Registration and Distribution of Biological Control Agents in Ghana.* DFID – Research Into Use grant. 2010-2012. £25,000.

3c D. Grzywacz. *Understanding the mechanisms of persistence and dispersal of an insect pathogen and its potential for novel strategic control of African armyworms*. BBSRC-DFID SARID grant BB/F004311/1. 2008-2011. £615,519.

3d D. Russell & D. Grzywacz. *CIMBAA, The Public/Private Partnership, the Consortium for Insect Management in Brassicas in Asia and Africa.* DFID grant. 2009-2010. £286,000.

3e D. Russell & D. Grzywacz. *CIMBAA, Sustainability of Pyramided Bt Genes for Insect Control in Crop Plants department for innovation.* Australia government. 2008-2011. £67,000.

3f D. Russell & D. Grzywacz. *CIMBAA, Maximising pro-poor benefits from the public/private partnerships: insect resistant veg for Asia/Africa*. DFID grant. 2006-2009. £351,000.

3g D. Grzywacz. *Novel controls for armyworm in East Africa adopted, demonstrated and disseminated to national and regional organisations*. DFID, Crop Protection Programme. 2005-2006. £71,000.

3h D. Grzywacz. *Novel technologies for control of African Armyworm in East Africa.* DFID, Crop Protection Programme. 2001-2004. £262,000.

3i D. Grzywacz. *Biopesticides development in West Africa*. IITA Grant. 1999-2003 $US 193,000.

3j D. Grzywacz. *Development of biorational brassica IPM in Kenya*. DFID, Crop Protection Programme. 1999-2003. £330,000.

3k D. Grzywacz. *Entomopathogenic baculoviruses for control of the African armyworm in Tanzania.* DFID, Crop Protection Programme. 1996-2000. £151,000.

3l D. Grzywacz. *Investigation of biorational methods for control of insect pests of vegetables in Kenya*. DFID, Crop Protection Programme. 1996-2000. £232,000.

3m D. Grzywacz. *Development of Helicoverpa insect viruses in India.* DFID. 1993-1997. £292,000.

3n D. Grzywacz. *Identification, production and formulation of insect viruses for pest control*. DFID. 1992-1996. £208,000.

4. Details of the impact

Local crops are critical to feeding developing nations in Africa and Asia, and also to earning precious foreign currency from exports that can raise living standards. So when the larvae of pests such as diamondback moth, cotton bollworm or armyworm literally eat their way through acres of cereals and vegetables, it can devastate the livelihoods of many thousands of people. Each of these global pests has been estimated to cost a billion or more dollars annually. They have traditionally required expensive chemical pesticides which cause environmental damage, and to which they are increasingly resistant. The University of Greenwich has worked with governments and local people to develop effective new biological pesticides which can be produced cheaply and locally. It has guided strategies to overcome barriers like inadequate national pesticide registration policies and lack of pesticide production infrastructure. It has shared the knowledge on how to use and produce the pesticides through national and international training, and its control strategies are becoming the norm in many countries. The Tanzanian government based its armyworm control policy on the research, including new knowledge about armyworm ecology which has enabled forecasting of outbreaks. The university was also a partner in research that successfully developed genetically modified (GM) brassicas to resist diamondback moth and other pests in cabbage and cauliflower.

Impact has been achieved not only through new knowledge but also long term capacity building of research partners in developing countries, and new small and medium sized enterprises (SMEs) who produce the biopesticides. In India for instance, new viral insecticide production took off after Grzywacz and local collaborators led training programmes for 16 private and public sector institutions who went on to produce many of the estimated 45 baculovirus insecticides registered in India since 2008 [5.1].

Research on developing better quality production of viruses in India led to international guidelines for baculovirus quality and a training manual in the techniques of baculovirus production and quality control. The results on new virus production and formulation techniques were disseminated actively through training courses for research institutes and new SMEs in UK, India, Nepal, Kenya, Tanzania, Benin, Ghana and Bolivia; they have been disseminated world-wide since 2010 by the UN Food & Agricultural Organisation [5.2]. Private company Kenya Biologics was set up in 2009, following research into baculoviruses in Kenya, to produce two new biopesticides now undergoing registration. After training received in 2000-01, River Bioscience developed new baculovirus insecticides which have been on sale in South Africa since 2008 and are currently undergoing registration in other African countries.

Research with Thailand Department of Agriculture led to establishment of a biopesticide company in 2008 and local production of insecticides to control horticultural crop pests including *Helicoverpa armigera* and *S. exigua*. This company now produces four new baculovirus insecticides with a capacity to treat up to 30,000 ha of high value export crops. Farmers can control these pests without chemical residues, allowing them to export to EU, a market worth >$50 million a year.

The diamondback moth research under the CIMBAA project developed insect resistant brassicas for Africa and Asia. A new Australian Government-funded project (valued at $2.9 million) has now taken up the outputs of this research to deploy the technology in India, Africa and Australasia to control a pest estimated to cause losses of >$2 billion per annum [5.3].

The Tanzanian Ministry of Agriculture's current policy of promoting armyworm virus for African

armyworm control in place of chemical pesticide is based on the Tanzanian research [5.4]. The DFID Safe and Affordable Armyworm Control Tools project has part funded the building of a biopesticides plant by a Tanzanian company which became operational in April 2013 [5.5]. The project also established the village community-based forecasting system that has set up armyworm pheromone forecasting traps in 120 locations and is now operational in Kenya and Tanzania. It is estimated to benefit 80,000 farmers in Kenya and 25,000 in Tanzania [5.5, 5.6].

Few African countries had a pesticide registration system that recognised biopesticides before 2003. Grzywacz helped the Kenyan authorities develop a new system, adopted as law in 2008; since then over 35 biopesticide products have been registered. Kenya's horticultural industry has benefitted from new biopesticide products which ensure its exports to EU continue to meet strict pesticide residue standards. An estimated two million Kenyans are dependent upon this sector. Grzywacz also advised the Ghana Environmental Protection agency on a biopesticides registration system which was adopted; the first commercial BV biopesticide, produced in Kenya, was registered in Ghana in June 2012 with Grzywacz as technical advisor.

5. Sources to corroborate the impact

5.1 Impact of research on biopesticides availability in India:
http://www.dbtbiopesticides.nic.in/index.php.
Dean of Postgraduate Studies, Central Agricultural University, Umiam, Barapani Shillong, 793 103, Meghalaya, India
Vice President, Bio-Control Research Laboratories, Pest Control of India, Bangalore, India

5.2 University of Greenwich training material on Biopesticides production on FAO Technologies and Platforms for small Agricultural producers (TECA) http://www.fao.org/docs/eims/upload/agrotech/2011/HaNPVmanual-pt1.pdf

5.3 Research on development of Insect Resistant Brassicas:
Programme Manager CARiB, Dept of Agric. and Food Systems, Melbourne School of Land and Environment, Univ. of Melbourne Australia
http://www.innovation.gov.au/Science/InternationalCollaboration/aisrf/Documents/AISRFScienceAndTechnologyBiotechGCandTAOutcomes.pdf

5.4 Research on armyworm control with biological pesticide:
Director Sustainable Agriculture and Agribusiness Development, Eco Agri consultancy Services LTD, P.O. Box 15040, Arusha, Tanzania,
http://researchintouse.com/bestbets/bb35armyworm.html

5.5 Research training and consultancy to assist biopesticide producers in Africa:

- Deputy Director, DFID Research into Results Programme, Edinburgh University.
- Portfolio Manager, Integrated Pest Management, Citrus Research International, South Africa.

5.6 Clark, N., Frost, A., Maudlin, I and Ward A. (2013) Biotechnology projects: safe and affordable armyworm control tools for poor farmers in East Africa to protect crops against devastating outbreak. In: Technology for Development Assistance for Agriculture, Routledge, Abingdon. pp. 51-59.