Institution: Newcastle University

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

Title of case study: Increased productivity, profitability and environmental sustainability of commercial soil-based greenhouse production systems

1. Summary of the impact (indicative maximum 100 words)

Newcastle research into improving commercial soil-based greenhouse productivity has led to an increase in profitability (due to higher yields and lower costs) and a significant reduction in the negative environmental impacts of commercial, organic and other soil-based greenhouse crop production systems in Europe (UK, Greece and Crete). Newcastle's research has led to improved profits to UK organic tomato farmers estimated to be up to £100,000/ha/year and has allowed large scale organic greenhouse production to be a viable option to meet the demands of the UK organic market. In Greece increased profits are estimated at €25,000 per ha/year and in Crete the estimated value of reduced soil disease control and pest management is €110,000 per ha/year.

2. Underpinning research (indicative maximum 500 words)

Soil and foliar diseases are the main reason for yield and quality losses in soil-grown greenhouse crops such as tomato and cucumber. As a result synthetic chemical fungicide and soil disinfection treatments (including the ozone layer depleting gas methyl-bromide) were widely used in conventional greenhouse production in the early 2000s [**P1** - **P5**]. Similarly in organic greenhouse production, routine annual steam disinfection treatments were widely used throughout Europe [**P2**, **P4**]. Increasing concern about the negative environmental and human health impacts resulted in prohibition of some of the most effective chemical soil disinfectants (including methyl bromide, chloropicrin) in conventional farming (for example see EC 2009 Strategy on the sustainable use of pesticides http://ec.europa.eu/environment/ppps/home.htm) and restrictions on the use of soil steam disinfection (for example see http://tinyurl.com/ydzkxod), and Cu fungicides in organic farming systems late 1990s/early 2000s [**P2**, **P4**]. This and the high cost and relatively low efficacy of alternative disease control treatments has resulted in increased commercial losses in commercial greenhouse production in both Northern and Southern Europe [**P1**, **P2**, **P4**, **P5**]. It was this need that the Newcastle Research directly addressed.

Newcastle University Research between 2000 and 2013 has focused on improving soil and foliar disease control in European greenhouse production systems. The research used bio-assay, pot and field experimental designs and plant and soil, pathogen and plant analysis methods. Key research insights that underpinned the impact included:

- Soil borne diseases (corky root rot, *Verticillium* and root-knot nematodes) in soil-based greenhouse crops can be efficiently controlled by integration of (a) grafting onto resistant rootstocks, (b) chitin/chitosan soil amendments and (c) use of suppressive composts [**P2]**, thus reducing the need for chemical and steam soil disinfection treatments [**P2**,**P3**,**P4**,**G2**,**G3**,**G4**].
- Powdery mildew and grey mould (*Botrytis cinerea*) in greenhouse crops may be efficiently

controlled by integrating the use of (a) less susceptible tomato hybrids with (b) improved greenhouse environmental (especially humidity) control systems and (c) foliar elicitors (milsana, chitin/chitosan) treatments [**P1**,**P5**,**G2**,**G4**].

- Late blight (*Phytophthora infestans*) severity in greenhouse tomato production may be reduced by (a) optimising soil management and especially N-supply and (b) improved greenhouse environmental (especially humidity) control systems [**P1**,**G2**, **G4**].
- A range of compost/weed/plant extracts and biological control agents (based on bacterial and fungal antagonists), that were used by farmers, were shown not to affect late blight severity [**G3**, **G5**]. Producers were advised (in farmer workshops and via project websites) to stop using such products (e.g. www.qlif.org, Ghorbani et al. 2007 *Pot Res.* **48**, 181-189) and this has contributed to reducing production costs.

The research programme focused on implementing UK and EU policies (e.g. replacement of methyl-bromide, chloropicrin and Cu-fungicides) in support of both organic and low-input farming. It was carried out by Prof C Leifert (Research Development Professor), Dr S Wilcockson (senior lecturer) and Dr J. Cooper (lecturer) with the support of 5 post-doctoral fellows (Dr R. Ghorbani, Dr C Schmidt; Dr N Volakakis; Dr MD Eyre; Dr L Lueck) and 7 PhD student programmes funded by the EU, DEFRA and the Greek and Thai National Research Foundations.

3. References to the research (indicative maximum of six references)

[**P1**] Dafermos,N.G., Kasselaki, A.M., Goumas, D.E., Eyre, M.D., Spandidakis, K., Leifert, C (2012) Integration of Elicitors and Less Susceptible Hybrids for the Control of Powdery Mildew in Organic Tomato Crops. *Plant Disease* **96***,* 1506-1512. doi: 10.1094/PDIS-10-11-0821-RE

[**P2**] Giotis, C., Theodoropoulou, A., Cooper, J., Hodgson, R., Shotton, P., Shiel, R, Eyre, M., Wilcockson, S., Markellou, E., Liopa-Tsakalidis, A., Volakakis, N. & Leifert, C. (2012) Effect of variety choice, resistant rootstocks and chitin soil amendments on soil-borne diseases in soil-based, protected tomato production systems. *European Journal of Plant Pathology* **134**, 605-617. doi:10.1007/s10658-012-0041-2

[**P3**] Tamm, L., Thürig, B., Bruns, C., Fuchs, J.G., Köpke, U., Leifert, C., Mahlberg, N., Nietlispach, B., Laustela, M., Schmidt, C., Weber, F., Fließbach, A. (2010) Soil type, management history, and soil amendments influence the development of soilborne (*Rhizoctonia solani*, *Pythium ultimum*) and airborne (*Phytophthora infestans*, Hyaloperonospora parasitica) diseases. *European Journal of Plant Pathology* **127**, 465-481. doi:10.1007/s10658-010-9612-2

[**P4**] Giotis, C., Markelou, E., Theodoropoulou, A., Toufexi, E., Hodson, R., Shotton, P., Shiel, R., Cooper, J. and Leifert, C. (2009) Effect of soil amendments and biological control agents on soil borne root diseases caused by *Pyrenochaeta lycopersici* and *Verticillium albo-atrum* in organic greenhouse tomato production systems. *European Journal of Plant Pathology* **123**, 187-400. doi:10.1007/s10658-008-9376-0

[**P5**] Markellou, E., Kalamarakis, A.E., Kasselaki, A.M., Dafermos, N., Toufexi, E., **Leifert, C.**, Karamaouna, F., Konstantinidou-Doltsinis, S. (2009) Potential use of botanical fungicides against grey mould and powdery mildew in greenhouse grown vegetables. *IOBC/WPRS Bulletin*, **49**: 61-66.

Grants

[**G1**] Improving nutrient use efficiency in major European food, feed and biofuel crops to reduce the negative environmental impact of crop production (acronym: NUE-CROPS; website: http://research.ncl.ac.uk/nefg/nuecrops). Duration: 2009-2014. Sponsor: EU-FP7. Co-ordinator/PI: C. Leifert. Co-PI: J. Cooper, A. Gatehouse. Total grant: £7,998K; Newcastle University grant: £1,348K.

[**G2**] Improving quality and safety and reduction of cost in the European organic and "low input" Supply chains (acronym: QualityLowInputFood; website: www.qlif.org). Duration: 2004-2009. Sponsor: EU-FP6. Co-ordinator/PI: C. Leifert. Co-PI: S. Wilcockson. Total Grant: £12,400K; Newcastle University grant: £2,450K

[**G3**] Development of a systems approach for the management of late blight in EU organic production (acronym: Blight-MOP). Duration: 2001-2005**.** Co-ordinator: C. Leifert. Co-PI: S Wilcockson. Sponsor: EU-FP5; Total grant: £3,300K. Newcastle University grant: £720K

[**G4**] Interactions between crop nutrition and soil and foliar borne diseases in organic tomato production systems. Duration: 2001-2003. PI: C. Leifert. Sponsor: DEFRA/DTI/Cantelo Nurseries-TCS Programme. Total grant: £108K.

[**G5**] Alternatives for the control of late blight in organic production systems. Duration: 2000-2004. PI: C. Leifert. Co-PI: S. Wilcockson. Sponsors: MAFF Open Contract with co-funding from Glenside Ltd. and Greenvale plc. Total grant: £145K.

4. Details of the impact (indicative maximum 750 words)

The research programme on improving soil and foliar disease control in greenhouse production systems at Newcastle University between 2000 and 2013 has led to the development of integrated crop management protocols for the control of soil-borne and foliar diseases in organic and soil-based greenhouse crop production systems across Europe. This has resulted in increased yields and reduced costs associated with soil disinfection and pest control in greenhouse production systems in the UK and Greece. In addition to these benefits the reduction in soil steaming techniques has led to decreased emissions of carbon dioxide.

<u>The impact of Newcastle research on organic production in the UK, Greece and Crete</u>

The UK produced 89,000 tonnes (t) of tomato and 66,500 t of cucumber in 2011 on approximately 330 ha of high value, environmentally controlled greenhouses (http://faostat.fao.org).

The British Tomato Growers' Association [**E1**] state that "*The resistant rootstocks, suppressive composts and (for some growers) chitin soil amendments identified in the… [Newcastle research] programme became part of the standard production protocols throughout the UK organic greenhouse production sector for tomatoes and indeed, most greenhouse crops. …all large scale organic producers of tomatoes nowadays use grafted plants and suppressive composts as a main fertility/soil health input. Also, virtually all soil association registered organic producers have been able to completely stop using soil steam disinfection to control soil borne diseases*" The research has led to an estimated *"…10-12% increase in marketable fruit yield and a 10% reduction in production costs, partly due to the omission of expensive soil disinfection treatments…*" The improvements in production techniques are *"…worth up to £100,000/ha, depending on the crop…*"

and "*…have helped to make large scale organic glasshouse production a viable option to meet the demands of the UK organic market…*"

Greece produced 1,169,900 t of tomato and 174,700 t of cucumber on approximately 23,000 ha both in the field and greenhouses (mainly simple plastic greenhouses with limited environmental control) with most farms being smaller than 1 ha. Before the Newcastle research economic losses were high (20-45% reductions in yield depending on the season) as a result of both soil borne diseases (corky root rot, Verticillium and Fusarium) and nematodes [**E2**: Nafpaktos Greenhouses]. After the implementation of the Newcastle protocols there has been a "*…15-35% increase in yield…*" and a "*…25% increase in profit margins (€25,000 per ha/year), because of the increased yield and reduced costs associated with soil disinfection and biological pest control…*" [**E2**] Currently, "*…more than 80% of farmers [in Greece] have implemented all or parts of [the Newcastle] new protocols*." In addition, the resistant rootstocks identified in the Newcastle research are also now being used by 10-15% of the conventional soil-based greenhouse production industry in Greece because of prohibition of the two most effective chemical soil disinfectants (methyl-bromide and chloropicrin) [**E2**]. The estimated value of reduced soil disease control and pest management in Crete is €110,000 per ha/year [**E3**].

The environmental benefits of the impact of Newcastle Research

The Newcastle research has negated the need for chemical and steam sterilisation of soil in greenhouse based production systems. We estimate that the resultant reduction in the use of these techniques is between 8750 and 12500 kg of CO_2 per ha of greenhouse. This estimate is based on published data on the diesel fuel use of commercial soil steam disinfection (3500-5000 litres per ha) and greenhouse gas emissions associated with the burning of diesel fuel (2.5 kg per litre of fuel) [**E4**]. In addition, by providing an effective, and relatively inexpensive alternative treatment to methyl-bromide, resistant rootstock/suppressive compost treatments are also thought to further reduce the use of this ozone-depleting soil disinfectant in countries where it is still legally used; however, this impact is difficult to quantify, due to a lack of suitable statistics.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[**E1**] Testimonial 1. British Tomato Growers' Association, UK

[**E2**] Testimonial 2. Theodoropoulos Konstantinos Greenhouses, Nafpaktos, Greece

[**E3**] Testimonial 3. Bioplakias Greenhouses, Plakias, Greece

[**E4**] ICCP (2006) ICCP guidelines for national greenhouse gas inventories. http://www.ipcc-nggip.iges.or.jp/public/2006gl/