Is durable blackleg resistance in Australia possible?

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Abstract

In recent years in Australia, monogenic resistance has failed dramatically causing severe yield losses in canola cultivars reliant on this resistance source. In addition, polygenic resistance in some cultivars has been eroded. This loss of resistance is due to populations of the blackleg fungus changing in virulence under selection pressure by disease resistance genes. The literature and experience in other crops suggests that rotation in space and time of different blackleg resistance genes may reduce the frequency that resistance genes are overcome by changes in fungal populations.

At two sites in south-eastern Australia, canola cultivars (each with a different blackleg resistance source) were grown in succession (2003 monogenic resistance from *B. rapa* ssp. *sylvestris*; 2004 polygenic partial resistance; 2005 European winter resistance *Rlm1* and *Rlm3* genes). In 2004, 2005 and 2006 pots of canola plants each with different sources of blackleg resistance were placed onto the sites containing the three years of canola stubble. A very low level of infection was observed. Plants with polygenic, European (*Rlm1* and *Rlm3* genes) and *Brassica juncea* all had less than 7% mortality. Plants with monogenic resistance from *B. rapa* ssp. *sylvestris* initially had 70% mortality; however by 2006 plant mortality had fallen to 25%. Thus rotation of canola cultivars reliant on different blackleg resistance genes may be a future method of increasing the longevity of canola cultivars and thus reducing yield loss caused by the blackleg fungus in Australia.

Introduction

Leptosphaeria maculans (blackleg) is the most damaging disease of *Brassica napus* (canola) worldwide. In Australia the disease is controlled primarily through genetic resistance, cultural practices and use of fungicides to protect seedlings. The main sources of blackleg resistance in Australian breeding programs originate from Japanese spring lines and French winter lines. Two types of blackleg resistance are utilised, monogenic total resistance (controlled by major genes), which is efficient from the seedling stage, and polygenic partial resistance which is effective at all growth stages. However, *L. maculans* is classified as having a high probability of overcoming resistance genes because it reproduces both sexually and asexually, it is capable of mutation, it has a large population size and its gene flow is vast and extensive due to windborne ascospores (McDonald and Linde, 2001).

Quantitative resistance is used in most Australian canola cultivars as it is the most stable type of resistance. A major effort has therefore been maintained in this breeding strategy (Salisbury *et al.* 1995). However, quantitative resistance needs to be renewed regularly to stay ahead of changes in the pathogen population. There is some evidence that polygenic resistance has eroded over time (Gororo *et al*,. 2004).

The use of major gene resistance in Australia (sylvestris-derived resistance) resulted initially in considerable yield improvements but was overcome in just three years of commercial production (Li *et al.*, 2003; Sprague et al. 2006). Blackleg resistance has also been overcome in Europe where up to six major resistance genes are no longer effective against the blackleg pathogen (Rouxel *et al.*, 2003).

General strategies for major gene resistance deployment include use of single major genes in isolation, rotation of resistance genes in space and time, pyramiding different resistance genes, deployment of different resistance genes regionally and the use multilines or mixtures (McDonald and Linde 2001).

The short life of sylvestris resistance indicates that single major gene use in isolation is likely to fail in Australia due to rapid breakdown of resistance genes. Rotation in space and time is a feasible option as farmers already do this with herbicides and also have adopted recommendations to sow canola crops away from blackleg inoculum. Regionally deployed resistance is a good option but practically very difficult. Pyramiding of major genes and quantitative genes is also a viable option, especially once molecular markes become available through projects such as the National Brassica Molecular Marker project.

This paper reports on field experiments designed to test if rotation of major and polygenic blackleg resistance genes can actually reduce blackleg severity and potentially reduce the ability of the blackleg fungus to overcome resistance genes.

Material and Methods

Field Sites

Two field sites were chosen. One site at Lubeck (approximately 30 km south of Horsham, Victoria) had a cropping history of sylvestris based cultivars until 2003 but resistance breakdown did not occur. The other site at Bordertown, South Australia, also has a cropping history of sylvestris based cultivars with resistance being overcome by populations of the blackleg fungus in 2003. Data from both sites have been combined in Figures 1 and 2.

Rotation field experiment

At both sites canola cultivars were grown on canola stubble for three consecutive years. Each year a cultivar with a different source of blackleg resistance was sown. In 2003 the paddocks were sown to a sylvestris based cultivar, Surpass603CL; in 2004 one hectare plots were sown to the polygenic cultivar ATR-Beacon; in 2005 the one hectare plots were sown to the European winter cultivar Columbus (containing major gene resistance).

Pots of canola plants containing the following range of blackleg resistances were placed on the stubble for each year of the experiment. Natural infection was allowed to occur, the plants assessed for internal blackleg infection at plant maturity and plant mortality. The sources of blackleg resistance used were: polygenic resistance cv. ATR-Beacon, *B. juncea* cv. JR46, European winter line cv. Columbus and sylvestris resistance cv. Surpass 400.

Results

In 2004, ATR-Beacon (polygenic resistance) plants placed onto canola stubble from sylvestris based resistant Surpass 603CL, had very low levels of blackleg infection. ATR-Beacon had only 40% internal infection and 6% plant mortality. Normally canola sown into canola stubble would have more that 60% plant mortality. In 2005, ATR-Beacon was placed onto ATR-Beacon stubble but internal infection levels actually fell and mortality was similar to 2004 levels. By 2006, ATR-Beacon on three years of stubble (2003-sylvestris, 2004–polygenic, 2005-winter) had internal infection had of just 20% and plant morality of 4% (see Figures 1 and 2).

Where the cultivar with sylvestris-derived resistance was placed onto stubble of this cultivar, the internal infection was over 80% with nearly 70% plant mortality. Twelve month later the internal infection was similar but the plant mortality had halved. By 2006 (2 years since exposure to sylvestris stubble) internal infection had halved and plant mortality had fallen from 70 to 25%.

For the other sources of blackleg resistance used in this experiment, the European winter internal infection was similar in 2004 and 2005 (2006 data not yet available), but by 2006 no plants died. The *B. juncea* lines had lower levels of internal infection by 2006 but plant died due to stem canker.

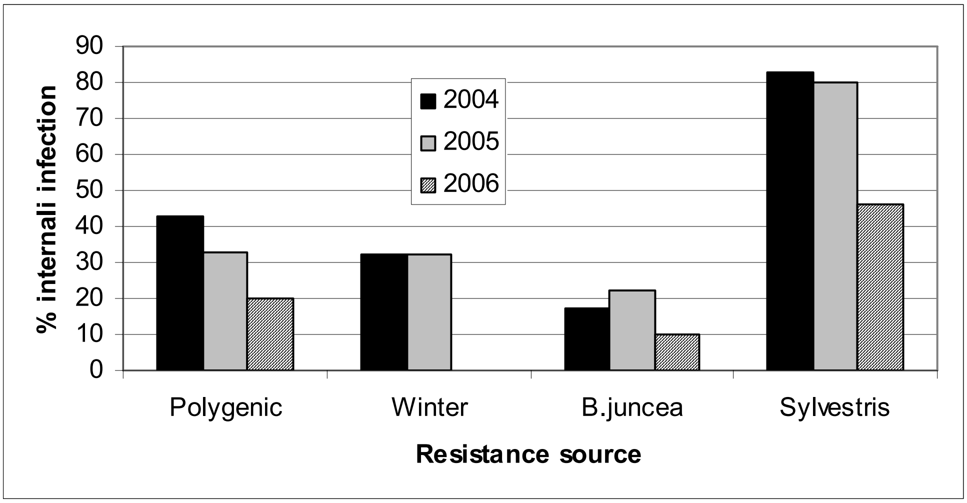

Figure 1. Blackleg internal infection severity on different sources of blackleg resistance

Discussion

These results suggest that rotating canola cultivars that are reliant on different blackleg resistance genes may reduce blackleg severity and the risk of blackleg resistance genes being overcome by the blackleg fungus.

As populations of *L. maculans* isolates are genetically very diverse, that isolates able to attack most sources of blackleg resistance probably already exist. However, they increase in frequency when consistently exposed to a particular resistance source. For instance on Eyre Peninsula (south Australia) within three years the population of *L. maculans* changed from a low frequency of strains unable to attack sylvestris-derived resistance to a high frequency of strains that were virulent on this resistance source.

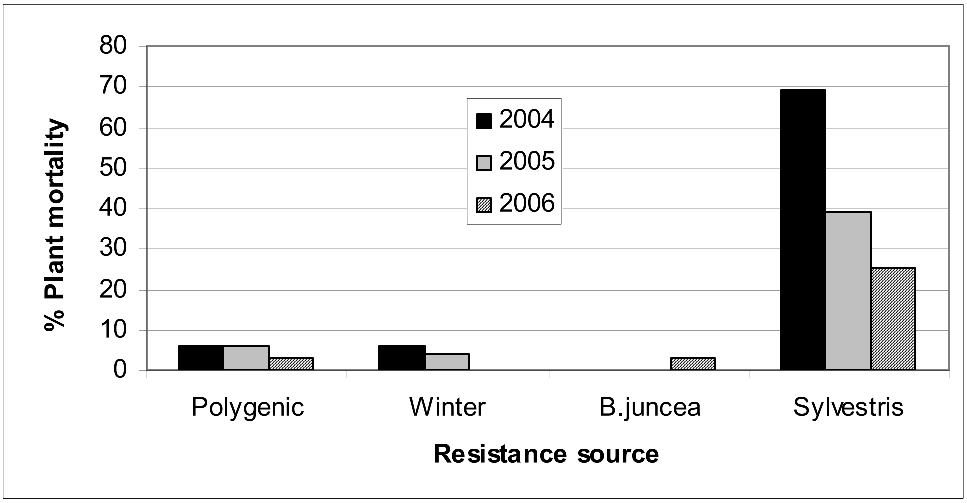

Figure 2. Blackleg plant mortality % on different sources of blackleg resistance

Given that *L. maculans* responds so quickly to new sources of blackleg resistance the Australian canola industry must develop production systems that do not expose the same resistance genes to the blackleg fungus for consecutive years. Rotation of resistance genes may be a method of reducing the frequency of blackleg strains that are capable of overcoming particular sources of resistance.

If such a system proved to be reliable over time, farmers would need to be trained to adopt this practice. Potentially farmers would be able to grow and subsequently benefit from using cultivars with resistance conferred by major genes. However they would need to be aware of the risks and be practicing suggested management strategies.

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