**Institution:** University of Hertfordshire

**Unit of Assessment:** 6 – Agriculture, Food and Veterinary Sciences

**Title of case study:** Benefits to UK and Chinese agriculture from new crop disease control strategies

**Period when the underpinning research was undertaken:** 2011 – 2020

**Details of staff conducting the underpinning research from the submitting unit:**

| Name(s): | Role(s) (e.g. job title): | Period(s) employed by submitting HEI: |
|---|---|---|
| Prof Bruce Fitt | Professor of Plant Pathology | Dec 2010 – present |
| Dr Yongju Huang | Reader in Plant Pathology | Dec 2010 – present |
| Dr Henrik Stotz | Reader in Crop Protection | Jan 2013 – present |
| Dr Avice Hall | Principal Lecturer, Plant Pathology | Sep 1970 – present |
| Dr Keith Davies | Senior Lecturer in Applied Nematology | Oct 2011 – present |
| Dr Aiming Qi | Research Fellow | Mar 2013 – present |

**Period when the claimed impact occurred:** 1 August 2013 – 31 December 2020

**Is this case study continued from a case study submitted in 2014?** N

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

University of Hertfordshire-led research into diseases that affect oilseed rape, barley and strawberry crops has shaped novel control strategies in the UK and China. These new evidence-based practices and processes have benefitted UK agriculture by £10m to £20m per annum through better disease management in oilseed rape crops, and have avoided millions of pounds in lost strawberry sales through changes to industry guidance and the development of a decision support tool for growers, now licensed commercially. UK arable crop breeders have been able to maintain seed volumes despite increasingly unfavourable conditions and have seen an increase in revenues from the sale of new cultivars. The oilseed rape agrochemical industry has benefited from additional revenue of £6.5m, with a £2.7m increase in profits for one leading UK agronomy firm and a £0.5m profit increase for another. Four postgraduate students have transferred to high-skilled roles in the UK agricultural industry. In China, changes in trade policy have helped to guard against spread of an oilseed rape pathogen.

## 2. Underpinning research (indicative maximum 500 words)

Plant diseases cost the global economy $220bn (~£150bn) each year according to the United Nations Food and Agricultural Organisation. Research by UH's Crop Protection and Climate Change Research Group, in partnership with the UK agriculture sector, has developed new understanding of the underlying mechanistic processes of plant pathogens that cause disease in three key crops: oilseed rape, barley and strawberries. The findings have shaped novel disease control strategies designed to increase crop resistance to these pathogens and reduce losses.

Oilseed rape is an important arable crop in the UK and many other countries (e.g. China, Canada, Australia and in continental Europe) as global demand for rapeseed oil continues increasing. The two main diseases affecting the crop in the UK are phoma stem canker (PSC), caused by two pathogens *Leptosphaeria maculans* (Lm) and *Leptosphaeria biglobosa* (Lb), and light leaf spot (LLS), caused by *Pyrenopeziza brassicae* (Pb). They cause annual losses greater than £150m; this figure will rise as the climate warms and fungicide insensitivity increases.

Three BBSRC-funded projects [**G1, G3, G4**], led by UH's Fitt and involving 50 industry partners and research institutions in Europe and China, sought to decrease future risk of severe PSC on oilseed rape by improving knowledge of host resistance and using this to guide breeding of resistant cultivars. The results provided new understanding of the type of major resistance genes (*R*-genes) operating against extracellular pathogens that cause both PSC and LLS [**3.1**]. They also developed methods for rapidly assessing quantitative resistance, controlled by several minor genes located at quantitative trait loci (QTL), which is longer-lasting than *R* gene-mediated resistance, especially against Lm [**3.2**]. For China, Fitt and colleagues used data from Poland to model potential spread of Lm through the winter oilseed rape crops growing along the Yangtze River. They found that crop debris (dockage) arriving with imported oilseed rape seeds poses a

greater risk of causing epidemics than seeds themselves [**3.3**]. Work on oilseed rape informed UH's EPSRC-funded contribution to SIBLINGS [**G2**], which, in partnership with agronomy/ breeding companies, revealed new understanding of symptomless leaf blotch (*Rhychosporium commune*) infection of barley [**3.4**], then used it to identify new disease-resistant cultivars.

Beginning in 2015, two interlinked UH-led research programmes [**G3**, **G4**], funded by BBSRC/ Innovate UK and involving 15 industry and charitable trust partners, developed new control strategies for PSC and LLS pathogens in oilseed rape. Fitt and colleagues studied emergence of new virulent races of Lm and Lb, determined the efficacy of new fungicides to control them, and assessed the effects of environmental factors on durability of resistance to the pathogens. They established that combining *R* gene and quantitative resistance increases effectiveness of cultivar resistance against Lm in oilseed rape [**3.5**]. They published the first evidence of Lm virulence against the *Rlm7* gene, an important source of resistance against Lm (used in 15% of UK oilseed rape area) and recommended new strategies to prolong efficacy of this gene [**3.6**].

The UK strawberry market has been valued at £386m, according to the Agriculture and Horticulture Development Board (AHDB). Production has doubled in 20 years, largely due to increased use of protective polythene tunnels. The disadvantage has been an increase in powdery mildew infection caused by the pathogen *Podosphaera aphanis*, which is favoured by the warm and humid conditions that can prevail under tunnels if they are not managed correctly. Hall worked on three research programmes [**G5**] to determine the environmental conditions that favour the spread and development of *P. aphanis* and developed guidelines for effective management and control [**3.7**]. These included recommendations on removal of plant debris from crops to reduce fungal inoculum, guidance on tunnel management, selection of effective fungicides, and development of a forecasting model to predict periods when crops are most at risk. Hall also discovered that adding a silicon nutrient via a fertigation system improved plant resilience to infection from both powdery mildew and two-spotted spider mite [**3.7**].

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

**3.1 Stotz HU**, Harvey PJ, Haddadi P, **Mashanova A, Kukol A**, Larkan NJ, Borhan MH, **Fitt BDL** (2018). Genomic evidence for genes encoding leucine-rich repeat receptors linked to resistance against the eukaryotic extra- and intracellular *Brassica napus* pathogens *Leptosphaeria maculans* and *Plasmodiophora brassicae*. PLOS One 13, e0198201. https://doi.org/gdntn4
**3.2 Huang YJ**, **Qi A**, King GJ, **Fitt BDL** (2014). Assessing quantitative resistance against *Leptosphaeria maculans* (phoma stem canker) in *Brassica napus* (oilseed rape) in young plants. PLoS ONE 9: e84924. http://doi.org/10.1371/journal.pone.0084924
**3.3 Zhang X**, White RP, **Demir E**, Jedryczka M, Lange RM, Islam M, Li ZQ, **Huang YJ**, **Hall AM**, Zhou G, Wang Z, Cai X, Skelsey P, **Fitt BDL** (2014). *Leptosphaeria* spp., phoma stem canker and potential spread of *L. maculans* on oilseed rape crops in China. Plant Pathology 63, 598-612 http://doi.org/10.1111/ppa.12146
**3.4** Looseley ME, Newton AC, Atkins SD, **Fitt BDL**, Fraaije BA, Thomas WTB, Keith R, Macaulay M, Lynott J, Harrap D (2012). Genetic basis of control of *Rhynchosporium secalis* infection and symptom expression in barley. Euphytica 184**,** 47-56. https://doi.org/b7t4fg
**3.5 Huang YJ, Mitrousia GK, Sidique SNM, Qi A, Fitt BDL** (2018). Combining *R* gene and quantitative resistance increases effectiveness of cultivar resistance against *Leptosphaeria maculans* in *Brassica napus* in different environments. PLOS One 13: e0197752. http://doi.org/10.1371/journal.pone.0197752
**3.6 Mitrousia GK, Huang YJ, Qi A, Sidique SNM, Fitt BDL** (2018). Effectiveness of *Rlm7* resistance against *Leptosphaeria maculans* (phoma stem canker) in UK winter oilseed rape cultivars. Plant Pathology 67, 1339-1353. http://doi.org/10.1111/ppa.12845
**3.7 Liu B**, **Davies K**, **Hall A** (2020) Silicon builds resilience in strawberry plants against both strawberry powdery mildew *Podosphaera aphanis* and two-spotted spider mites *Tetranychus urticae*. PLoS ONE 15(12): e0241151. http://doi.org/10.1371/journal.pone.0241151

Key underpinning grants

**G1** BBSRC (BB/I017585/2), Understanding resistance to decrease risk of severe phoma stem canker on oilseed rape. £486,572. 2011-2014. PI: Fitt. Additional funding for this project from AHDB (£124,000, RD-2009-3676) and agricultural charities (£80,000).
**G2** EPSRC (TS/I000747/2) / Innovate UK (100888), Symptomless infection of barley; resistance breeding and integrated crop protection strategies (SIBLINGS). £39,387. 2010-2015. PI: Fitt.
**G3** BBSRC (BB/M028348/1) / Innovate UK (10200), Strategies to increase durability of host resistance for effective control of phoma stem canker on oilseed rape. £116,649. 2015-2018. PI (research): Fitt.
**G4** BBSRC (BB/P00489X/1) / Innovate UK (102641), Integrated control of Leptosphaeria pathogens on UK winter oilseed rape. £375,166. 2016-2020. PI (research): Fitt.
**G5** HDC (SF62 and 62a). £110,000, 2004-2008; (SF157). £18,000, 2015-2020. PI: Hall.

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

Novel insights developed through UH research into how damaging pathogens infect the key crops oilseed rape, barley and strawberries have shaped new disease control strategies. These UH-led studies have increased profitability for UK farmers and growers. They have delivered commercial benefits to the wider sector, supported the employment of postgraduates within the industry and changed Chinese government trade policy on oilseed rape imports.

**Protecting crop yields and increasing the profitability of UK agriculture and horticulture**

Research at UH was done in collaboration with end-users across UK agriculture: farmers and growers, crop breeders, agronomy and agrochemical companies, AHDB (the levy board that represents farmers/growers and the wider supply chain) and charitable trusts. Its core aim was to translate new scientific knowledge directly into practical improvements to the industry's disease management strategies. Evidence-based recommendations were communicated through the networks of project consortia members, through industry briefings and events including Cereals (Europe's largest event for the arable industry) and Fruit Focus (the UK's key event for the fruit industry), via new guidelines published by AHDB and in articles in the farming press. As an example, the lead industry partner for **G3** and **G4** was Hutchinsons, one of the UK's largest agricultural advice and supply companies; from 2015, the company disseminated the research insights on oilseed rape to 13,000 farmers per year through their network of agronomists [**5.1**]. UH findings shaped AHDB's *Phoma leaf spot and stem canker* guidelines (2014/15; updated online) for growers of oilseed rape [**5.2**] and AHDB's principal guidelines for strawberry growers: *Control of strawberry powdery mildew under protection* (2016) [**5.5**].

Net benefits to farm incomes

Two corroborating sources – Hutchinsons [**5.1**] and a former AHDB research director (also chair of the project consortium for **G1**) [**5.3**] – quantify the **cumulative net benefit of UH's research on oilseed rape to UK agriculture at between £10m and £20m per annum**. Hutchinsons reports that via the evidence-based advice disseminated by its agronomists, '*farmers were able to plant cultivars with greater disease resistance and to improve timing of fungicide sprays so that their yields were increased and costs decreased, improving their gross margins*' [**5.1**]. This benefitted farm incomes by £5m per year (total of £10m to date) [**5.1**]. The former AHDB research director said the implications of UH's research findings '*have been discussed widely with members of the industry*' which has '*enabled the industry to apply the knowledge gained to improve the … control of diseases in oilseed rape crops, leading to reduced losses*' and net benefits worth £10m per year (total of £20m taken from late 2018) [**5.3**]. Hertfordshire-based Woodhall Estate, which produces several arable crops including oilseed rape, is an example of a farming business that has changed its practice as a result of UH research insights. Forecasting yield gains of 5%, it now grows two oilseed rape cultivars with different resistance genes and quantitative resistance in addition to *Rlm7* cultivars '*to prevent Rlm7 resistance breakdown*' and undertakes more targeted fungicide applications to control PSC [**5.4**].

Citing Hall's strawberry powdery mildew management guidelines [**5.5**], AHDB stated: *'[It] is*

*now considered the principal guidance information on strawberry powdery mildew control by UK strawberry growers. The majority of UK growers and their agronomists have followed the guidance contained within this factsheet, amending their management and control practices accordingly*.' It added: '*Before this guidance was published, strawberry growers producing crops under protection could lose between 20-70% of their crop to powdery mildew.* ***In 2016, the total UK-season strawberry market was valued at £386 million (Kantar). Should 20% of the crop have been lost to strawberry powdery mildew, this would have represented lost sales of £77.2 million****, so the impact of this research and subsequent guidance for growers has been considerable'* [**5.5**].

Commercial benefits to crop breeders

Rapid breakdown of resistance in new cultivars is very costly to breeders. UH research into the regional distribution of virulent races of Lm guided the deployment of oilseed rape cultivars with suitable resistance. New knowledge also guided breeders in the development of new cultivars that have durable resistance and temperature resilience. Leading seed supplier Grainseed Ltd reported that improved understanding of Lm and Lb in oilseed rape via UH research had enabled them to identify more resistant cultivars for UK growers and therefore maintain their market share. In the light of increasing challenges, **Grainseed wrote: '*We consider maintaining seed volumes a major achievement*'** [**5.6**]. LS Plant Breeding, a UK-based subsidiary of German plant breeding company NPZ-Lembke, specified two main areas of benefit: a more rapid introduction of resistance against Lm into their new cultivars and improved marketing of their new cultivars [**5.7**]. **This equated to a net benefit of £70,000 per year, or cumulatively £140,000** since late 2018 [**5.7**].

Commercial benefits to agronomy and agrochemical companies

Agronomy companies have used UH research evidence to provide better disease control advice to growers on the use of resistant cultivars and more precise timing of fungicide sprays. Agrochemical companies benefit from better targeting of fungicide sprays as this decreases the risk that pathogens will develop insensitivity to their products. Agrii is a leading provider of agronomy services, technology and strategic advice. UH findings from the SIBLINGS project [**G2**] improved Agrii's understanding of the management of *Rhynchosporium* in barley; the research data provided evidence of barley yield increases from targeted use of early spring (T0) fungicide sprays [**5.8**]. Agrii shared the optimal control strategies with 5,000 farmers at training workshops [**5.8**]. Agrii said that, as a result of UH research, it saw a 65% industry-wide increase in sales of T0 fungicide sprays; this translated into **additional revenue of £6.5m for the industry as a whole and a cumulative £2.7m increase in profit margin for Agrii itself** [**5.8**]. Hutchinsons said their involvement in **G3** and **G4** had increased their customer base and enabled them to sell more services, resulting in a **net benefit to the company of £250,000 per annum – a total of £0.5m from 2018** [**5.1**].

AHDB-funded research at UH developed and trialled a decision support system that alerts strawberry growers to the risks of powdery mildew outbreaks and when to target fungicide applications [**5.5**]. Through £220,000 translational funding from Ceres Agri-Tech [**5.9**] the efficacy of the platform was demonstrated through large-scale, on-farm testing. It was licensed to precision agriculture specialist Agri-tech Services and is now available to growers, via subscription, through the company's online dashboard [**5.9**]. **The cost benefit to growers is a minimum of £250 per hectare giving a potential saving of £1.7m per annum to the UK strawberry industry** through reducing use of fungicide sprays. User comments included: '*Very easy to use and also to enter in data such as when sprays have been applied*' and '*This season, following the Mildew Model I would say, has been our 'cleanest year' in terms of Mildew, with no outbreaks at all*' [**5.9**]. UH research findings on the efficacy of silicon nutrients in increasing plant resilience [**3.7**] benefitted the business model of Orion FT. Orion FT's trademarked iNHiB technology delivers bioactive, plant-available silicon to enhance natural plant defences. UH research over the impact period used the company's products in its trials [**5.10**]. With its

products validated through peer-reviewed research, **Orion FT was acquired by investment firm Milbank Group** in June 2020 and a new management team was employed [**5.10**].

**Enabling skills transfer from academia to the UK agricultural industry**

Across **G1**, **G3** and **G4**, UH worked closely with three agricultural charitable trusts – the Chadacre Agricultural Trust, the Felix Cobbold Trust and the Perry Foundation – that all have the stated aim of improving agriculture through education of farmers and the provision of support for young people to enter the agricultural sector. **Four trust-funded UH postgraduate students have subsequently moved into high-skilled industry employment.** PhD studentships funded by Chadacre resulted in one student joining RHS Wisley, two entering the breeding industry (LS Plant Breeding; Limagrain) and one current student has been working at the consultancy ADAS [**5.11**]. Through funding from Perry and Felix Cobbold, one PhD student secured a position at Elsoms Seeds, while three others took up academic research posts [**5.3, 5.12**].

[TEXT REDACTED FOR PUBLICATION] [**5.13**]

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

**5.1** Corroborating statement from the Technical Development Director, Hutchinsons.
**5.2** AHDB Information Sheet 37 (PDF): *Phoma leaf spot and canker* (Winter 2014/15) and online knowledge library: https://ahdb.org.uk/knowledge-library/phoma-symptoms-in-oilseed-rape
**5.3** Corroborating statement from the former research director at AHDB and current chair of the AgriFood Charities Partnership.
**5.4** Corroborating statement from the Farm Manager at Woodhall Estate, Hertfordshire.
**5.5** Corroborating statement from AHDB's Knowledge Exchange Manager on impact of research by UH on powdery mildew control in protected strawberry; AHDB Factsheet 29/16: *Control of strawberry powdery mildew under protection* (2016). https://ahdb.org.uk/knowledge-library/control-of-strawberry-powdery-mildew-under-protection-2
**5.6** Corroborating statement from the Technical Director at Grainseed Ltd, Suffolk.
**5.7** Corroborating statement from the Oilseed Breeder at LS Plant Breeding Ltd, Cambs.
**5.8** Corroborating statement from the Head of Crop Science at Agrii, Essex.
**5.9** Commercialisation of the Strawberry Powdery Mildew Prediction Model. Ceres press release: https://www.ceresagritech.org/updates/sweet-success-for-ceres-funded-strawberry-decision-support-system/ Webpage on Agri-tech Services website citing UH research & benefits for growers: https://www.agri-tech.co.uk/services/agri-tech-agronomics/disease-forecasting
**5.10** Article on Orion FT website about impact of UH research: https://www.orionft.com/news/the-benefits-of-bioactive-silicon-in-strawberry-fertigation; article on acquisition: https://agritradenews.co.uk/news/2020/06/04/milbank-acquires-crop-biologicals-range/
**5.11** Corroborating statement from the Administrator at Chadacre Agricultural Trust.
**5.12** Corroborating statement from the Administrator at Felix Cobbold Trust.
**5.13** [TEXT REDACTED FOR PUBLICATION]