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Risk and Plant Disease Management: Supply Chain Perspectives in the UK Wheat Sector

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Abstract

While the relationship between food security and plant diseases has been the subject of scientific research, little is known about the attitudes of key supply chain actors towards plant diseases within specific food supply chains. Drawing on concepts of crop protection, control and risk perception, this paper examines ways in which endemic plant disease risks in the UK wheat supply chain are perceived and managed by key 'upstream' and 'downstream' businesses. Septoria and Yellow Rust emerge as the main perceived disease threats to UK wheat production. However, interviewees feel that plant disease is a controllable risk and one that rests mainly at the production end of the supply chain. As a consequence of this assumed 'control', there is a tendency to grow higher-yielding but less disease-resistant wheat varieties. This increases risk along the wheat supply chain, potentially raising costs and prices. Climate change and the potential banning of certain fungicides under EU legislation are perceived future threats that could increase uncertainty and change the balance between 'control' and 'resistance', the latter through the use of more disease-resistant varieties. More research is urgently needed on the perceived impacts of plant disease on other food supply chains and on the relationship between crop protection and risk perception.

Keywords: Plant disease; crop protection; control; resistance; risk perception; UK wheat supply chain.

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1.0 Food Security and Plant Disease

The sudden surge in global food prices in 2007 and 2008 re-established food security as a key element of the international agricultural policy agenda (Beddington, 2010; Ingram et al. 2010; Foresight, 2011). Caused by such factors as poor harvests, rising energy prices, the use of food crops for biofuels and increasing demands for certain foods (e.g. more meat in China), food prices have remained fairly volatile ever since, leading some analysts to suggest that food security will become one of the master frames of early 21st century public policy (von Braun, 2009; Mooney & Hunt, 2009). While open to multiple meanings at different geographical scales, Ericksen (2008) suggested that food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. Thus food security is about access and affordability, as well as providing sufficient supplies of food.

While intensive farming characterised food production in developed market economies until the end of the 1980s, this proved to be environmentally and economically unsustainable. Thus recent food security debates have called for more *sustainable intensification* which emphasises an effective rather than exploitative use of resources (Beddington, 2010; Maye & Ilbery, 2012; Kirwan & Maye, 2013, pp. 101-112). However, critics see sustainable intensification as still inherently productivist (Horlings & Marsden, 2011). Whichever viewpoint is favoured, food security discussions have been dominated by climate change and environmental degradation (Tomlinson & Potter, 2009). Very rarely have plant and animal diseases figured prominently in such debates, although their threat to food production is significant and growing (Mills et al., 2011).

The threat to food security from pests and diseases is not that well understood, even though pest outbreaks have caused up to 15 per cent losses in global crop production (Strange & Scott, 2005) and decimated non-food crops (Potter et al., 2011). According to Waage and Mumford (2008, p.865), biosecurity problems are getting worse owing to globalisation and 'growing trade, travel, transportation and tourism'. Attempts to manage the possible risks from plant diseases have focused on preventing and controlling invasive and 'exotic', rather than 'endemic', pathogens (MacLeod et al., 2010). Thus little attention has been given to the potential impacts of endemic diseases such as potato blight, which can destroy large areas of agricultural production. The focus of this paper, therefore, is on endemic diseases and the ways in which plant disease risks in the UK wheat sector are perceived and managed by different 'actors' in the food supply chain. It also seeks to explore the potential impacts of disease on supply chain management, especially as perceived by 'downstream' actors. This is one of the first pieces of social science research in the UK on plant diseases[1] and is thus exploratory in nature. The next section provides some conceptual insights into food supply chains, agricultural biosecurity and risk perception. This is followed by an outline of the 'whole-chain' methodology used to examine wheat diseases in two regions of England. The results focus on the impacts and management of wheat diseases, before a brief conclusion relates the key findings to conceptual debates on risk and food security.

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[1] This paper draws on 'Growing risk? The impacts of plant disease on land use and the UK rural economy', funded under the third round of the UK's Rural Economy and Land Use (RELU) research programme. For further details, see www.relu.ac.uk

2.0 Food Supply Chains, Plant Biosecurity and Risk Perception

The routes traced by particular foodstuffs from 'farm to fork' are often referred to as a *food chain* (or network) and geographers have attempted to 'map' the system of connections for different products which may vary both in complexity and geographical coverage. Hartwick (1998, p. 425) defines food supply chains as 'significant production, distribution and consumption nodes, and the connecting links between them', and geographers have adopted the supply chain metaphor to trace and follow the nature of 'connections' for particular commodities (see Ilbery & Maye, 2005; Cook, 2006). While terms such as circuits, networks and assemblages may have greater intellectual credibility within the social sciences, Jackson et al. (2006, p. 140) state that 'commodity chains remain a legitimate focus of academic enquiry… because of their continued salience among a wide range of state, corporate and non-governmental agencies'. According to Yakovleva and Flynn (2004, p. 246), the supply chain can be broadened to encompass a food system which includes regulators, suppliers of equipment and materials, as well as waste disposal operations. However, this particular study focuses on parts of the wheat supply chain and not the whole food system; thus analysis stops at the flour and feed mills and does not include retail (supermarkets) and consumption nodes or regulators and waste disposal. This is because the key actors in the wheat chain are the flour and feed mills. Separate studies are needed to examine consumer perceptions of plant diseases and how they might impact on the supply of food products made from wheat and flour.

There are many challenges facing increasingly globalised food supply chains, including economic recession, population growth, climate change and plant and animal diseases. Thus building resilience into agri-food supply chains is crucially important (Beddington, 2010) and agricultural biosecurity is becoming a critical area of study (Waage & Mumford, 2008). Indeed, international trade has intensified the threat posed by plant and animal diseases (Brasier, 2008; Stack, 2008), so much so that international governance dominates biosecurity practice-based discussions, including for plants (MacLeod et al., 2010). Defined by Bingham et al. (2008, p. 1528) as a 'set of policies and practices that are based around making life safe', biosecurity has become an organising concept around which one anticipates and mitigates the adverse effects associated with, for example, plant disease incidents. This is primarily a pre-emptive exercise, but agricultural biosecurity must also function within an environment of unpredictability and uncertainty with regards to what might constitute a threat in the future.

Biosecurity practice relies upon strategies of segregation, containment, quarantine, surveillance, monitoring, inspection and isolation. These are enacted at scales from the global to the local and can range from on-farm management practices to the international regulatory framework established by the World Trade Organisation (WTO). An important component of biosecurity is *plant biosecurity*, which Stack et al (2010, p. 115) define as 'the protection of natural and managed plant systems from the introduction of exotic organisms or from the emergence of indigenous organisms'. Apart from the distinction drawn between exotic and indigenous plant diseases, MacLeod et al. (2010) also draw a second important distinction between plant health, which deals with 'invasives', and crop protection, which is the farm-level management of endemic pests and pathogens. This distinction is important because, while the state tries to prevent exotic diseases entering a country, it is farmers and other supply chain actors (such as agri-chemical companies) who are responsible for dealing with and controlling endemic plant diseases. Indeed, without crop protection disease could cause up to 17 per cent losses in the global wheat crop (MacLeod et al., 2010). Thus changes to legislation that reduces the availability of chemical controls, as proposed in the European Union (EU) under Directive 91/414/EEC, will translate into difficult decisions for the future (Beddington, 2010; Jaggard et al., 2010).

A majority of biosecurity measures have overtly spatial overtones and geographers have contributed to debates by problematising the notion of a universal, harmonised approach to biosecurity measures (Bingham et al., 2008; Ingram, 2009; Mather & Marshal, 2011; Maye et al., 2012). The unequal adoption of biosecurity measures, at different spatial scales, is highlighted and Bingham et al. (2008) suggest that biosecurity is mediated, contested and spatially differentiated, making a 'one size fits all' difficult. Thus at the local level, biosecurity as crop protection is enacted by thousands of UK farmers and their advisors on a weekly basis through crop management strategies. This offers social scientists an opportunity to investigate how and why farmers make their decisions on crop management. Disease mitigation strategies are often vital components of supply chain management and actors' perceptions of particular risks (such as plant disease) become especially important.

Risk is a central element of supply chain management practices. Defined as the probability (or frequency) of occurrence of a threat or hazard and the possible impacts of this occurrence (see Slovic et al., 2002), risk is a multi-faceted and inherently subjective concept. People's reactions vary according to different types of risk and once a judgement is made about a particular risk it can be difficult to change that view, especially if individuals feel they are well-informed about the subject. Non-rational factors also play an important part in risk perception, just as personal experiences, memories (e.g. of past disease events) and societal values can influence decision making. Consequently, Slovic et al. (2004) suggest that individuals deal with risk in three main ways: first, by using logic and scientific reasoning, otherwise known as *risk as analysis*; secondly, through fast and instinctive reactions to danger, which they term *risk as feelings*; and thirdly, via a process described as *risk as politics*, which refers to the clash of interests between intuitive instincts and more scientific analyses of risk. These types of risk can be expected to characterise the decision-making processes of supply chain actors and have been shown to be significant in the relationship between wheat and potato growers and their agronomists (Ilbery et al., 2010).

For arable farmers, plant disease is one risk among many to affect the farm business; others include weather patterns and variability in input costs and output prices. For Hardaker et al. (2004), these are all part of business risk - including production, market and institutional risks – which can affect the whole of the food supply chain. Indeed, risk management decisions are often made on the basis of imperfect information and a feeling of what is right in any particular set of circumstances. Given such a situation, researchers have identified *trust* as another key concept in helping to understand how risk is constructed and perceived by individuals (Poortinga & Pidgeon, 2003; Sligo & Massey, 2007; Palmer et al., 2009). Sligo and Massey (2007) suggest that trust, experience and observation are mechanisms that help to shelter people from risk. They argue that localised forms of knowledge are critical to relationships between risk and trust, while also recognising the importance of scientific information; this reiterates the interplay between Slovic et al.'s (2004) notions of 'risk as analysis' and 'risk as feelings'. For Poortinga and Pidgeon (2003), trust is an essential component of risk perception. They believe that trust exists along a continuum, ranging from critical emotional acceptance to downright rejection. Thus critical trust denotes 'a practical form of reliance on a person or institution combined with some healthy scepticism' (Poortinga & Pidgeon, 2003. p. 971). One might expect the relationship between risk and trust to vary among the different actors in the UK wheat supply chain, and the next section outlines the methodology used to examine some of the attitudes of different supply chain actors.

3.0 Methodology

As part of a much larger study examining three food sectors (potatoes, mushrooms and wheat) and one non-food (ornamentals) sector, a whole-chain methodology was used to examine the views of key actors in the wheat supply chain, from 'upstream' suppliers and farmers to 'downstream' distributors and processors, on the relative significance of plant diseases and their management. According to Ilbery and Maye (2009), a whole-chain approach aims to investigate how the wheat supply chain is constructed by growers and to trace the links between growers and other actors in the chain.

Interviews with 16 wheat growers in two regions of England – Lincolnshire and Herefordshire – provided an entry point into the wider wheat supply chain. The two study areas were selected on the basis of three sequential stages: first, advice from the National Farmers' Union (NFU) that a comparison between an area in the 'wetter' western part of England (Herefordshire) and the 'drier' eastern part of England (Lincolnshire) would be instructive because of differences in the incidence of wheat diseases; secondly, disease incidence maps provided by one of the project's partners[2] showed a much higher incidence of *septoria* (one of the main wheat diseases in the UK) in Herefordshire than in Lincolnshire; and thirdly, location quotient analysis identified a higher spatial concentration of wheat farming in Lincolnshire than in Herefordshire. Purposive sampling was employed to identify a range of wheat growers, including larger-scale, intensive enterprises through to smaller-scale mixed and organic holdings. Some initial contacts were provided by the NFU and snowballing was used to recruit additional growers. The average land area of the sampled holdings in Lincolnshire is almost double that of Herefordshire, reflecting well known contrasts in farm-size characteristics between the two areas.

During the semi-structured interviews with the 16 wheat growers, use of supply chain diagrams helped to identify other key actors who have an influence on their on-farm practices and disease management programmes. In this way, 10 agronomists (five from each region) were identified and interviewed. By 'following' the wheat chain (Cook, 2004 and 2006), 10 other supply chain actors were also identified and interviewed; these included 'upstream' fertiliser/agri-chemical suppliers and plant breeder/seed developer and 'downstream' grain/agricultural merchants and flour/feed mills. While some of these 'actors' were located in one of the two study regions, others were located elsewhere. The latter tended to be larger integrated companies that had an input into nearly every stage of the wheat supply chain, from supplying seed, fertiliser and chemicals to marketing and delivering the farmers' grain to their own (Associated British Nutrition) mills, of which there are three in the UK. Thus there is a relatively high level of vertical integration in the wheat supply chain, with merchants acting as an important intermediary between

[2] FERA: Farming and Environment Research Agency

growers and both breeders and end-users. Contracts are sometimes used to mitigate risk: for growers, a contract guarantees sale of their crop at a known price and for merchants, it ensures continuity of supplies, eliminates competition and allows an element of control. Contracts are also common between mill operators and their customers (e.g. bakers) and between mill operators and merchants. The risk with contracts is that one may lose out on any opportunity to exploit high wheat prices should they occur.

Overall, 36 in-depth interviews were conducted with key wheat supply chain actors, ensuring a good insight into attitudes toward the risks presented by different wheat diseases. The semi-structured interview schedule sought information from wheat growers about their farm businesses and disease management strategies, disease advice and risk. This interview schedule was continuously modified for use with agronomists and other supply chain actors. Thus, for agronomists, questions were asked about fungicide spray programmes, spray timings and dosage rates, as well as the ways in which they discussed their plans with growers and the extent to which these were followed. Likewise, other actors were asked about the significance and relevance of disease to their company, risk and contingency plans in the event of an outbreak, and potential future problems relating to continuity of supply and plant health regulation. All interview materials were professionally transcribed, coded and analysed to provide detailed qualitative insights into supply chain actors' perceptions of plant disease priorities and impacts, management prescriptions and attitudes towards risk and trust. The next two sections provide empirical evidence on the impacts and management of wheat diseases from different parts of the wheat supply chain.

4.0 Plant Disease Priorities and Impacts

For both growers of wheat and their agronomists, *septoria tritici* and rusts (particularly yellow rust, but also brown rust) were their main plant disease concerns. A broad geographical distinction occurred, with growers and agronomists in Lincolnshire being more concerned about rusts and their counterparts in Herefordshire concentrating on the threat from *septoria*. Where growers were planting second or continuous wheats[3], root diseases such as eyespot and take-all were also cited as concerns. The disease risk was driven principally by weather-related conditions, but also by varietal choice. In all cases, disease poses a real threat because of its potential to reduce yields and profits significantly. The problem is often enhanced by the choice of wheat varieties, either because of their lack of resistance to disease or because they break down over time. Growers generally felt that disease was relatively controllable, but expressed disquiet about resistance to fungicides; for example, one large wheat producer in Lincolnshire suggested "our biggest concern is *septoria* resistance to fungicides, which is increasing slowly year for year" (LG5). Likewise, for agronomists in Herefordshire no wheat varieties are considered 'resistant' to *septoria*. Thus:

> None of the varieties has got what you would term resistance to *septoria*. Even the good resistant ones get it in a bad year. They might give you a little more flexibility in terms of timing (when sprays are applied to the crop), but you still end up spraying them (HA5).

[3] Where there is no break crop in between wheat plantings

Agronomists from both areas used the variety Oakley as an example of how yellow rust had become a problem in 2008-9. As a consequence, the variety was downgraded on the recommended list of varieties. Nevertheless, given its high yielding potential, many growers and agronomists were prepared to grow Oakley again the following year – despite the risks involved. Thus the general consensus among growers and agronomists was that they had fungicide programmes that were capable of controlling *septoria,* rusts and mildew. For them, while disease is an important concern, economic considerations relating to profitability, rising input costs and difficulties when dealing with other elements of the wheat supply chain are of primary importance.

The other supply chain actors confirmed *septoria* as a primary disease of wheat, but they distinguished between milling and feed wheat. Thus those dealing with milling wheat are concerned with diseases that affect grain quality (such as *fusarium*), while those involved with feed wheat are concerned more with yield-robbing diseases such as *septoria*. However, most of these supply chain actors were not that concerned about specific diseases because they regard them as the territory of those supplying growers with inputs. Thus a seed merchant stated:

> I think the plant disease aspect of it all is far more for the chemical companies than it is for people like us, to be quite honest (SC4).

The real issue is that the incidence of different diseases changes over time. Disease is thus dynamic, with each season being different due to the varieties grown and changeable weather conditions.

Most supply chain actors felt that, through fungicide spray programmes, there was control over plant disease. They argued that the volume of wheat produced each year varies and they can manage this variation. A trust-based relationship is developed between key supply chain actors and growers through negotiation and adjustment. Nevertheless, responses to how plant disease would impact on their business did vary according to position within the supply chain. Thus there was agreement that growers bear most of the burden of disease through chemical purchases and yield losses, although there was a sense that some responsibility and risk are spread along the supply chain. For flour and feed mills, disease would have just a short-term impact as they sought alternative sources of supply (including imports) or substituted soya, maize or tapioca for wheat in the final feed product. As a feed compounder suggested:

> In the feed industry, if price jumps we will use less cereal. We are flexible – we don't have fixed formulation feeds and so can provide the nutrition in other ways (SC8).

As a key intermediary, merchants can be impacted more by disease than millers. Although not experiencing a disruption to supply due to disease, there was recognition of the potential risk and the need to plan ahead. Thus:

> If you think that a particular variety is going to be extremely popular and then it has a serious breakdown during the growing season, you're suddenly left with loads of unwanted seed which you have already committed with the seed growers – and they are expecting a premium over and above for growing it in the first place (SC2).

In such a scenario, the merchant bears some risk as seed will be sold as feed rather than milling wheat at the merchant's expense. Normally, merchants have a sufficient number of suppliers to spread the risk and can ultimately source wheat from abroad. However, to reduce the number of rejections for their wheat, many have incurred an extra cost through installing grain testing facilities prior to sending their products to the flour or feed mills. As one merchant emphasised:

> At the end of the day, you are totally reliant on the end-user as to how they are able to take the lower quality; they can reject the grain or manipulate their requirements according to the quality that they have on offer – this is reflected in the price they offer (SC2).

Towards the production end of the wheat supply chain, manufacturers of chemicals are used to annual variations in demand for specific fungicides in response to the unpredictability of the weather and growers' response to it. They thus plan accordingly, just as grower buying groups ensure they have adequate stocks at the start of the growing season. As one buying group explained, the ability to change plans and order very quickly with the manufacturer is the key to coping with disease; not surprisingly, therefore, trust-based relationships are developed with manufacturers to allow flexibility in orders.

Perhaps the grower-agronomist nexus is at the heart of dealing with wheat diseases on the farm (Ilbery et al., 2010 and 2012). Agronomists often develop long-term relationships with growers and know their limitations. Their response to the impact question was that, with robust fungicide spray programmes, sensible agronomy and varietal choice, they are able to exert control over plant disease. While some marginal wheat growers in Herefordshire could be forced out of wheat production, the most likely response is greater use of disease-resistant varieties, new chemical products, GM technology, better rotations and preventative management. Growers confirmed that movement out of wheat production would be a last resort measure because of a) its centrality to the farm business and b) the lack of suitable and financially viable alternatives. Even with the removal of key ingredients in the chemical armoury (e.g. under Directive 91/414/EEC), they would continue growing wheat and look towards improvements in seed breeding and wheat varieties, as well as better rotations and agronomy.

Given that growers are likely to bear most of the cost of a disease outbreak and are reluctant to consider changing out of wheat production into other land uses, considerable importance is attached to the management of plant disease through fungicide spray programmes – the topic of the next section.

5.0 Control and Plant Disease Management

The two main controls available to growers and/or their agronomists for wheat diseases are agri-chemicals and more disease resistant varieties. All respondents stressed the great reliance on agri-chemicals, particularly where vulnerable varieties are grown in an attempt to maximise yield. However, even if 'chemistry' can manage wheat diseases, much depends on whether a) the weather will allow spraying to take place at the correct time and b) farmers do not try to 'get away' without applying one of the sprays, especially the first T0 spray[4]. For suppliers and merchants, this can compromise yields, as explained by one interviewee:

> If a farmer does not put on the T0, because he thinks his crop's clean, suddenly a disease like yellow rust comes in. He goes on with his T1 and thinks he's sort of put it at bay, but he hasn't necessarily totally controlled it. It's absolutely critical he gets his first spray on at the right time (SC1).

Merchants described the reluctance among many growers to apply the full amount of chemicals in order to save costs. As one respondent put it, 'it's not the technology that is lacking, it's the attention to detail' (SC3) and growers could 'do things better'. They distinguished between smarter growers, who are typically younger, well qualified (often with BASIS training[5]) and keep on top of the spray programme, and growers who are 'stuck in the old ways using old chemistry' and do not keep up with the spray programme (SC3). Agronomists tended to tailor their suggested spray programmes to individual grower needs and idiosyncrasies, and to recommend particular varieties of wheat. However, they did recognise that:

> Growers tend to stick with what they know, especially if yields have been good. Occasionally, they will try a new recommended variety in one field, but they usually want to keep things relatively simple (LA3).

Flexibility and the ability to respond to varietal choices, changing disease pressures and weather patterns were emphasised by agronomists. As another Lincolnshire agronomist explained, "I can't really just write down a fungicide programme that's going to be applicable; it depends on so many things" (LA4). However, the timing of different spray applications becomes crucial and agronomists cannot always convince growers. For instance:

> There are a lot of farmers who put their sprayer in the shed until the spring; that is the mentality of some farmers (LA2) and

> The difference between a good and bad farmer is about a week (HA5).

Growers varied significantly in their attitude towards fungicide spray programmes, especially in relation to whether or not to apply the initial T0 spray. Thus:

> We'll pick our best crops to do a T0. That's part of the managerial decision – whether to spend that money on that crop or not (LG2).

> I don't ever think about putting a T0 on. Even if there is a bit of disease early on, it doesn't seem long to me before we are getting to T1 and we seem to achieve respectable yields (HG12).

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[4] A four spray programme is recommended for wheat, starting with a T0 in March and moving through to a T1 in April, a T2 in May and a T3 in June (timings being dependent on the growth stage of the crop). With favourable weather conditions and few signs of disease, some farmers will try to avoid the first (T0) spray in order to save cost. This is risky because disease can still get in and affect growth before application of T1.

[5] BASIS is an independent organization charged with promoting professional standards in the UK pesticides and fertilizer industry. As part of its programme, it offers a certificate in crop protection – which all agronomists and some growers will take and pass.

Similar differences were identified in relation to the final T3 spray, with some growers hoping to 'get away' without applying this final spray and thus making an economic saving. As well as spray timings, the focus is often on how much to spray on each occasion. All agronomists have available to them scientifically generated dose response curves for different varieties of wheat[6]. But, disease pressure varies between sites and across seasons, depending on varietal choice and local weather conditions. Thus agronomists often have to adjust dosage rates according to these factors and the level of risk a grower is prepared to take. This emphasises the importance of 'risk as feeling' in their decisions, as illustrated in the following two quotes:

> It is an arbitrary shift in the curve. It's just using my bit of common sense as I see it (LA5).

> Actually, a lot of it is instinctive, but with a scientific background (HA4).

The grower-agronomist relationship is central to what to spray, when and how much (Ingram, 2008; Ilbery et al., 2010 and 2012). Much of this relationship is based on the accumulation of trust – including friendship and social interaction - over a considerable period of time, as demonstrated in these representative quotes:

> They are trusting me to grow them the crops to give them the highest financial return (HA2).

> A lot of it comes down to trust in the first instance, personality in the second instance. If the two personalities don't get on, it's never going to work (LA4).

The use of disease-resistant varieties is the second main method of control. However, actors throughout the supply chain have different perspectives on variety selection. A plant breeder (SC1) stressed the importance of variety diversification in reducing disease pressure. Yet, as a grain merchant explained "ultimately, it's the farmers' call; they chase yields" (SC2). Disease resistance in variety selection becomes less important as one moves towards the processing end of the supply chain. Disease is something that is filtered at the production stage and processors are concerned only in terms of how it might affect overall supply. So, while breeders, growers and agri-chemical companies recognise the need for a balance between high yielding and disease resistant traits, merchants encourage varieties that are required by downstream users like mills and other processors. Likewise, the flour mills emphasise that the wheat varieties they use are crucially important. Thus:

> We purchase specific wheat varieties, so that's one of our selling points that we know the individual wheat varieties. The actual variety is important to us for consistency and quality (SC8).

Each cog in the chain promotes its own self-interest, although this varies according to whether the companies involved are independent or integrated. The breeders spend much time talking to end users who communicate their wishes to the merchants who, in turn, recommend specific varieties to growers. This often highly

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[6] Based on extensive field trials conducted by independent organizations and commercial companies, dose response curves provide scientifically recommended and appropriate spray dosage rates for each wheat variety.

interrelated process is re-inforced by the integrated nature of the wheat supply chain. One breeder summarised well the relationship between yields and disease resistance:

> Really, you've got to get yield and you've got to get above those minimum standards for disease resistance. Then the farmer is more likely to take the variety on, particularly if he thinks he can manage the disease (SC2).

Assuming chemical control, risks from plant disease are perceived to be low relative to other business risks. However, it is recognised by most supply chain actors that achieving a balance between high-yielding and disease-resistant varieties is not an exact science because of changing weather conditions, spray timings and other elements of uncertainty. Actors militate against risk by developing trust-based relationships throughout the wheat supply chain and these do not operate in a simple linear fashion.

6.0 Conclusions

Plant diseases rarely figure in debates on food security, even though their threat to food production is increasing through globalising processes. Geographers are beginning to engage in food security discussions and the spatially differentiated nature of plant bisosecurity. This is one of the first papers to examine the attitudes of different 'actors' in the UK wheat supply chain to the nature and impact of plant diseases. Exploratory in nature, the paper 'follows' the wheat supply chain, from upstream breeders and agri-chemical companies to growers, agronomists and downstream merchants and processors, to assess ways in which plant disease risks are perceived and managed.

Based on interviews with wheat growers and agronomists in two study regions, and other supply chain 'actors', a number of key findings have emerged. First, *septoria* and yellow rust are the main perceived diseases to affect the wheat sector, varying in significance between Herefordshire and Lincolnshire. No wheat variety has total resistance to these diseases, increasing the risk of a possible breakdown over time. Secondly, risk is perceived to rest mainly at the production end of the supply chain and thus with growers and/or their agronomists. Plant disease does not figure as a significant risk factor among downstream actors, although an outbreak could increase costs and lead to a search for alternative supplies of wheat or substitute products. Thirdly, growers and agronomists feel that, through crop protection, they can control the risk of plant disease. Yet, decisions relating to what fungicide to spray, when and in what quantities are complex, varying according to weather conditions, knowledge and grower idiosyncrasies. While having access to scientific guidelines on spray timings and dosage rates (risk as analysis), final decisions are often based on subjective and intuitive responses to local conditions, cost saving and levels of trust developed between growers and agronomists (risk as feeling).

Fourthly, as a consequence of 'control' over plant disease, there is a tendency to grow higher-yielding wheat varieties that are not necessarily disease resistant. This increases risk, especially at the production end of the chain where the grower has the ultimate choice of variety. A severe disease outbreak could force marginal wheat growers out of production, but the general view is that wheat will continue to be grown because of its centrality to the farm's business and the lack of financially viable alternatives. Fifthly, all supply chain 'actors' expressed concern over the potential loss of certain fungicides under the proposed 91/414/EEC legislation, accepting that it could have a fundamental impact on supply chain relationships in the future (risk as politics). If certain agri-chemicals are banned, disease resistance becomes a much higher priority for growers and breeders. Only then will more disease-resistant varieties (including GM varieties), biotechnical developments and improved agronomy take on increased significance. Finally, another future threat was perceived to be climate change and the increased disease risk associated with milder and wetter summers. This was complemented by concerns over the increasing demand for wheat from other markets such as biofuels. Nevertheless, some supply chain actors could also see opportunities through, for example, more rigorous food assurance schemes, integrated pesticide systems and increased efficiency by farmers as they pay more attention to agronomy and potential yields.

More research is now urgently needed on other supply chain sectors in different parts of the world. This will help to gain a better and more detailed insight into the relationships between biosecurity, plant protection, risk perception and trust.

References

Beddington, J. (2010). Food security: contributions from science to a new and greener revolution. *Philosophical Transactions of the Royal Society B, 365*, 61-71.

Bingham, N., Enticott, G., & Hinchliffe, S. (2008). Biosecurity: spaces, practices and boundaries. *Environment and Planning A, 40,* 1528-1533.

Brasier, C (2008). The biosecurity threat to the UK and global environment from international trade in plants. *Plant Pathology, 57*, 792-808.

Cook, I. (2004). Follow the thing: papaya. *Antipode, 36*, 642-664.

Cook, I (2006). Geographies of food: following. *Progress in Human Geography, 30*, 655-666.

Ericksen, P. (2008). Conceptualising food systems for global environmental change. *Global Environmental Change, 18*, 234-245.

Foresight (2011). *The future of food and farming: challenges and choices for global sustainability.* London: The Government Office for Science.

Hardaker, J., Huirne, R., & Anderson, J. (2004). Introduction to risk in agriculture. In: J. Hardaker, R. Huirne, J. Anderson, & G. Lien (Eds.), *Coping with risk in agriculture* (pp. 1-22). Wallingford: CABI Publishing.

Hartwick, E. (1998). Geographies of consumption: a commodity chain approach. *Environment and Planning D, 16,* 423-437.

Horlings, I., & Marsden, T. (2011). Towards a real green revolution: exploring the conceptual dimensions of a new ecological modernization of agriculture that could feed the world. *Global Environmental Change, 21*, 441-452.

Ilbery, B., & Maye, D. (2005). Alternative (short) food supply chains and specialist livestock products in the Scottish-English borders. *Environment and Planning A, 37,*823-844.

Ilbery, B., & Maye, D. (2009). Placing local food in a cross-border setting. In: C. Stringer, & R. Le Heron (Eds.), *Agri-food commodity chains and globalizing networks* (pp. 121-136). Aldershot: Ashgate.

Ilbery, B., Maye, D., & Little, R. (2010, July). *Growing risk? Grower-agronomist relationships and plant disease management in the UK potato and wheat sectors.* Colchester: Anglo-French Rural Symposium.

Ilbery, B., Maye, D. & Little, R. (2012). Plant disease risk and grower-agronomist perceptions and relationships: an analysis of the UK potato and wheat sectors. *Applied Geography, 34*, 306-315.

Ingram, A. (2009). The geopolitics of disease. *Geography Compass, 3*, 2084-2097.

Ingram, J. (2008). Agronomist-farmer knowledge exchanges: an analysis of knowledge exchange in the context of best management practices in England. *Agriculture and Human Values, 25,* 405-418.

Ingram, J., Ericksen, P., & Liverman, D. (Eds.). (2010). *Food security and global environmental change.* Earthspan.

Jackson, P., Ward, N. & Russell, P. (2006). Mobilising the commodity chain concept in the politics of food and farming. *Journal of Rural Studies, 22*, 129-141.

Jaggard, K., Qi, A., & Ober, E. (2010). Possible changes to arable crop yields by 2050. *Philosophical Transactions of the Royal Society B, 365*, 2835-2851.

Kirwan, J., & Maye, D. (2013). Integrating local food systems within debates about food security: reflections from the UK. *Journal of Rural Studies, 29*, 101-112.

MacLeod, A., Pautasso, M., & Jeger, M. (2010). Evolution of the international regulation of plant pests and challenges for future plant health. *Food Security, 2*, 49-70.

Mather, C., & Marshall, A. (2011). Biosecurity's unruly spaces. *The Geographical Journal, 177*, 300-310.

Maye, D., & Ilbery, B. (2012). Changing geographies of food production. In: P. Daniels, M. Bradshaw, D. Shaw., & J. Sidaway (Eds.), *An introduction to human geography: issues for the 21st century* (pp. 314-333). Harlow: Pearson.

Maye, D., Dibden, J., Higgins, V., & Potter, C. (2012). Governing biosecurity in a neo-liberal world: comparative perspectives from Australia and the UK. *Environment and Planning A, 44*, 150-168.

Mills, P., Dehnen-Schmutz, K., Ilbery, B., Jeger, M., Jones, G., Little, R.,MacLeod, A., Parker, S., Pautasso, M., Pietravelle, S., & Maye, D. (2011). Integrating natural and social science perspectives on plant disease risk, management and policy formulation. *Philosophical Transactions of the Royal Society B, 366*, 2035-2044.

Mooney, P., & Hunt, S. (2009). Food security: the elaboration of contested claims to a consensus frame. *Rural Sociology, 74,* 469-497.

Palmer, S., Fozdar, F., & Sully, M. (2009). The effect of trust on West Australian farmers' responses to infectious livestock diseases. *Sociologia Ruralis, 49*, 360-374.

Poortinga, W., & Pidgeon, N. (2003). Exploring the dimensionality of trust and risk regulation. *Risk Analysis, 23*, 961-972.

Potter, C., Harwood, T., Knight, J., & Tomlinson, I. (2011). Learning from history, predicting the future: The UK Dutch Elm Disease outbreak in relation to contemporary tree disease threats. *Philosophical Transactions of the Royal Society B, 366*, 1966-1974.

Sligo, F., & Massey, C. (2007). Risk, trust and knowledge networks in farmers' learning. *Journal of Rural Studies, 23*, 170-182.

Slovic, P., Finucane, M., Peters, E., & MacGregor, D. (2002). The affect heuristic. In: D. Golovich, D. Griffin, & D. Kahneman, (Eds.), *Heuristics and biases.* (pp. 397-420). New York: Cambridge University Press.

Slovic, P., Finucane, M., Peters E., & MacGregor, D. (2004). Risk as analysis and risk as feelings: some thoughts about affect, reason, risk and rationality. *Risk Analysis, 24*, 311-322.

Stack, J. (2008). Challenges to crop biosecurity. In: M. Gullino, J. Fletcher, A. Gamliel, & J. Stack (Eds.), *Crop biosecurity: Assuring our global food supply (NATO Science for Peace and Security Series C: Environmental Security)* (pp. 15-24). Springer.

Stack, J., Suffert, F., & Gullino, M. (2010). Bioterrorism: a threat to plant biosecurity? In: R. Strange, &.M. Gullino, (Eds.), *The role of plant pathology in food safety and food* security (pp.115-132). Springer.

Strange, R., & Scott P. (2005). Plant disease: a threat to global food security. *Annual Review of Phytopathology, 43*, 83-116.

Tomlinson, I., & Potter, C. (2009). Too little, too late? Science policy and Dutch elm disease in the UK. *Journal of Historical Geography, 36*, 121-131.

von Braun, J. (2009). The food crisis isn't over. *Nature, 456*, 701.

Waage, J., & Mumford, J. (2008). Agricultural bio-security. *Philosophical Transactions of the Royal Society B, 363,* 863-876.

Yakovleva, N., & Flynn, A. (2004). Innovation and sustainability in the food system: a case of chicken production and consumption in the UK. *Journal of Environmental Policy and Planning, 6*, 227-250.