# Break crops for disease and nutrient management in intensive cereal cropping

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**Abstract**
The use of break crops in crop rotations provides options to better manage soil biological functions by changing populations and activities of beneficial and plant pathogenic microorganisms. Plant species and the residues of different plant species vary in their effects on the abiotic and biotic properties of the rhizosphere.These rhizosphere interactions affect the biological populations and activities related to carbon turnover, nutrient supply and disease suppression. For the lower fertility soils of the Mallee region, an improved understanding of how break crops influence the functional diversity of microbial communities will help to identify and maximize the biological benefits of break crops to the following cereal crop. All break crops provided some yield benefit compared to continuous wheat, the magnitude of the effect varied across soil types. Non-cereal break crops substantially reduced populations of soil-borne pathogenic and mycorrhizal fungi and altered diversity and activity of microbial communities involved in C, N and P cycling. The key benefits of the medic-based pasture and grain legume break crops were increased soil N from fixed N in residues, whereas the benefits from mustard and canola were from a reduction in *Rhizoctonia solani* AG8 inoculum while canola, mustard and rye all increased microbial activity and N mineralisation potential. The reduction in *Rhizoctonia solani* inoculum and mycorrhizal fungi after canola and mustard lasted for one following wheat crop only whereas nutrient related benefits may extend for more than one following cereal crop.

**Key Words**
Crop rotation, *Rhizoctonia solani*, mycorrhizae, microbial biomass, mineralisation, molecular techniques

## Introduction

Crop rotation provides options to better manage soil biological functions by modifying populations and activities of beneficial and plant pathogenic microorganisms. In addition, incorporation of flexible break options will help address some of the challenges associated with weed and disease management, fertilizer costs and soil organic matter management in continuous cereal systems (Kirkegaard et al. 2008). Plant species vary in their influence on the rhizosphere and the quality (e.g. C:N ratio) and quantity of crop residues, all of which can affect the populations and biological activities related to C turnover, nutrient supply and disease suppression (Gupta et al. 2011a). For example, grain and pasture legumes provide benefits through symbiotic $N_2$ fixation whereas brassica crops modify the activity of different microbial groups involved in C and N turnover and are known to affect the populations of soil fungi. Soil microorganisms also play a vital role in the dynamics of soil P and their activities mediate the availability and uptake of P by plants.

Soilborne diseases such as rhizoctonia bare patch are one of the major constraints to cereal productivity in large areas of southern Australian agriculture. The incidence and severity of Rhizoctonia bare patch (caused by *R. solani* AG8) depends on the amount of Rhizoctonia inoculum, composition and activity of the soil biology community (inherent suppressive activity) and available soil N over the fallow period (Gupta et al. 2010). For the low fertility Mallee soils, an improved understanding of how rotation (break) crops influence composition and activities of microbial communities will help to maximize benefits from biological functions to the following cereal crop. The aim of our work is to evaluate the short-term benefits of alternate rotations through improved soil fertility (microbial activity, N supply potential, P availability) and reduced risk of Rhizoctonia disease in the following wheat crop in different landscape positions (hill (dune), mid-slope and swale (flat)) at Karoonda in South Australia.

## Methods

Crop rotation experiments with five break crops (peas or lupins, volunteer medic-based pasture, cereal rye (grain or hay) and canola) and continuous wheat were established in 2009 and 2010 on the hill (sand), mid-slope (sandy loam) and swale (loam) followed by wheat in 2010 and 2011. Planting rates and fertiliser applications were the same across all soil types but differed according to crops. All treatments were replicated four times in a randomised complete block design experiment on each of the three locations (Davoren et al. 2012). Soil samples were collected during the summer and at sowing of 2010 and 2011 crops and analysed for various nutrient and biological properties. Soil biological properties were measured using biochemical (e.g. microbial biomass - MB; P enzyme activity), incubation (catabolic diversity and nutrient mineralization) and DNA based (*R. solani* AG8 and Mycorrhizae) methods. Soil samples were also collected within the break crops during October 2010 for *R. solani* inoculum DNA analysis. Plant growth and grain yield were monitored for all crops. All growing seasons were above Decile 5.

## Results and Discussion

*Yield*

Most break crops provided some yield benefit in the order of 0.1-1 t/ha compared to continuous wheat, the magnitude of the effect varied with the crop and soil type (Table 1). Legume breaks gave the most consistent yield advantage to subsequent wheat crops across the three soil types, while canola offered a significant break benefit in the heavy swale soil.

**Table 1. Wheat yield and yield gain (in brackets compared with continuous wheat) in 2011 and 2010 following 2010 and 2009 break crops, respectively.**

| | Swale | Mid-Slope | Hill |
|---|---|---|---|
| 2011 Wheat Yield following 2010 Break Crop and (yield difference to continuous wheat) | | | |
| Legume (lupins) | 4.7 (0.93) | 4.1 (0.60) | 4.3 (0.70) |
| Brassica (canola) | 4.5(0.71) | 3.7 (0.27) | 3.9 (0.31) |
| Cereal Rye Grain | 3.7 (-0.02) | 3.4 (-0.08) | 4.2 (0.64) |
| Cereal Rye 'Grazed' | 3.7 (-0.03) | 3.5 (0.02) | 3.9 (0.26) |
| Pasture | 4.3 (0.52) | 4.2 (0.73) | 3.8 (0.18) |
| LSD within site P<0.05 | 0.42 | 0.41 | ns |
| 2010 Wheat Yield following 2009 Break Crop and (yield difference to continuous wheat) | | | |
| Legume (peas) | 6.1(0.95) | 5.0(0.96) | 4.0(0.96) |
| Brassica (mustard) | 6.3(1.13) | 5.0(0.95) | - |
| Cereal Rye Grain | 5.9(0.71) | 4.4(0.36) | 3.3(0.28) |
| Cereal Rye 'Grazed' | 6.1 (0.91) | 4.5(0.49) | 3.0(0.21) |
| Pasture | 5.9(0.73) | 4.7(0.63) | 4.1(1.12) |
| LSD within site P<0.05 | 0.45 | 0.56 | 0.68 |

*Nutrition*

The nutrient supply potential of a soil through biological activity is a product of microbial activity, turnover of microbial biomass (MB) and crop residue, and soil organic matter. Significant effects of rotational crops on microbial biomass C, N and P, and nutrient mineralisation potential, compared to continuous wheat, were observed at sowing of 2010 and 2011 wheat crops). The amounts of MB carbon, nutrients and nutrient mineralisation potentials were higher in the swale (MB-C 79% higher) compared to the hill and mid-slope which can be attributed to the greater amounts of C from the crop stubbles and roots in the swale (>2.5 t C/ha) compared to that in the hill (~1.0t C/ha). Microbial biomass was generally higher after canola and cereal rye in the hill (ave. >35% higher) and canola, pasture, lupins in the swale (ave. >50% higher). The microbial catabolic diversity (ability of microorganisms to utilize various carbon substrates) in surface soils over the 2010/2011 fallow period were higher after rotational crops such as canola, lupins and pastures compared to cereals (wheat and rye).

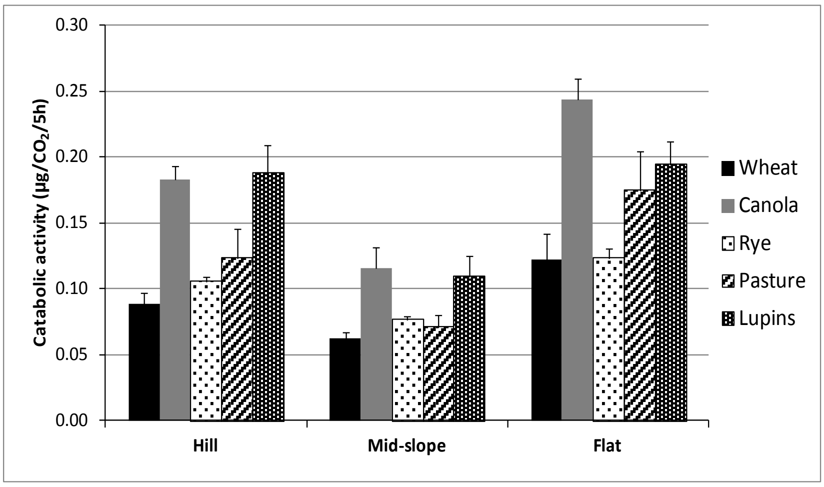


**Figure 1. Soil microbial catabolic activity in March 2011 as influenced by previous season rotational crops at the three positions in the landscape. Error bars represent standard error of means.**

In general, N mineralisation potential was highest after legume crops, canola and rye and lowest in the continuous wheat treatment in all three experiments (Table 2).Rotation crop based differences in microbial properties were reflected in the amount of mineral N in the soil profile at sowing. Some of the effects include: (i) in the continuous wheat treatment, mineral N in the soil profile at sowing was highest in the swale and there were no significant differences between the hill and mid-slope, (ii) mineral N was higher in the 1st year after rotational crops compared to 2nd year after break crops, (iii) mineral N was highest after pasture and lupins compared to after canola and rye, (iv) in the swale mineral N after canola and rye was lower than continuous wheat. Overall, break crop effects on N availability are due to the changes in mineralization-immobilization processes as shown here and also inputs from $N_2$ fixation by symbiotic and free-living $N_2$ fixing bacteria (Gupta et al. 2011a).

**Table 2. Nitrogen mineralisation potential[#] of surface 0-10cm soils (kg N / ha) and mineral N in the profile at sowing in 2010 and 2011 as influenced by previous year's rotational crops.**

| Location | Crop | N mineralization potential kg N / ha | | Min N in 1M profile kg N / ha | |
|---|---|---|---|---|---|
| | | 2010 | 2011 | 2010 | 2011 |
| **Hill** | **Canola** | - | 13.48 c | - | 92 |
| | **Lupins** | - | 15.40 d | 82 | 117 |
| | **Pasture** | - | 15.29 d | 95 | 135 |
| | **Rye** | - | 11.50 b | 54 | 106 |
| | **Wheat** | 5.07 | 9.11 a | 72 | 71 |
| **Mid-slope** | **Canola/Mustard** | 11.28 | 14.85 b | - | 89 |
| | **Lupins** | - | 13.51 b | 87 | 155 |
| | **Pasture** | 12.67 | 20.79 c | 118 | 115 |
| | **Rye** | 11.89 | 14.08b | 86 | 111 |
| | **Wheat** | 10.37 | 9.09 a | 87 | 75 |
| **Swale** | **Canola/Mustard** | 19.72 | 21.31 bc | 146 | 106 |
| | **Lupins** | - | 22.54 c | 146 | 151 |
| | **Pasture** | 13.75 | 27.78 d | 164 | 132 |
| | **Rye** | 26.40 | 19.00 b | 128 | 106 |
| | **Wheat** | 8.50 | 13.29 a | 134 | 123 |

[#] Determined using a laboratory incubation method; 2011 values for each location followed by different letters are significantly different from each other at $P<0.05$

The importance of colonization of plant roots by AM fungi for enhanced P nutrition is well known. With their extensive network of mycelia, AM fungi absorb and translocate P from a large soil volume to the plant. However, not all plant species are colonized by AM fungi, for example canola and lupin are considered non-mycorrhizal plant species. Canola and lupin crops in 2010 significantly reduced the amount of AM fungi DNA present at sowing of the 2011 wheat crop, in all three soil types (Figure 2). However, these reductions were largely recovered by the end of second wheat crop following canola or lupins.

Soil enzyme activity involved in P release from less available pools (data not shown) was greater after lupins, canola and rye compared to after wheat suggesting that break crops alter the contribution of various biological processes involved in P availability. Detailed analysis of the functional (genetic) diversity of soil microorganisms in soils collected in March 2011, showed that wheat-canola had the highest between-crop differences followed by wheat-pasture and wheat-rye treatments (Gupta et al. 2011b).

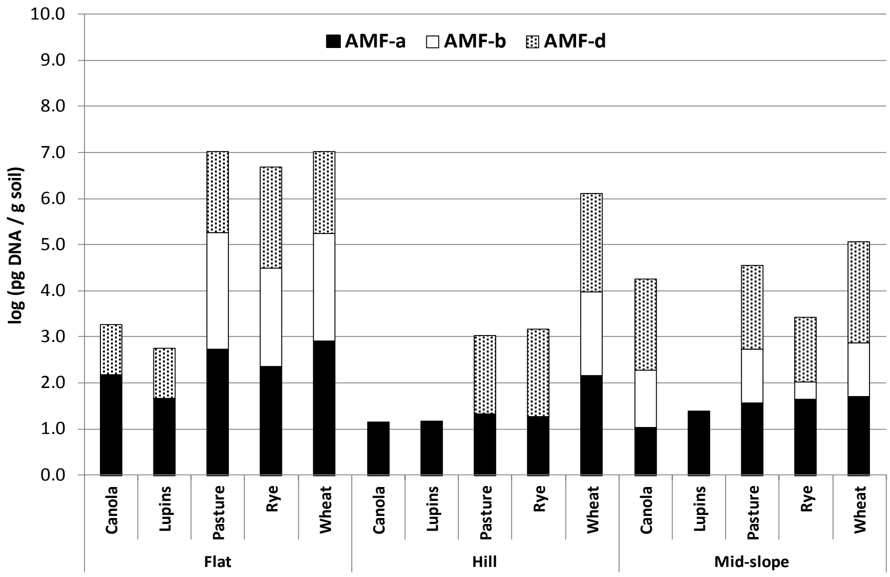


**Figure 2. Effect of previous season break crops on the amount of mycorrhizal fungi DNA at sowing of the 2011 wheat crop. AMF-a, b and d represent different phenotypic groups of Mycorrhizae. LSD values for break crop effect within a location = 0.36, between locations = 0.26.**

*Disease*

There was a build-up of Rhizoctonia inoculum through the 2010 crop season in all crops, and was lowest in the canola crop and highest in the wheat crop in all soils (Figure 3). Differences in the inoculum after 2009 rotation crops were reflected in the disease incidence in the 2010 wheat crop. Reduced inoculum levels following mustard (2009) or canola (2010) and pasture were correlated with lower levels of disease and increased grain yield ($R^{=}0.86$; 2010 wheat yields). Disease inoculum in the cereal rye crop was higher than in the lupins and pasture crops in the hill and mid-slope. Similar effects of crop type based changes in Rhizoctonia inoculum levels were found in experiments in Eyre Peninsula, SA and NSW (Gupta et al. 2010). The effect of disease incidence on yield of wheat after canola compared to that after cereal rye (on swale and mid-slope) highlights the importance of cereal disease control from break crops in the Mallee soils. While the root and stubble carbon from cereal rye crop increased microbial biomass and N mineralization potential, cereal rye did not reduce Rhizoctonia disease in the following wheat crop. However, disease incidence was found to be associated with differences in a combination of inoculum levels and microbial properties e.g. swale soils with higher microbial activity and catabolic diversity showed lower disease incidence. Higher rainfall during the summer reduced the inoculum loads by sowing in 2011, resulting in a decrease in disease risk category for all treatments (Gupta et al. 2010). Due to the lower inoculum at sowing, disease incidence in the 2011 wheat crop was lower than that in the 2010 wheat crop and there were no significant differences in disease incidence after cereal rye, pasture and wheat in the swale and mid-slope (data not shown).

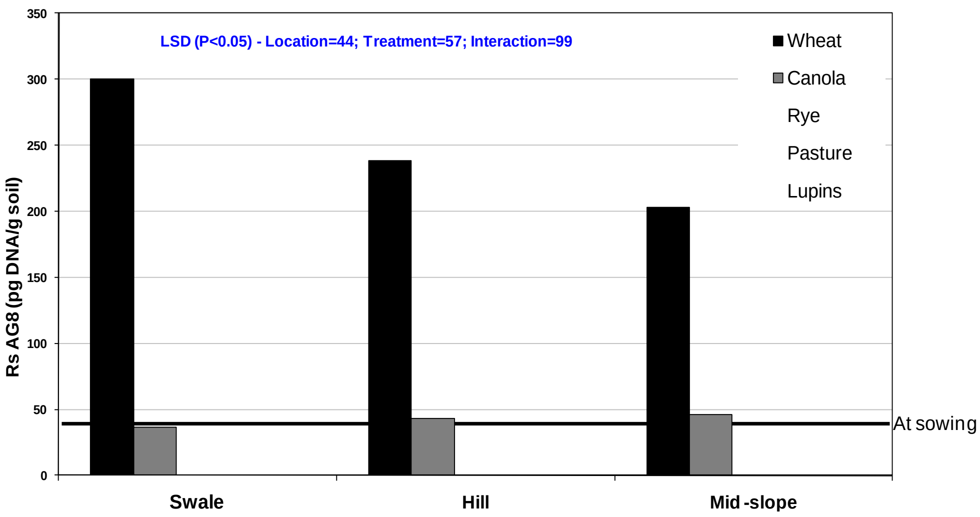


**Figure 3. *Rhizoctonia solani* AG8 inoculum levels in soils under different crops during the 2010 cropping season.**

## Conclusion

The use of break crops in continuous cereal rotations resulted in substantive yield, nutrition and disease based benefits in decile 5 and above growing seasons in the Mallee environment. Yield benefits of rotational crops for wheat crops can be attributed to a reduction in Rhizoctonia disease incidence coupled with improved soil biological activity in terms of catabolic N supply potential, N inputs from symbiotic $N_2$ fixation by legumes and changes in biological properties involved in P availability. In addition, residual water following break crops would also have contributed to part of these yield gains. The magnitude and relative importance of the components of the break are both season and soil type dependent.

## Acknowledgements

Financial support was provided by the CSIRO and GRDC (projects EC248, CSA00025, CSE00048, CSP 00150). Authors wish to thank the Loller family for the provision of land and acknowledge the collaboration by the Karoonda Mallee Sustainable Farming advisory group.

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