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Dissemination of information about management strategies and changes in farming practices for the exploitation of resistance to *Leptosphaeria maculans* (phoma stem canker) in oilseed rape cultivars

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Abstract

The management of phoma stem canker (blackleg disease, caused by *Leptosphaeria maculans*) is an integral component of oilseed rape production. In this paper, we discuss the information about management strategies that is disseminated in Europe and Australia. New cultivars have been introduced with improved resistance to disease, but sometimes this resistance has been overcome as new races of the pathogen have emerged. When cultivars with single major gene resistance have been introduced into areas with high inoculum concentrations, significant economic damage has been caused by new races of *L. maculans* within 2–3 years. Quantitative or polygenic resistance has also been used successfully against stem canker and offers more durable disease resistance if plant breeders and farmers deploy this resistance more effectively. Strategies to improve the durability of resistance need to be developed and tested in practice. New information on the occurrence of virulence and avirulence genes in populations of *Leptosphaeria maculans* and modelling of the durability of resistance provide opportunities for plant breeders, specialist technical organisations, cooperatives, advisory services and farmers to collaborate and better exploit cultivar resistance. Changing economic and environmental factors influence cropping practices and, if to be considered successful, management strategies must show clear financial benefits. Technology transfer will need to address all aspects of managing stem canker and other diseases of oilseed rape and using effective written, verbal and electronic methods of communication.

Abbreviations: DSS – decision support system

Introduction

Phoma stem canker (blackleg), caused by *Leptosphaeria maculans*), is one of the most economically important diseases of Brassicas world-wide. It is particularly damaging on oilseed rape (canola) in the major production areas of Europe, Australia and North America (West et al., 2001). Oilseed rape was first grown in Australia in the early 1960s (Colton and Potter, 1999) and these crops were of Canadian spring cultivars which were susceptible to phoma stem canker. By 1971, *L. maculans* had become endemic to the oilseed rape producing areas (Bokor et al., 1975; McGee and Emmett, 1977). Severe epidemics soon after crop emergence in Australia (Bokor et al., 1975) and in parts of France (Brunin and Lacoste, 1970) caused complete loss of crops. Epidemiological studies and breeding programmes were started in France during the late 1960s. The winter oilseed rape cultivar Major, registered in 1971, was the first stem canker tolerant cultivar to be widely used and had the resistance gene *Rlm4* (Delourme et al., 2006). The cultivar Jet Neuf, registered in 1978, represented an important advance, combining very good quantitative (polygenic) resistance to stem canker and specific resistance (*Rlm4*) to *L. maculans* (Delourme et al., 2006). Jet Neuf was the main cultivar used all over continental Europe during the following 10 years and has been widely used as a source of resistance in breeding new cultivars.

Phoma stem canker problems only re-emerged at the end of the 1980s when a change in European Union policy led to the introduction of double zero (low erucic acid and low glucosinolate content in seed) cultivars (Bearman, 1989). These problems were evident before the modern winter oilseed crop became established in the UK in the late 1970's and provided early awareness of the phoma stem canker disease cycle in oilseed rape in relation to components of disease management. Phoma stem canker problems soon developed in southern and eastern England, even where crops were grown for the first time (Gladders and Musa, 1980). As the areas of the UK and Australia that were cropped, respectively, to winter and spring oilseed rape cultivars expanded, government research and technology transfer programmes increased. Such research and technology transfer recorded the prevalence of pests and diseases and provided strategies for their management using cultivars and agrochemicals (Fitt et al., 1997). This led to more detailed epidemiological studies and the development of improved control strategies using resistant cultivars, fungicides and modified crop agronomy (West et al., 1999; Zhou et al., 1999; Gladders et al., 2004b). Government funding of research continues and includes partnerships with industry ('LINK funding') in the UK (Gladders et al., 2004a). In France, CETIOM has strongly supported stem canker research since the beginning of the 1990's. Government, public and European Union funding helped these efforts, notably Agence de l'environnement et de la maitrise de l'energie (ADEME), Ministère de la Recherche et de la Technlogie (MRT), Ministère de l'Agriculture et de la Pêche (MAP) Comité Technique Permanent de la Selection (CTPS), and the EU-funded projects NORDIC, IMASCORE and SECURE. In Australia, state governments and grower levies invested by the Grains Research and Development Corporation account for most research and extension funding, but several private breeding companies have also been established.

A common feature, world-wide, of damaging stem canker epidemics is the importance of air-borne ascospores of *L. maculans* that are produced on crop residues (West et al., 2001). In Australia, epidemics of stem canker have been more damaging than in Europe. These epidemics prevented production of canola for approximately 15 years until suitable resistant cultivars became available (Salisbury et al., 1995). Rainfall at sowing and minimum tillage cropping practices that leave infected crop residues on the soil surface combine to produce very severe early epidemics on seedlings. Technology transfer activities have emphasised the use of resistant cultivars, isolation of new crops from fields with crop residues (Barbetti et al., 2000; Khangura and Barbetti, 2001; Marcroft et al., 2004; Wherrett et al., 2004) and use of fungicides as seed or soil treatments (Ballinger et al., 1988; Khangura and Barbetti, 2002). Little emphasis has been placed on the use of fungicide spray treatments for stem canker control because of the low input – low yield production systems in many parts of Australia (Barbetti et al., 2000).

In Europe, phoma stem canker has been more damaging in some regions of France and Germany than in the UK. Several major resistance genes have been overcome (Brun et al., 2000; Rouxel et al., 2003; Balesdent et al., 2006; Sprague et al., 2006) and improved strategies to manage stem canker are required (Aubertot et al., 2006). Technology transfer to farmers has been led by CETIOM with emphasis on understanding the development of *L. maculans* and controlling it with resistant cultivars. As in the UK, current research is directed to understanding the seasonal variation in disease development (Poisson and Pérès, 1997; Thürwächter et al., 1999) and management by improved husbandry and targeting of agrochemicals. Nevertheless, the benefits from foliar fungicide treatments are uncertain due to the long periods of dissemination of ascospores and relatively short periods of fungicide persistence. Efficient disease control has been achieved when fungicide application timings are correctly guided by spore trap records indicating prevalence of

L. maculans ascospores and forecasts of the risks of onset of phoma leaf spot development (P. Gladders, unpublished data).

Technology transfer

In Australia and Europe, the transfer of results of research and development on phoma stem canker to farmers and the wider industry was initially funded by government through programmes commissioned with state advisory services and national organisations doing cultivar testing. This was achieved through a network of plant pathologists and advisers, using local meetings with farmers, and supported by various publications and press features (Table 1). There are some differences between the UK, France and Australia in the use of written, verbal and electronic communication, but all use a range of different methods. Cultivars were promoted mainly by their breeders and agrochemicals by their manufacturers. These activities have changed over the last two decades as advice to UK and Australian farmers is now usually provided by private consultants and agrochemical distributors on a chargeable basis. In Australia, France and the UK, research results and technology transfer to farmers and industry are conveyed by levy-funded bodies (GRDC, CETIOM and Home-Grown Cereals Authority (HGCA) respectively) that receive funding from farmers based on their oilseed rape production (Table 2). Activities of these bodies include conferences and meetings, field demonstrations and publications that are available to industry, consultants and farmers. In the UK, where agrochemical usage is important, manufacturers have made a significant contribution to technology transfer. Most research projects have a component of technology transfer, although this is necessarily short-term and generally only done during the course of the project. In Australia, the Canola Association of Australia, and Oilseeds Western Australia provide links between researchers, growers, marketers, oilseed crushers and exporters in eastern and Western Australia, respectively.

Technology available for the transfer of information on disease management, continues to evolve. Advances in personal computers and the electronic media, such as the Internet, have been exploited since the late 1990s. A first step is to have technical paper documents also available on Internet (see for example www.cetiom.fr), including recommendations on how to select cultivars and agronomic practices to decrease the impact of stem canker. For other diseases, such as light leaf spot (*Pyrenopeziza brassicae*) in winter oilseed rape (Welham et al., 2004), a regional forecast exemplifies free Internet-based technology transfer (Evans et al., 2002). Individual farmers and con-

Table 1. Summary of methods used for technology transfer of information and advice on control of stem canker and other diseases of oilseed rape

Method	Format	Australia	France	UK
Written	Technical leaflets	**	**	*
	Books	*	*	*
	Specialist magazines	**	***	***
	Scientific papers	**	*	**
	Conference papers	**	**	**
	Project reports	*	*	*
	Farming press (weekly)	***	***	***
	Non-specialist Press e.g. newspapers	*	–	*
	Weekly crop reports	**	*	**
Verbal	Telephone	*	*	*
	Farmer meetings	***	**	**
	Specialist training events	*	**	**
	Scientific conferences	**	*	**
	Advisory visits	**	**	*
	On farm consultancy	***	**	***
Electronic	Email	*	*	**
	Fax	**	**	*
	Websites	**	**	**
	DSS	**	*	**
	Databases	*	*	*

The relative importance of technology transfer activities is indicated by the number of asterisks (*** is the most important).

Table 2. Funding of technology transfer activities for improved disease management of oilseed rape crops

Funding sources	Australia	France	UK
EU	–	**	*
Government (State – AUS) includes Research Councils	*	*	**
Government/industry LINK	*	*	**
Levy	***	***	***
Agrochemical industry	*	*	**
Plant breeders	*	*	*
Individual farmers/consultants	*	*	*

The relative importance of funding for technology transfer activities is indicated by the number of asterisks (*** is the most important).

sultants can access the forecast to determine the risk of damaging attacks of light leaf spot and use the forecast interactively to judge the benefits of using resistant cultivars and/or fungicides (see www3.res.bbsrc.ac.uk/leafspot). The regional forecast provides strategic guidance about the changes in disease risk from year to year. Similar forecasts are being developed for phoma stem canker, but have not yet been validated (Gladders et al., 2004a). Crop-based information is still required to guide decisions on individual fields. There has been increased emphasis on rapid transfer of information on disease development in crops to provide improved guidance on seasonal risk and the timing of fungicide sprays in autumn. In the UK, information on the development of *L. maculans* in crops in autumn has been made available by Syngenta Crop Protection UK Ltd (www.syngenta-crop.co.uk/SPAWS/). Both spore trap records and crop assessment records are updated weekly in autumn to provide improved guidance on the year-to-year and crop-to-crop variation in disease development. Disease surveys and live monitoring data are available for the England through the Defra-funded CropMonitor project (www.cropmonitor.co.uk). Recently CETIOM has released on-line ''@oléovar'', which is an interactive tool available to select cultivars or combinations of cultivars (www.cetiom;fr/oléov@r).

The complex interactions of pathogens, crop and environment present many challenges for technology transfer. Modelling of some of these interactions and the development of decision support systems (DSS), such as the PASSWORD project (Gladders et al., 2004a), are in progress for *L. maculans* and other pathogens of oilseed rape. DSS have the advantage of allowing wide access to guidance on disease management and for decisions to be made for individual crops in response to changing conditions. To be successful, DSS must be up to date, easy to use, reliable and cost-effective (Henriksen et al., 2000).

The impact and success of technology transfer activities may be judged in part by changes at the farm level detected in surveys. New oilseed rape cultivars are taken up by the industry in 1–2 years and most have a relatively short period of commercial production before higher yielding cultivars replace them (Hardwick et al., 2002). Similarly new fungicides have been strongly promoted and adopted rapidly in the UK (Turner et al., 2000; Hardwick et al., 2002). Technology transfer to encourage use of autumn sprays to control stem canker (and light leaf spot) and to improve fungicide spray timing has taken place since autumn 1996 (Gladders et al., 1998). At that time, few farmers were applying fungicide sprays at optimum times and they therefore derived little disease control or financial benefit from fungicide application (Gladders et al., 1998). Crop surveys in England indicated a large increase in the use of autumn sprays from 2.5% of crops treated in 1992 to 75% of crops treated in 1999 (Turner et al., 2000). Changes in timing of fungicide sprays have occurred more rapidly in oilseed rape than in wheat, probably because there are more sources of information available for fungicide treatment of wheat. This is probably due to the fact that while there are more sources of information available for fungicide treatment of wheat, sources tend to give conflicting advice (Hardwick et al., 2002). A consistent message (supported by industry partners) on the benefits of autumn fungicide sprays in oilseed rape, with clear indications of disease-induced yield loss and economic benefits (Fitt et al., 1997; Turner et al., 2002), has been important for the success of this technology transfer.

In Germany and some other European countries where winter damage is important, fungicides (often triazoles) are applied in autumn to improve winter hardiness rather than for disease control. In France, especially in the Central region, the market share of fungicide applications in autumn also increased greatly (from nearly 0% in 2002 to 9% at the national level in 2003, and from 0 to 23% in the Central region near Orléans in 2003 (CETIOM postal surveys)) in response to commercial pressure from agrochemical suppliers and in opposition to independent advice from CETIOM. This increase in use of fungicides appears to be linked to an increase in no tillage techniques. In Australia, changes in cultivars and fungicide use demonstrate the adoption of new technology by farmers. In early 2004, the Canola Association of Australia, and Oilseeds Western Australia together reported that it was no longer feasible to grow cultivars containing the major gene for resistance to *L. maculans* derived from *Brassica sylvestris* and the area sown with these cultivars decreased from 60% in 2003 to $<5\%$ in 2004. Furthermore, as a response to concerns about phoma stem canker, the uptake by farmers of fungicide treatment of seed in Australia has risen from 0% in 2000 to about 80% of all seed in 2004.

Management strategies for enhancing durability of resistance in oilseed rape

To decrease the risk that new races of *L. maculans* will overcome host resistance genes, a holistic crop management approach must be adopted by the oilseed rape industry. In many situations, a combination of cultural and chemical control measures will be required to supplement the sowing of resistant cultivars to prevent yield loss from stem canker. Oilseed rape production is expected to expand in Europe in response to economic and environmental factors affecting production of arable crops. Farmers are increasingly favouring minimum tillage practices to both improve organic matter content and soil erosion and to reduce the costs of crop establishment. Minimum tillage may also solve problems associated with increasing size of farms and reductions in farm workers. However, if this minimum tillage extends to wheat production after oilseed rape, debris-borne diseases such as phoma stem canker are likely to have a strong impact on yield and oilseed rape production may not be sustainable. Higher densities of oilseed rape cropping will potentially increase air-borne inoculum of *L. maculans* and consequently result in more severe stem canker epidemics and increased yield loss (Aubertot et al., 2006). The future of the crop in both Europe and Australia will be determined by crop yields and economic performance. The benefits of improved disease management already have a strong financial basis (Fitt et al., 1997; Barbetti et al., 2000) and benchmarks for disease, yield and economic performance could be introduced to define effective crop management strategies.

Gene deployment and management strategies to reduce the likelihood of resistance breakdown

To date, strategies for breeding stem canker resistance in oilseed rape have focused on increasing the level of stem canker resistance, with less emphasis on understanding the durability of resistance. Rapid breakdown of major gene resistance has been associated with areas of high *L. maculans* inoculum concentrations (Sprague et al., 2006). General strategies for improving the durability of resistance genes include rotation of different resistance genes in space and time, pyramiding different resistance genes and the use of multilines or mixtures of cultivars with different resistance genes (McDonald and Linde, 2002). Modelling provides some insights into the effects of different strategies (Pietravalle et al., 2006). *L. maculans* can overcome novel single major gene resistance within 3 years (Brun et al., 2000; Li et al., 2003b; Rouxel et al., 2003; Sprague et al., 2006) and has caused erosion of resistance in quantitatively resistant cultivars (Salisbury et al., 1995; Delourme et al., 2006; Li et al., 2003a, 2004). Such erosion of resistance has been reported in several Australian cultivars, such as Dunkeld, Monty, Karoo, Charlton and Ripper that are no longer grown, primarily due to their greater susceptibility to *L. maculans* than when they were first released.

In European populations of *L. maculans*, there is a high frequency of virulence alleles that can overcome resistance genes *Rlm1*, *Rlm2*, *Rlm3*, *Rlm4*, *Rlm5* and *Rlm9*, often in complex races (Balesdent et al., 2006; Stachowiak et al., 2006). This largely reflects the history of use of these resistance genes in oilseed rape and the predominance of small number of cultivars in commercial production at any one time. The cultivar Jet Neuf (*Rlm4*) was widely grown in the early 1980s, and more recently Capitol (*Rlm1*), Bristol (*Rlm2*, *Rlm9*), Express (*Rlm2*), Mendel (*Rlm3*), Falcon (*Rlm4*), Synergy (*Rlm4*) and Apex (*Rlm9*) have been widely grown in some countries. Two resistance genes, *Rlm6* and *Rlm7*, appear to still be useful for phoma stem canker control in Europe. However, there is evidence from France that *Rlm6* may be overcome in 2–3 years (Brun et al., 2001) and isolates with virulence against *Rlm7* have been detected (Stachowiak et al., 2006). Very careful management of these specific resistance genes will therefore be required if they are introduced into commercial cultivars.

Quantitative resistance or field resistance (Delourme et al., 2006) is considered to be stable in France, though it is less effective than specific (major gene) resistance. As it is a partial resistance, its effectiveness for stem canker control is sensitive to inoculum concentration. Pyramiding of resistance genes has been used successfully for control of wheat rust (Pederson and Leath, 1988) and combinations of quantitative and major gene resistance should be considered for control of phoma stem canker (Salisbury et al., 1995; Pinochet et al., 2004). It may also be appropriate to release cultivars that have more than one major resistance gene (such as Bristol) and to use cultivars with differing combinations of resistance genes. Thus cultivar diversification schemes, as used for management of various cereal pathogens, can be introduced to improve phoma stem canker management as has been proposed in France (Anon. 2004, Pinochet et al., 2004; Table 3). Cultivars of oilseed rape may be assigned to groups based on their major specific resistance genes and quantitative resistance. Within these groups (currently designated 1, 2, 3 and 4), sub-groups with the same major resistance gene or genes (e.g. cultivars with quantitative resistance and major resistance genes *Rlm1, Rlm4* or *Rlm1* and *Rlm4* could be sub-groups in Group 2) may be identified (Table 3). To exploit major gene resistance, the strategy involves careful planning of cropping so that cultivars with the same major resistance genes are not grown in successive years or in nearby fields. Where cultivars lack quantitative resistance and their major resistance genes have been overcome by *L. maculans*, they should be grown only in areas where the risk of stem canker is low. Alternation and rotation of cultivars presents some difficulties for management between neighbouring farms and may only be appropriate for use on a regional scale. With changing preferences from year-to-year, seed production would also require careful management. These strategies are untested and improved control of volunteer oilseed rape plants may be required to decrease selection pressure on the pathogen.

There may be opportunities to have localised use of resistance genes and use of cultivar mixtures or multilines (Mundt, 2002). The latter may be of greater value in Australia where secondary spread of *L. maculans* is more important than in Europe (West et al., 2001) but suitable commercial material is not yet available. Regionally deployed resistance is another option, but would be difficult to manage. To be successful, information on the nature of a new cultivar's genetic resistance should be available before its commercial release. Careful monitoring of new *L. maculans* races would be required annually after the introduction of new

Table 3. Diversification scheme to exploit different types of phoma stem canker resistance in oilseed rape cultivars

	Group 1	Group 2 (with sub-groups based on different major resistance genes)	Group 3 (with sub-groups based on different major resistance genes)	Group 4
Efficacy of resistance based on specific genes	None	Partial	Partial	High
Presence of quantitative resistance (polygenic)	Yes	Yes	None	Possible, but not identified
Field resistance rating to stem canker	Highly resistant or resistant	Highly resistant or resistant	Susceptible	Highly resistant
Durability of resistance	Stable	Some risk that specific resistance genes will be overcome	Low or already failed	Uncertain
Compatibility with other groups or sub-groups	No restriction	Compatible with Groups 1 and 4, but alternate with cultivars with different specific resistance genes from Groups 2 and 3. Ensure nearby crops do not have the same resistance genes	Compatible with Groups 1 and 4, but alternate with cultivars with different specific resistance genes from Groups 2 and 3. Do not grow in high risk areas.	Compatible with Groups 1–3, but Group 4 cultivars should only be grown in alternate years
Current cultivars* (selected examples only)	Aviso (*Rlm9*) Campala (*Rlm9*) ES Astrid (*Rlm9*) Récital (*Rlm9*)	Banjo (*Rlm1*, *Rlm4*) Columbus (*Rlm1*) Pollen (*Rlm4*)	Maestro (*Rlm4*) Nelson (*Rlm4*)	Caiman (*Rlm7*) Roxet (*Rlm7*)

*Data from CETIOM (Anon., 2004; Pinochet et al., 2004).

cultivars so that timely action can be taken on future production strategies.

Cultural control practices

To successfully produce oilseed rape commercially and reduce the likelihood of resistance breakdown, producers are now advised to grow their crops in ways that avoid high inoculum concentrations. Experience in France (where five genes for resistance to *L. maculans* (*Rlm1, 2, 3, 4* and *9*) have been overcome) has shown that resistance genes have remained effective in regions where inoculum concentrations are low (Rouxel et al., 2003). Therefore, growing oilseed rape crops under consistently lower inoculum concentrations is a crucial management recommendation in Australia and Europe.

Cultural control practices principally aim to decrease the number of ascospores landing on oilseed rape plant tissue. This can be achieved by burying or destroying oilseed rape stubble (allowing stubble to break down naturally within a few months) or isolating crops from stubble. However, there are some environments, such as Western Australia, where stubble residues continue to produce *L. maculans* ascospores for more than 18 months because they decay slowly in the dry Mediterranean climate. Most farmers leave 2 or 3 years between oilseed rape crops in the same field in Australia, but a 1-year break is now common in some regions. Previous studies on cultivars with quantitative resistance have shown that an isolation distance of 500 m between the current crop and the stubble of the previous year's crop is sufficient to avoid the highest concentrations of *L. maculans* inoculum in Australia (Marcroft et al., 2004) and Europe (Gossende et al., 2003). If isolation distances required are relatively small (500–1000 m), individual farmers or groups of farmers could successfully manage resistance rotation on their own properties. Rotation of oilseed rape in space and time is a practical option and farmers have adopted recommendations to sow oilseed rape crops well away from *L. maculans* inoculum.

In Australia, farmers destroy primarily by burning and in Europe, where burning is not permitted, by cultivations (Schneider et al., 2003). Chopping, slashing and/or harrowing is also used to break up the stubble. This process reputedly enhances the natural decomposition of the stubble, reducing survival of the pathogen (Bokor et al., 1975; Gladders and Musa, 1979; Turkington et al., 2000). The main limitation of actively destroying oilseed rape stubble is that most methods still leave large quantities of stubble on the soil surface. In addition, they may also have detrimental environmental side-effects if they increase soil erosion or water loss. To ensure that major sources of inoculum are managed effectively, it is essential to show significant economic advantages accruing from such practices. The costs of cultivation for burial of stubbles are considerable, but should be balanced against the value of the yield benefits from decreased disease severity. Early establishment of oilseed rape is also important so that seedlings have reached the 6-leaf stage before the main phoma leaf spot epidemic develops. Phoma leaf spotting can result in death of seedlings and early infection results in the most damaging attacks of phoma stem canker (Hammond et al., 1985; Hammond and Lewis, 1986).

Chemical control practices

In Australia, triazole fungicides, including flutriafol and fluquinconazole, are registered for the control of phoma stem canker. Flutriafol is used as a fertiliser-amended fungicide as it causes toxicity if applied directly to the seed coat. Ballinger et al. (1988) found that flutriafol increased plant height, decreased stem canker severity, increased plant survival, decreased leaf lesion severity and increased yields. Fluquinconazole is the predominant fungicide used by farmers for stem canker control due to the ease of application (seed dressing) and low cost. Seed treatment may be undervalued as it is a strategically important control measure with potential to prevent the introduction of new races of seed-borne pathogens.

There has been some interest in chemically treating crop residues to delay or inhibit ascospore production, but this has not yet been developed for use on farms (Humpherson-Jones and Burchill, 1982; Wherrett et al., 2003, 2004). In the UK, foliar fungicides have given good control of stem canker and resulted in significant increases in yield (Gladders et al., 1998, 2004a; West et al., 1999; Zhou et al., 1999). However, fungicide use is not always warranted as its economic viability will depend on yield benefits in relation to disease severity (dependent on seasonal conditions) and host resistance. Early guidance based on weather factors could be used to identify situations where chemical treatment is required (Gladders and Symonds 1995; Salam et al., 2003). In future, the role of fungicides may change if fungicide-resistant populations of *L. maculans* and other pathogens should arise or if existing product registrations are not supported in future.

Targets for technology transfer

Technology transfer for improving the management of phoma stem canker will focus on several target groups (Table 4). Oilseed rape breeders must be conversant with issues relating to the durability of resistance genes and combinations of quantitative and major gene resistance. Policy makers should be made aware of the importance of quantitative resistance for sustainable production and the need to characterise it (Delourme et al., 2006). Exploitation of resistance genes requires detailed understanding of pathogen populations and virulence genes and how these are changing in time and space. This will require further annual monitoring using methods already developed (Balesdent et al., 2006) and funding should be co-ordinated internationally. Single major resistance genes are unlikely to survive unless supported by other effective resistance genes. Strategies to ensure resistance remains durable must be economically viable if they are to influence where new cultivars are grown. Equally, farmers and their advisers need to be informed about the necessity to conserve genetic and chemical resources and the benefits of managing disease risk. Levy-funded bodies are expected to have a major role to play in supporting this technology transfer. An integrated approach to control of phoma stem canker will be required, as use of resistant cultivars must be supported by contributions from crop agronomy (including rotations and spatial distribution of crops), general hygiene to bury or reduce the impact of crop residues and fungicides. It is important to consider the economic benefits from improved control of other diseases affecting oilseed rape (e.g. sclerotinia stem rot, light leaf spot) and adapt the strategies to maximise overall benefits. While plant breeders can be targeted as a group through technical seminars and direct contact, advice to farmers and their advisers will require a more sustained approach using a variety of methods for technology transfer.

Table 4. Targets for technology transfer activities on improving disease management in oilseed rape

Target	Australia	France	UK
EU/policy	*	*	*
Government (National State – AUS)	**	*	*
Government/industry LINK	*	*	*
Levy bodies	***	***	**
Agrochemical industry	**	**	**
Plant breeders	***	***	***
Other scientists	*	*	*
Individual farmers/consultants	***	***	***
General public	*	*	*

Priorities for technology transfer activities are indicated by the number of asterisks (*** is the most important).

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