Institution: University of Nottingham		
Unit of Assessment: 6; Agriculture, Veterinary and Food Science		
Title of case study: Underpinning the biostimulant and crop protection action of novel seedcare (Vibrance™) for the development of new markets for root health and improved crop yield		
Period when the underpinning research was undertaken: 2008 - 2019		
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:**
Rumiana Ray	Associate Professor in Crop Pathology	2008 - present
Period when the claimed impact occurred: March 2017 – ongoing		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

Research conducted at the University of Nottingham (UoN) has provided evidence of the effectiveness of Syngenta's new Vibrance™ seedcare products against soil-borne pathogenic threats causing root diseases in wheat and oilseed rape (OSR). Syngenta, a leading global agriculture company, utilised UoN research outcomes from 2017 to establish a new 'biostimulant and root health' market within the seedcare and crop protection areas. UoN research provided industry confidence in Syngenta's new Vibrance™ seedcare products, and supported product uptake, with significant market traction achieved for Vibrance™ Duo. UK wheat farmers who adopted Vibrance™ Duo have realised yield increases equivalent to additional UK farm business income of GBP24,083,400 per annum (2019). UoN research also provided Syngenta with critical evidence to support the 'biostimulant' label claim and international product registration of a range of Vibrance™ seedcare products. Specifically, UoN research outcomes enabled Syngenta and a major EU OSR seed company to achieve emergency registration for [redacted] of Vibrance™ OSR in 2020.

2. Underpinning research

Modern farming utilises active fungicides as part of crop management to combat plant diseases that can severely reduce crop yield but are not adequately controlled by non-chemical methods. The introduction of the EU pesticide framework directive (2009/128/EC) in 2009 aimed at minimising the impact of pesticides on human health and the environment. This resulted in restrictions on crop protection active ingredients including main seed treatments (eg thiram) effective against soil-borne pathogens. The new legislation led to a void in seed protection and an urgent need for novel crop protection products and integrative control strategies to minimise yield losses from significant abiotic and biotic stresses occurring at crop establishment. Fundamental and applied understanding of the physiological and protective action of seed protection products (such as fungicides) is required to optimise use within crop management in different environments to achieve new product registrations. In response to these challenges, Dr Rumiana Ray from the University of Nottingham (UoN) collaborated with Syngenta, a leading global agriculture company, on a series of research projects between 2008 and 2020 to determine the effects of a novel class of fungicide (succinate dehydrogenase inhibitor - SDHI) on the protection of wheat and oilseed rape (OSR) under abiotic and biotic stress. Wheat is the most extensively grown crop in the UK (1,816,000ha), while OSR is the third most extensively grown crop (530,000ha; Defra – Farming Statistics, 2019). These crops are critical to UK farming, generating farm income of GBP3,027,000,000 in 2019 (Defra – Total income from farming in the UK, 2020).

Mechanisms and effect of novel crop protection in wheat under abiotic stress

The succinate dehydrogenase inhibitor (SDHI) class of fungicides is the fastest growing in terms of new compounds produced and launched onto the crop protection market. SDHIs offer broad spectrum control of fungi by inhibiting mitochondrial respiration. Fungicide effects of increased resilience and yield of wheat under abiotic stress (eg drought stress) in the

absence of disease have been reported by growers in the farming press but the basis of this phenomenon was not understood.

To provide information on the mechanism of these effects, initial UoN research centred on the SDHI isopyrazam, applied as foliar fungicide application on wheat grown under drought stress in controlled conditions and in field **(G1)**. The results showed that the application of isopyrazam improved wheat biomass (up to 28%) and increased yield (up to 4%) in the absence of disease; these effects were associated with increased efficiency of photosystem II (PSII) (up to 24%) and photosynthesis **(1)**. To obtain a comprehensive understanding of the regulatory genetic mechanisms underlying the observed physiological responses of SDHI-treated plants, further UoN research used a second generation SDHI, sedaxane, formulated as a seed treatment **(G2)**. This work integrated whole plant physiological responses with changes in the global gene expression in the seed, leaf and root tissues of plants subjected to drought stress. Physiological analysis confirmed improved wheat photosynthetic efficiency and increased seedling biomass (dry weight) by 37% under drought stress following treatment with sedaxane **(2)**. Gene expression analysis revealed that sedaxane altered the plant physiological response to environmental stress by redirecting plant metabolism from defence towards adaptive development and growth **(2)**. The research found that the increase in biomass following SDHI treatment **(1,2)** was also associated with changes in plant architecture **(2)**.

Mechanisms and effect of novel crop protection in wheat and OSR under biotic stress

Rhizoctonia solani anastomosis group (AG) 2-1 and *R. cerealis* are soil-borne pathogens causing pre- and post-emergence damping-off and impaired crop establishment in OSR and wheat (respectively). One of the major challenges in developing appropriate integrative control strategies for these soil-borne pathogens is to accurately identify infected farm fields in need of targeted treatment prior to crop seed sowing.

To address this challenge, UoN research **(G3)** developed a highly specific and sensitive TaqMan real-time PCR assay that can detect and differentiate *Rhizoctonia cerealis* in the soil matrix **(3).** The assay was used to test 102 field soils in England over the period of 2 years and it was found that *R. cerealis* and *R. solani* AG 2-1 predominated in more than 68% of fields tested **(4)**. Using the assay developed and tested in wheat **(3,4)**, UoN research undertaken within a collaborative Innovate UK project lead by Syngenta (Integrating Control strategies Against soil-borne Rhizoctonia solani in OilSeed rape – ICAROS) **(G4)** provided detailed understanding on the prevalence of *Rhizoctonia* spp. in UK and EU soils and identified crops and fields at risk from infection **(5)**.

Further research focussed on the development of control strategies, inclusive of an effective seed treatment, to protect crop establishment in infected fields. Sedaxane is the first SDHI seed treatment to act against soil-borne *Rhizoctonia spp.* UoN research showed that, when used in formulation with fludioxonil, sedaxane significantly increased establishment and yield of wheat and OSR in infected fields. Research showed that in OSR, this was through reducing pathogen DNA in soil and *in planta* **(5)**. Sedaxane was also found to protect lateral root development, increase root length and volume in OSR seedlings in soils infected with *R. solani* AG2-1 **(5)**.

3. References to the research

University of Nottingham UoA6 staff are **bold.**

Underpinning references:

1. **Ajigboye, O.O., Murchie, E., Ray, R.V.** (2014) Foliar application of isopyrazam and epoxiconazole improves photosystem II efficiency, biomass and yield in winter wheat. Pesticide Biochemistry and Physiology, 114, 52-60. DOI: 10.1016/j.pestbp.2014.07.003.
2. **Ajigboye, O.O.**, Lu, C., **Murchie, E.H.**, Schlatter, C., Swart, G., **Ray, R.V.** (2017) Altered gene expression by sedaxane increases PSII efficiency, photosynthesis and growth and improves tolerance to drought in wheat seedlings. Pesticide Biochemistry and Physiology. 137, 49-61. DOI: 10.1016/j.pestbp.2016.09.008.

3. Woodhall, J.W., Brown, M.J., Perkins, K., Valdeolmillos, E.S., Boonham, N., **Ray, R.V.** (2017) A TaqMan real-time PCR assay for Rhizoctonia cerealis and its use in wheat and soil. European Journal of Plant Pathology, 148, 237-245. DOI: 10.1007/s10658-016-1083-7.
4. Brown, M., Woodhall, J.W., Nielsen, L.K., Tomlinson, D., Farooqi, A., **Ray, R.V.** (2020) Population dynamics of Rhizoctonia, Oculimacula and Microdochium species in soil, roots and stems of English wheat crops. Plant Pathology, *Article in Press*, DOI: 10.1111/ppa.13329
5. **Ray, R.V., Jayaweera, D.P., Graham, N., Sturrock, C.J., Jilani, T.** (January 2020) Integrating Control strategies against soil-borne Rhizoctonia solani in OilSeed rape (ICAROS) AHDB Project Report.

Underpinning grants:

G1. Commercial research programme on the properties, biology and effectiveness of izopyrazam against pathogens and tolerance to stress. Sponsor: Syngenta, 2009-2012. [redacted]. PI: Rumiana Ray
G2. Physiological and genetic basis of sedaxane. Sponsor: Syngenta, 2011-2015. [redacted]. PI: Rumiana Ray
G3. PhD Studentship: The occurrence and population dynamics of Rhizoctonia spp. in winter wheat. Sponsor: Syngenta, 2011-2014. [redacted]. PI: Rumiana Ray
G4. Integrating Control strategies Against soil-borne Rhizoctonia solani in Oil Seed rape (ICAROS). Sponsor: Innovate UK/BBSRC, 2016-2019, 102649, BB/P005071/1. GBP619,000. PI: Rumiana Ray

4. Details of the impact

Syngenta are a leading global agriculture company with sales in seedcare products of USD1,100,000,000 (Syngenta Global, 2019). Syngenta's major seedcare brands include Vibrance™ for broad spectrum disease control for all major crops and optimum protection against *Rhizoctonia* spp. Vibrance™ includes sedaxane, a fungicide in the succinate dehydrogenase inhibitor (SDHI) class, which has a biostimulant effect. Syngenta's expanding Vibrance™ portfolio includes Vibrance™ Duo for wheat, Vibrance™ Gold for other cereals, and Vibrance™ OSR for oilseed rape (OSR). Dr Rumiana Ray, University of Nottingham (UoN), played a key role in evaluating the performance of the Vibrance™ active ingredient (sedaxane) in wheat and OSR. UoN research delivered key outcomes that have been used by Syngenta since 2017 to support international registration and launch of the new Vibrance™ products. This has enabled Syngenta to establish a new 'biostimulant and root health' market. Furthermore, the fundamental mechanistic understanding provided by UoN research has increased industry confidence in the Vibrance™ product portfolio and uptake by end users.

UoN research contributed to 'biostimulant and root health' market position and uptake of Vibrance™

UoN research showed that sedaxane had a biostimulant effect and provided comprehensive understanding of the underlying genetic mechanisms resulting in improved crop performance under abiotic stress (eg drought) **(2)**. This directly contributed to innovation within Syngenta's crop protection product portfolio through providing Syngenta with critical scientific evidence to establish a new 'biostimulant and root health' market **(a)** and to register and sell Vibrance™ fungicide packages with 'biostimulant' label claims **(b)**. Syngenta first used the biostimulant label claim on Vibrance™ Gold, a cereal fungicide package which improved seedling establishment, which was registered in France (2017) after independent verification of the biostimulant effect **(b)**.

Subsequently, Syngenta used the biostimulant label claim on Vibrance™ Duo, a broad spectrum seed treatment registered in 2017 for the control of a range of soil-borne diseases in winter wheat, winter triticale, winter rye, spring oats and barley in Europe **(b)**. Vibrance™ Duo substantially boosted crop growth **(2)** and the contribution made by UoN towards understanding the physiological response in wheat was recognised in Vibrance™ Duo marketing literature, including the product landing page, post-launch product update and

product brochure **(c)**. Acknowledging the contribution of UoN research, Syngenta's former Technical & Solutions Manager for Seedcare stated, *'Syngenta have worked with Dr Rumiana Ray on developing our understanding of the new seed treatment active substance, sedaxane… considerably [enhancing] our understanding of sedaxane and [facilitating] its successful introduction in the UK and other markets. [...With] Dr Ray we were able to show that under drought stress that sedaxane was able to up regulate certain genes which allowed wheat plants to more effectively photosynthesise than untreated plants […demonstrating] that the product has properties over and above fungicidal action. […]* ***Dr Ray's research has been extremely valuable in helping to position sedaxane in a highly technical and competitive market, allowing us to quickly gain industry confidence and market traction'*** **(a).**

To establish the 'biostimulant and root health' market, provide industry wide confidence in Vibrance™ Duo product claims and support product uptake, Dr Ray was invited to present findings of the UoN research **(2)** and crop trials at Syngenta's Vibrance™ Duo European product launch (March 2017, UK) **(a)**. The event was attended by 100 companies representing Syngenta's European key corporate account holders for crop protection. Dr Ray was also invited to speak at multiple Syngenta annual Root Health Forums (5 invitations, 2013 onwards), providing scientific information and knowledge directly to global industry and research communities to facilitate the uptake of Vibrance™ **(d)**. Through the support of Dr Ray in establishing and disseminating the strong scientific basis for Vibrance™ Duo product claims, Syngenta have quickly gained industry confidence and market traction for Vibrance™ Duo **(a)**. Syngenta estimate that **60% of UK farm advisors were aware of the benefits of using the product (2019). Furthermore, 20% of UK farmers were using Vibrance™ Duo and realising the crop establishment benefits on wheat (2019) (a)**. *'[Syngenta] also used the data to support subsequent launches of the product in 21 EAME [Europe, Africa and the Middle East] countries between 2017 and 2020. Vibrance™ Duo is a strong product in this region, with an average uptake of 80% in wheat farmers […] Vibrance™ Duo was surely the starting point and since then we have launched a series of new products containing this technology within the evolution of our portfolio. Rumiana Ray had a huge impact on the general technology and marketing message map behind the active ingredient sedaxane'* **(b)**.

UoN research contributed to yield and farm income increases

UK wheat farmers face increased threats from soil-borne pathogens causing yield reduction due to losses in emergence and establishment **(3-5)**. The launch of Vibrance™ Duo provided a new solution for farmers for improved crop establishment and protection of root health. Syngenta conducted further field trials to quantify the yield benefits to farmers on a commercial scale. Syngenta trials across 64 UK farms showed Vibrance™ Duo increased wheat yields an average of 0.34-0.51 t/h across two soil types and cropping rotations **(a)**. Based on Defra Farm Business Survey wheat production data (UK wheat area and price per tonne), assuming no change in input costs or output prices, a yield enhancement of 0.41 t/h from a 20% UK wheat area adoption of Vibrance™ Duo, provided an **additional UK farm business income (profit) of GBP24,083,400 per annum (2019) (e)**.

UoN research supports Vibrance™ OSR product registrations

The EU restriction on crop protection actives in 2018 left a gap in the seed protection market, with the leading thiram-based treatments being no longer approved for EU and UK use in OSR. *Rhizoctonia* spp. cause a wide range of commercially significant crop diseases yet little is known about the prevalence of soil-borne pathogens in soils as they are difficult to detect. Using novel molecular assays **(3-5)**, UoN provided Syngenta and EU regulatory authorities with information on the prevalence of *Rhizoctonia* spp. in UK and EU soils and identified crops/fields at risk from infection **(5)**. Specifically, research within the Innovate UK ICAROS project **(G4)** has been used to inform expansion of the Vibrance™ product portfolio to include protection for OSR in the EU, marketed as Vibrance™ OSR **(b)**. Acknowledging the role UoN research has played in this area, Syngenta's Seedcare Technical Expert EAME (Europe, Africa, Middle East) stated, '*Syngenta have the chemistry but not always the ability to identify pathogens which need to be targeted.* ***The collaboration with Dr Ray has been***

unique for Syngenta, allowing us to access detection tools not available anywhere else**. […] **The ICAROS project has paved the way for Vibrance™ OSR registration our first commercial seed treatment to act against Rhizoctonia solani' **(b).**

UoN research drives demand for Vibrance™ from seed companies

Sedaxane, as part of Vibrance™ is the first Syngenta molecule developed specifically for seed treatment, as such, market access requires uptake from seed companies. The ICAROS project demonstrated to seed companies that Vibrance™ provides best in class protection against *Rhizoctonia* spp. **(5)** and generated significant interest amongst OSR seed companies. Specifically, Norddeutsche Pflanzenzucht Innovation (NPZ), who hold the largest market for OSR seeds in the EU, travelled to the UK to view UoN field trials **(f)**. Based on UoN results that demonstrated a strong effect of Vibrance™ OSR on *R. solani* AG2-1, NPZ requested Syngenta arrange emergency product registration in Germany to enable testing using NPZ seed. This allowed Syngenta to sell an initial [redacted] of Vibrance™ OSR to NPZ (June – Sept 2020) **(b)**. Acknowledging the role UoN and Syngenta's collaborative research has played in this area, NPZ's Seed Technology Manager stated that these research outcomes had led to a change in their crop product registration portfolio strategy, *'Dr Ray's findings have demonstrated the potential impact R. solani AG2-1 can have on OSR, which has led us to continue to monitor for R. solani in our winter OSR crop and extend the monitoring in our trial network. […]* ***The ICAROS project [supported] our decision to request Vibrance™ OSR from Syngenta and hence support them in their application for emergency registration**. The ICAROS project has increased our awareness of R. solani AG2-1 as an OSR pathogen and provided evidence for the efficacy of Virbance™ OSR and we are continuing to work with Syngenta to make the product available to OSR growers in key EU countries'* **(f)**.

Summary

Pivotal research conducted by UoN has increased industry confidence and uptake of Syngenta's first broad spectrum seedcare brand Vibrance™. Research outcomes have underpinned UK sales of Vibrance™ Duo and yield benefits have been realised by the 20% of UK wheat farmers who have adopted Vibrance™ Duo as part of their crop protection strategies. This has led to a cumulative additional UK farm business income of GBP24,083,400 per annum (2019). Vibrance™ OSR has gained significant pre-registration market traction as the ICAROS project demonstrated the need for Vibrance™ OSR to protect against *R.solani* AG2-1. A major OSR seed company requested emergency product registration, which allowed Syngenta to trade [redacted] of product between June and September 2020.

5. Sources to corroborate the impact

a) Letter of support from the former Technical & Solutions Manager for Seedcare, Syngenta (November 2020) [PDF]
b) Letter from Seedcare Technical Expert EAME, Syngenta Global (November 2020) [PDF]
c) Syngenta marketing material for Vibrance™ Duo, including: product website, product update and product brochure [PDF]
d) Syngenta Root Health Forum and related web pages [PDF]
e) Calculations from FBS on 2019 UK wheat farmer income [PDF]
f) Letter of support from the Seed Technology Manager, NPZ (December 2020) [PDF]