Institution: University of Worcester

Unit of Assessment: 5 Biological Sciences

Title of case study: Improving crop protection for brassicas through the development of in-field devices to detect fungal pathogens

1. Summary of the impact

Brassica production contributed £245.7m to the UK economy in 2012 and is growing year on year.[i] Research described below has led to the development of simple to use hand-held devices which enable brassica growers to identify the presence of a specific plant disease in the air or soil. With this knowledge, the grower can make an informed decision about when to plant a new crop or to spray an existing crop. This benefits the grower economically through a decrease in losses to disease and lower pesticide costs. Beyond the benefits for the grower, the reduction in pesticide use is consistent with UK and European policy on the environment.

2. Underpinning research

The National Pollen and Aerobiology Research Unit (NPARU) has an established track record in research on the detection of fungal spores, initially under the directorship of Professor Jean Emberlin (1993-2010) and subsequently under the current director Professor Roy Kennedy (2010-present).

Early research in NPARU on the modelling of changes in biological material in the air was reported in the 2001 and 2008 assessment exercises. NPARU developed expertise in fungal spore identification initially at the genus level using microscopy which underpinned a body of research on asthma and hay fever (**Reference 1**). EU-funded research established a new approach to detecting and monitoring airborne allergens (including fungal spores) utilising an innovative air sampler in conjunction with immunochemical identification methods which allow classification of fungal spores at the species level (**Grant a**).

The appointment of Kennedy as Director and of Alison Wakeham (2010-present) extended NPARU's research in immunochemical identification and redirected it towards crop protection. Their research, which began at the University of Warwick but has been taken forward at Worcester, has focused on the development of monoclonal antibodies that bind to the spores of specific fungal species which have been exploited to produce hand-held diagnostic devices. This required investigations of the kinetics of the binding reactions to allow the development of competitive assays in which components are immobilised on a filter through which sample material is moved by capillarity. After a few minutes, positive reactions result in the production of a coloured band; the intensity of the band is proportional to the abundance of the fungal spore. A positive control has been incorporated to produce a coloured band in a different position to indicate that the device is working properly. This enables rapid detection of the presence of a fungal pathogen and it underpins the selectivity of the testing systems now deployed in the field.

Earlier methodologies developed by NPARU for sampling biological material from the air (mainly pollen) required subsequent analysis of collected samples in a laboratory (**Reference 2**); Kennedy and Wakeham's research has allowed the development of hand-held monoclonal antibody-based lateral flow devices (a 'lab on a stick') which can be used in the field. These tests not only forecast the risk of particular plant diseases ahead of planting a crop but also assist in the management of the disease throughout the growing season. On-going research, funded by the Agriculture and Horticulture Development Board (**Grants b, c** & **d**), has validated in-field tests for a series of fungal pathogens: see, for example, **Reference 3** which shows the efficacy of the tests in identifying different pathotypes of *Plasmodiophora brassicae* or clubroot.

The output from these tests has been shown to be easily applicable to a range of pathosystems where there is one dominant pathogen present (**Reference 4**). Research has also shown that the deployment of tests in the field can be enhanced by using them in association with mathematical models. For example, the use of diagnostics within a mathematical model output (Brassicaspot) enabled more effective control of the horticultural brassica pathogen *Albugo candida* (**Reference 5, grant e**).

3. References to the research

1. Atkinson, R.W., Strachan, D.P., Anderson, H.R., S Hajat, S., Emberlin, J. (2006) Temporal associations between daily counts of fungal spores and asthma exacerbations. *Occupational and Environmental Medicine* 63 (9), 580–90. DOI:10.1136/oem.2005.024448.
2. Carinanos, P., Emberlin, J., Galan, C. & Dominguez-Vilches, E. (2000) Comparison of two pollen counting methods of slides from a Hirst type volumetric trap. *Aerobiologia*, 16: 339-346. DOI: 10.1023/A:1026577406912.
3. Kennedy, R., Wakeham, A. Lewis, M., Keane, G., Petch, G., Proctor, M. & John, S. (2013) Further development of in field tests for resting spores of clubroot and the development of clubroot control based on detection. Final Report to ADHB. [http://www.hdc.org.uk/sites/default/files/research_papers/FV%20349_Report_Final_2013.pdf]
4. Wakeham, A.J., Keane, G., Proctor, M. & Kennedy, R. (2012). Monitoring infection risk for air and soil borne fungal pathogens using antibody and DNA techniques and mathematical models describing environmental parameters. In Mendez-Villas, A. (ed.), *Microbes in Applied Research – Current Advances and Challenges*, World Scientific Publishing, Singapore, 152-6.
5. Minchinton, E.J., Auer, D.P.F., Thomson, F.M., Trapnelli, L.N., Petkowski, J.E., Galea, V., Faggian, R., Kita, N., Murdoch, C., & Kennedy, R. (2013) Evaluation of the efficacy and economics of irrigation management, plant resistance and Brassicaspot™ models for management of white blister on Brassica crops. *Australasian Plant Pathology*, 42, 169-78. DOI: 10.1007/s13313-012-0181-z.

Grants

a. Jean Emberlin (Co-I), MONALISA (*MOnitoring Network of Allergens by Immuno-Sampling*), Life (EU Programme), (01/2005-04/2008), €667,362.

b. Roy Kennedy (PI), Further development of in field tests for resting spores of clubroot and the development of clubroot control based on detection, Agriculture and Horticulture Development Board - Horticulture Development Company, (04/2009 – 05/2013), £200,000.

c. Roy Kennedy (PI), Further development and calibration of detection tests for conidia of onion downy mildew in combination with MORPH forecast model MILONCAST**,** Agriculture and Horticulture Development Board - Horticulture Development Company, (10/2009 – 08/2012), £50,000.

d. Alison Wakeham (PI), Validation of the lateral flow detection devices for the light leaf spot and powdery mildew, Agriculture and Horticulture Development Board - Horticulture Development Company, (08/2012-07/2014), £122,500.

e. Roy Kennedy (PI), Benchmarking predictive models, nutrients and irrigation for management of downy and powdery mildews and white blister, Department of Primary Industries, Victoria, Australia (2008-2011), A$ 120,000.

The University is confident that the underpinning research meets the 2* threshold. Reference 1 was returned to UoA6 in RAE2008 by St George's Hospital Medical School: 95% of the Schools' research was rated at 2* or higher. References 3, 4 & 5 were derived from funded research won in open competition which is indicative of its excellence.

4. Details of the impact

The research has had an impact on production of brassicas by enabling growers to make better informed decisions about when to utilise fungicides as part of their disease control management, which has had associated economic benefits for growers. It has also had environmental impacts through a reduction in the use of fungicides. The Agriculture and Horticulture Development Board state that: '*This research [is] highly important to Horticulture UK PLC…the daily availability of accurate predictions relating to the occurrence of crop pathogens and their control allows UK businesses and producers to better plan their production schedules and reduce damaging impacts of diseases…In addition to impacting on commerce and saving money, correct identification of disease can prevent the unnecessary application of fungicides which will have positive impacts on*

the environment'. (**Source A**).

The outcome of the research fundamental to these impacts is the development of the in-field rapid detection devices which allow the user to determine whether a specific pathogen is present. The device can be used on its own by growers or in tandem with mathematical models that predict when infection of crops from fungal pathogens is likely to occur. NPARU itself provides such a model for brassica growers (**Source B**). The model establishes whether a crop is theoretically at risk of infection; then, where a risk is apparent, the grower (or alternatively a consultant providing information to an agricultural network) can go into the field and use the device to identify the specific pathogen in the air and spray crops accordingly.

The primary impact of the research is thus on crop protection. The vital importance of diagnostics in crop protection is emphasised by recommendations arising from a 2013 Food Research Partnership Stakeholder Workshop (**Source C**). Specifically the impact is on brassica crops. A 2010 report produced for DEFRA predicts a £43.1m potential increase in value to the brassica industry if 100% control of fungal pathogens could be achieved.[ii] Brassica producers, through use of this diagnostic system, are now in a better position to limit significantly the impact of fungal pathogens on their crops.

The extent to which this diagnostic system is used in the UK is evidenced in a number of ways:

- In 2012-13 approximately 1500 test kits were sold for the fungal pathogen *Mycosphaerella brassicicola* which causes ringspot, a major leaf disease in vegetable brassicas.
- The 2013 Red Tractor Crop-Specific Protocols for Broccoli, Brussels Sprouts, Cabbage and Cauliflower each explicitly require its growers to use this system (**Source D**). Red Tractor provides a Farm Assurance Fresh Produce Scheme that allows retailers and consumers to have confidence in the quality of the produce. Many major retailers expect growers to have this assurance; crop protocols act as a template for good practice that growers must follow to gain this assurance and the wider market access that comes with it. 78,000 farm enterprises are signed up to the overall scheme.
- A number of networks provide information to growers on a regional basis using this system. To give two examples:
  - the 'Brassica Alert' operated by the Allium and Brassica Centre and sponsored by Syngenta Ltd. (see http://www.syngenta-crop.co.uk/brassica-alert/) disseminates information on the three major fungal pathogens (*Alternaria brassicae*, *Mycosphaerella brassicicola*, *Albugo candida*) to over 70 producers and growers in the Lincolnshire region on a weekly basis (**Source E**).
  - Kettle Produce Ltd, a major producer of horticultural brassica crops in Scotland, provides an information network for its 50 growers, representing approximately 2,500 hectares. In this case, information relates to the light leaf spot pathogen caused by *Pyrenopeziza brassicae.* Kettle Produce Ltd have stated that '*combining this information with the appropriate fungicide spray regime and variety has improved control of this disease in our production system…The continual improvements you have provided…have given us an invaluable tool in our battle against light leaf spot and have radically improved our control of this disease helping us to increase yields and secure the economic sustainability of Brussels sprouts'* (**Source F**).
- The benefits of the diagnostic system have been disseminated to vegetable growers through trade magazines such as *The Vegetable Farmer* which has approximately 6,000 readers per month (**Source G**).

The associated economic benefits for brassica growers are clear through the increased yield arising from more effective protection of crops and the decrease in costs through the reduction in fungicide use that goes hand in hand with this approach (**Source H**). An evaluation study of the use of integrated pest management techniques in an Australian context predicted that the use of such a diagnostic system increased farm profit by 15% per hectare (**Source I**).

The environmental benefits of this diagnostic system are also apparent. Evidence has shown that

use of such a system leads to a significant decrease in the number of fungicide sprays required: fourteen to just two in this example (**Source I**). This is in line with UK Government and European Union policy on the rationalisation of fungicide use.

5. Sources to corroborate the impact

A. Letter of Support from the Agriculture and Horticulture Development Board.

B. NPARU's BRASSICASPOT Forecast: http://www.worcester.ac.uk/discover/6273.html.

C. Government Office for Science (2013) *New Innovative Approaches to Crop Protection Report from Food Research Partnership Stakeholder Workshop*, Theme 4 Recommendation 4. http://www.bis.gov.uk/assets/goscience/docs/i/13-892-innovative-approaches-crop-protection.pdf

D. Red Tractor Assurance for Farms 2013 – Fresh Produce Scheme Crop-specific Protocols:

Broccoli: http://assurance.redtractor.org.uk/resources/000/706/417/Broccoli_031013.pdf

Brussels Sprouts: http://assurance.redtractor.org.uk/resources/000/713/012/Brussels_Sprouts_031013.pdf

Cabbage: http://assurance.redtractor.org.uk/resources/000/711/851/Cabbage_031013.pdf

Cauliflower: http://assurance.redtractor.org.uk/resources/000/713/013/Cauliflower_031013.pdf

E. Letters of support from:

(i) Allium and Brassica Agronomy Ltd

(ii) Syngenta Ltd.

F. Letter of support from Kettle Produce Ltd.

G. "Brassica Disease Control", *The Vegetable Farmer* June 2012, 17-20.

H. "Brassica Disease Control", *The Vegetable Farmer* June 2011, 14-17.

I. Minchinton, E.J., Auer, D.P.F., Thomson, F.M., Trapnelli, L.N., Petkowski, J.E., Galea, V., Faggian, R., Kita, N., Murdoch, C. & Kennedy, R. (2013) Evaluation of the efficacy and economics of irrigation management, plant resistance and Brassicaspot™ models for management of white blister on Brassica crops. Australasian Plant Pathology, 42, 169-78. DOI: 10.1007/s13313-012-0181-z.

[i] DEFRA (2013) *Basic Horticultural Statistics. United Kingdom areas, production, valuations and trade statistics for fruit and vegetables to 2012 with historic statistics for ornamental plants and flowers*.

[ii] DEFRA (2010), *Impact of changing pesticide availability on horticulture and an assessment of all impacts and priorities on a range of arable, horticultural and forage crops*, p.23 (Table 5).