Benefits of brassica break crops in the southeast wheatbelt

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Summary. Wheat yields are usually increased when grown following 'break crops' in a rotation. This can be partly attributed to reduced levels of soil borne disease pathogens. particularly take-all *(Gaeumannomyces graminis* var. tritici). Experiments in Europe and Australia have shown that *Brassica* crops such as canola (or edible rapeseed) *(B. napus)* and mustard *(B. juncea)* are more effective break crops than other species such as oats or linseed. The nature of these effects is unclear, although in some cases, the increased yield of wheat crops is associated with improved root growth or function. Two possible mechanisms include (a) the effect of brassicas on soil structure, and (b) the effect of *Brassica* residues on pest or disease organisms. A better understanding of these effects is necessary to maximise potential benefits within crop sequences.

Introduction

Alternative crops to wheat such as grain legumes and winter oilseeds are being increasingly grown in the cropping phase of wheat/sheep farms in south-eastern Australia (8). This trend reflects both lower wheat prices and an increasing awareness of the need to rotate crops to control soil-bome diseases. These 'break crops' (defined as species which do not host the takeall fungus (Gaeumannomyces graminis (Sacc.) von Arx and Oliver var. trate((Walker)]) (I) increase the growth of subsequent wheat crops by providing a period free of disease hosts, which reduces the inoculum levels available to infect subsequent crops. Grain legumes have the added advantage of removing less nitrogen from the soil.

Break crops may provide benefits beyond simply providing a period free of a disease host. Several experiments have shown that wheat yields vary significantly depending on the type of break crop grown. Reeves (12) found larger break crop benefits from lupins than from canola and attributed the difference to the fixation or saving of N by the legume. However, Angus *et al.* (I) found significant differences in break crop effects of several non-legume species which could not be explained by differences in residual N after the break crops and could not be overcome with applied N. The largest break crop effects were observed after the *Brassica* crops canola *(B. napus)* and Indian mustard *(B. juncea),* with mustard being superior to canola. The water use efficiency of wheat crops grown after brassicas has also been shown to be greater than that of wheat grown after lupins, peas or oats with the effects most noticeable in drier seasons (8).

In northern Europe, where *Brassica* species (predominately rapeseed) have been part of the rotation for several decades, longterm experiments have shown 10-26% increases in wheat yield in rotations with brassicas compared to wheat monoculture (5) or those involving other cereals such as barley, oats or rye (14). The effects could not be entirely attributed to disease control and could not be substituted with applied N.

This paper examines the nature of *Brassica* break-crop effects. Possible mechanisms of the superior break-crop effect and opportunities to maximise these benefits under Australian farming conditions are considered.

Magnitude of break crop effects

Table I summarises dry matter and yield data for several experiments which investigated the effect of different non-legume break crops on the growth and yield of wheat in southern New South Wales. While early growth is consistently increased by Brassica break crops, the effect on final grain yield depended on seasonal conditions.

In seasons when rainfall is adequate throughout the growing season (as at Barellan 1989 and Temora 1991), the early growth and yield advantage of wheat grown after the *Brassica* break crops was in the range of 15-25% (compared with wheat after wheat) while oats provided only 2-14% yield advantage. This is consistent with the 10-26% yield increases reported for wheat after rapeseed in longterm rotation trials in northern Europe where water availability rarely limits growth (5, 14). In the same trials, rotations with other cereals increased wheat yields by only 5%.

Table I Effect of previous crop on dry matter production and yield of wheat at three sites in southern NSW.

At Ariah Park in 1991. where conditions became dry after anthesis the early growth advantage provided by the break crops was not translated into yield. At anthesis there was greater dry matter production by wheat after the brassicas than after wheat, but no additional growth during the post anthesis period during which time there was no significant rain. The wheat after wheat maintained growth during the post anthesis period presumably as a result of more soil water remaining at anthesis due to slower early growth. Although the effects of break crops on grain yield are dependent on seasonal conditions, the consistent increases in early dry matter production represent a significant increase in yield potential.

How do brassica break crops influence the yield of subsequent wheat

The effect of *Brassica* break crops appears to go beyond simply providing a period free from a pathogen host. Although the nature of additional benefits remain unclear, several studies have related the yield advantage in subsequent crops to improved root growth and function. In experiments in southern Germany from 1970-84 (14), wheat in rotation with rapeseed yielded on average 15% more than wheat in monoculture. Only a minor part of the yield increase could be attributed to the reduced incidence of the fungal diseases eye spot and take-all, or cereal cyst nematodes. However, from an early stage the root growth of wheat following rapeseed was always superior to that after wheat or other cereals (15). In the Barellan experiment (I), wheat grown after Indian mustard extracted more water and nitrogen from the subsoil after anthesis than wheat following the other break crops indicating improved root growth and/or efficiency. In both of these studies the mechanism of the effect remains unclear. Here we consider two possible mechanisms for improved root growth of wheat following *Brassica* break crops compared to other break crop species which may explain the greater effectiveness of *Brassica* break crops.

Biological drilling

Taprooted crops may improve soil structure by penetrating dense soils and creating stable pores which can be utilised by subsequent crops. The evidence for this process, often termed 'biological drilling', has recently been reviewed (6). Although there is considerable evidence that this process occurs, the benefits arising from improved subsoil structure have been small relative to other benefits such as disease control and nutrient availability. The large taproot of the *Brassicas* such as canola and mustard make them candidates for such speculation. It has been shown that in some cases *Brassica* roots can penetrate 40-70 cm deeper than a range of other crops such as wheat, linseed and grain legumes (6). That wheat crops can benefit from the larger or deeper pores created by these crops remains to be demonstrated.

Although the benefits from structural improvement at depth remain uncertain, there is evidence for improvements to surface structure resulting from *Brassica* crops. In longterm trials in Europe (16) the aggregate stability of the surface soil increased in rotations containing rapeseed. In Australia. increased infiltration and reduced runoff were measured on a paddock previously sown to canola compared to one sown with wheat, both with or without surface residue removed (10). The large vertical channels left by the decayed taproot were thought to be responsible. Improvements in surface structure may increase root growth and increase the plant available water in the soil profile.

Previous Crop	Dry Matter (g/m2) and grain yield (t/ha)							
	Barellan 1989[a]		Temora 1991		Ariah Park 1991			
	DC30[b]	Yield	DC30[b]	Yield	DC30[b]	Anthesis	Matulity	Yield
Indian Mustard	99	3.77	-	-	287	814	830	3.20
Canola	100	3.58	278	4.05	264	855	770	3.23
Linseed	96	3.40	-	-	-	-	-	-
Oats	81	3.31	219	3.72	-	-	-	-
Wheat	75	3.23	201	3.26	228	680	801	3.38
l.s.d.(P=O.O5)	20	0.18	44	0.48	34	84	ns	ns

[a]from Angus *et al* (1)
[b]DC30 from Zadoks Development Code refers to the start of stem elongation.

Biological fumigation

The superior break crop effect of *Brassicas* may result not only by denying a host to pathogens but by actively suppressing pathogen activity. The active suppression may be due to the activity of the breakdown products of a family of glucosinolate compounds found in their tissue. High levels of glucosinolates are undesirable in seed required for edible oil (canola). However there are about ten different glucosinolates found in *Brassicas* which vary in concentration between species and different plant parts (13). The breakdown products of glucosinolates include isothiocyanates, which arc powerful biocides. They are formed by an hydrolysis reaction when the glucosinolates come into contact with the myrosinase enzyme during decomposition in the soil. The biocidal effects of *Brassica* residues are currently used in practical farming systems throughout the world. In northern Germany, mustard, rapeseed and fodder radish are grown as intercrops in sugar beet rotations to control sugar beet nematodes (2). Nematode adults are able to infect the roots, but egg development is affected resulting in a ratio of 1:100 male to female offspring. This effectively reduces the next generation of nematodes allowing sugar beet to be grown. Similarly, in the irrigation area of the Columbia River valley in Washington State, USA, *Brassica* crops are grown as green manure and ploughed in to control potato cyst nematodes (9). Up to 80% reduction in eggs and mature adults has been achieved. More effective control has been demonstrated with rapeseed varieties containing higher glucosinolate levels. In Canada better control of the nematode *Pratylenchus penetrans is* achieved using mustard green manure rather than rapeseed apparently due to a higher level of the butenyl form of glucosinolate in the mustard tissue (G.Santo, pers. comm. 1992). Incorporating undecomposed *Brassica* residues or green manure crops in soil has also been shown to repel wireworms (4), reduce the fungal disease, *Aphanomyces,* in peas (3) and inhibit the germination of wild oats (7).

These examples of the biocidal activity of *Brassica* residue breakdown products indicate the potential for breakcrops to influence the growth of subsequent crops by reducing populations of pest organisms. In the longterm European studies, it was concluded that the *Brassicas* resulted in a microbial environment which was favourable for the growth of wheat roots, although the organisms involved were not identified. The effect of *Brassica* residues on the growth of wheat disease organisms has not been investigated.

Negative effects of Brassica break crops

In some cases residue breakdown products may have deleterious effects on subsequent crops. In Canada, where wheat is often sown directly into undecomposed canola stubbles, seedling growth is reduced by phytotoxins released from the stubble (18). Similar effects have been observed in Australia (11) although in many situations stubbles are grazed, burnt or in an advanced stage of decay prior to sowing subsequent crops. The exception would be after a dry summer in southern Australia where the stubble remains undecomposed and where wheat is direct drilled. Harvesters may also concentrate stubble in bands creating areas with heavy stubble loads.

Brassicas are known to be non-mycorrhizal and so they may affect the growth of subsequent crops that are dependant on mycorrhizae. The growth of linseed, which depends on mycorrhizae has been shown to be adversly affected by previous canola crops as a result of reduction in mycorrhizal populations necessary for phosphorus uptake (17).

Practical implications

A greater understanding of the break crop effects of Brassicas will help realise the potential benefits within a cropping sequence. If biocidal effects are confirmed, the development of a canola variety with low levels of glucosinolates in the seed (required for edible oils) but high levels in the roots would provide an ideal break crop for dryland agriculture. A fodder rape with biocidal activity could be grown on an opportunity basis in summer to reduce pest organisms prior to a cereal crop. The development of new Brassica crops such as Indian mustard may also provide opportunities to increase biocidal activity due to higher concentrations or different forms of glucosinolate in the tissues.

Biological drilling effects of brassicas could be enhanced by increased plant density, tillage to encourage deeper rooting and soil management to preserve macropores. It is like') that benefits from improved macroporosity will increase as more tap-rooted crops are included in the rotation.

The advantages of brassicas in crop sequences may not apply in all regions. For example, in a dry region the excessive vegetative growth of wheat after a *Brassica* may result in rapid early water use, reducing that available for grain filling during a dry spring. If the apparent biocidal effects of *Brassicas* affect mycorrhizae there may also be limitations to their use as break crops in situations where mycorrhizal activity is important for the growth of subsequent crops.

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