A review of break-crop benefits of brassicas

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ABSTRACT
Wheat grown after *Brassica* crops normally yields more than wheat grown after wheat. Previously we reviewed 33 experiments and concluded that wheat after canola yielded about 19 % more than wheat after wheat and that the gross margin of a canola-wheat sequence was 27 % greater than a wheat-wheat sequence. Further analysis of other published, replicated experiments revealed that the mean increase in wheat yield after brassicas was better represented as a fixed amount rather than a percentage. The mean yield benefit of canola (B napus) to subsequent wheat yield was similar (0.8 t ha-1) over 180 experiments where wheat yield varied from 1.1 to 9.5 t ha^{-1}. Over 36 experiments where canola and juncea canola (*B juncea*) were compared the break-crop effects were identical at 0.6 t ha^{-1}. Part of the reason for the additional wheat yield is increased uptake of soil water and nutrients, which may explain the fixed, rather than percentage, increase in mean yield as a response to the limited supply of these resources. The earlier conclusion about canola-wheat providing a 27 % increase in gross margin over wheat-wheat must be revised since the financial benefit is relatively greater at low levels of wheat yield. A canola-wheat sequence provided an 85% increase in gross margin over wheat-wheat at low (2 t ha^{-1}) yield levels but only 3% at high (6 t ha^{-1}) yield levels.

Key words: canola, juncea canola, crop sequence, rotation, wheat

INTRODUCTION

Cereals grown after broadleaf crops generally yield more than those grown after other cereals due to several processes that constitute the break-crop effect. A survey of 33 experiments in Australia previously suggested that growing a *Brassica* crop rather than wheat increases the yield of the following wheat crop by 19% (Angus et al. 1999, Angus et al. 2001, Kirkegaard et al. 2008). The yield increase is believed to be mostly because the brassica crop deprives soil-borne cereal pathogens of a host so that inoculum levels are depleted and they do little damage to the following cereal crop. Other factors involved may be that brassicas stimulate mineralisation of soil nitrogen (Kirkegaard et al. 1999; Ryan et al. 2006) and suppress arbuscular mycorrhizal fungi which can be responsible for parasitic loss of soluble carbohydrate from cereal roots (Ryan et al. 2005). A further benefit of brassicas is that they improve the reliability of the response to nitrogen fertiliser by the following wheat crop (Angus et al. 1989). The increased area of canola in Australia during the 1990s triggered an increase in the use of N fertiliser; the combination of break crops and N fertiliser was responsible for much of the large increase in wheat yield during that decade (Angus 2001). *Brassica* break crops give environmental benefits because they improve soil structure (Kirkegaard et al. 2008) and the healthy wheat crops growing after brassicas extract more water and mineral nitrogen from the soil than wheat after wheat (Angus et al. 1991; Kirkegaard et al. 1994).

There may be other benefits of brassicas for the following crop that do not show up in experiments but which are nevertheless important. These include a reduction in the density of weeds growing in brassica stubble, which, combined with the small amount of stubble means that the following crop can be sown earlier than after a cereal because there is less delay for weed control and stubble burning.

The break-crop effect of brassicas has economic benefits for the cropping system. For example in the survey of experiments where brassicas increased the yield of the following wheat crop by 19%, the canola-wheat sequence had an average gross margin that was 27% greater than for the wheat-wheat sequence. In this case most of the increased gross margin came from the increased wheat yield rather than from the canola (Angus et al. 1999).

Despite the benefits of break crop sequences, in 2010 brassicas occupied only 1.7 m ha (7 %) of the 24 m ha of Australian dryland crops, and all broadleaf crops occupied only 3.4 m ha (14 %) of the crop area. Clearly most cereal crops are not preceded by a break crop and the national cereal yield would be increased if the area broadleaf crops expanded (Robertson et al. 2010). Greater recognition is needed of the value of break crops in general, and particularly of brassicas in view of the options now provided by juncea canola, early maturing cultivars and herbicide resistance. In this study we examine a more extensive set of data on the break-crop value of brassicas than was available a decade ago to see if they provide evidence that could promote more efficient cropping systems.

MATERIALS AND METHODS

We reviewed experiments comparing yields of wheat after wheat with wheat after canola or juncea canola. Some were long-term rotation experiments but most were biennial crop sequence experiments. Of the 180 canola experiments, 53 were in Australia, 100 in Sweden and the rest in other parts of Europe and North America. Most of the 42 experiments with juncea canola and the 36 experiments with both canola and juncea canola were in Australia. The data are presented in graphs in which each point represents the results of two treatments in a replicated experiment in one season. The data sources are not cited because of space restriction but will be presented in a larger report.

Another evaluation of break crops came from a survey of 52 whole-paddock wheat yields conducted by the Harden-Murrumburrah Landcare Group in 1995. This survey obtained data from farmers about sowing date, soil nutrient status, fertiliser application, pH, lime, rainfall and previous crop.

RESULTS

Review of break-crop experiments

Data collated from 180 canola experiments and 42 experiments with juncea canola where the grain yields of wheat grown after a *Brassica* were compared to yields of wheat following a previous wheat crop are presented in Fig. 1. Yields of wheat grown after brassicas were generally greater than wheat grown after wheat (i.e. most of the data points in Fig. 1 are above the 1:1 line). Yields of wheat following canola were greater than yields of wheat following wheat in 156 of 180 experiments (Fig. 1a) and yields of wheat following juncea canola were greater than wheat following wheat in 31 of 42 experiments (Fig 1b).

A regression equation (1) fitted to all the data in Fig. 1a relating yield of wheat after canola (Y_{cw}) to the yield of the wheat after wheat (W_{ww}). The intercept of 0.80±0.16 and the slope of 1.00 indicate that the average yield response of wheat to a preceding canola crop is 0.80 t ha^{-1}, with no change in response over the range of observed yield. Standard errors of coefficients are shown in brackets.

$$Y_{cw} = \underset{(\pm 0.16)}{0.80} + \underset{(\pm 0.04)}{1.00}\, W_{ww} \qquad r^2 = 0.77 \qquad (1)$$

A similar equation (2) fitted to the data in Fig. 1b.shows the yield of wheat after juncea canola (Y_{jw}) in relation to Y_{ww}. This shows a wheat yield response of 0.54±0.27 t $ha^{-1}$to a preceding juncea canola crop, again with no significant change in response over the range of observed yield.

$$Y_{jw} = \underset{(\pm 0.27)}{0.54} + \underset{(\pm 0.08)}{1.01}\, W_{ww} \qquad r^2 = 0.79 \qquad (2)$$

There was no significant difference between the regressions for canola sequences in Australia and other countries and not enough data from outside Australia for an equivalent comparison for juncea canola.

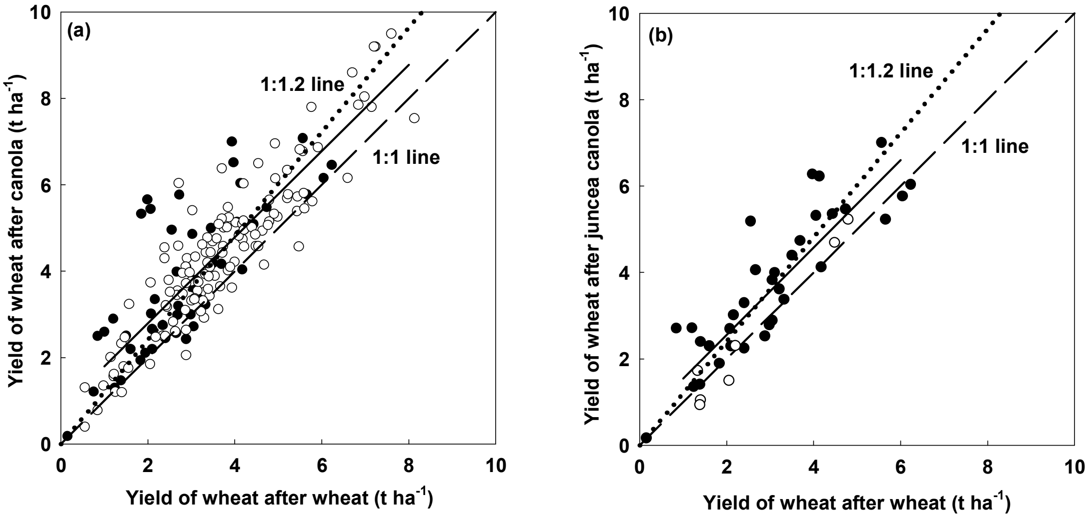

Fig.1. Effect on wheat grain yield of a previous crop of (a) canola and (b) juncea canola compared to yield of wheat after wheat. Solid points refer to experiments in Australia and open points to experiments elsewhere. The solid lines represent fitted regression equations, the dotted lines represent a 20% yield increase and the dashed lines represent equal yields.

Because the slopes of the lines for both equations are not significantly different from 1.0, we infer that the magnitude of the *Brassica* break crop effect is independent of yield level rather than a percentage of the yield of wheat after wheat. Table 1 shows wheat yield responses to preceding *Brassica* crops. The break crop effects of canola and juncea canola are identical when wheat yields are averaged over the 36 experiments in which both brassicas were included.

Table 1. Wheat yield and yield responses (t ha^{-1}) to previous *Brassica* crops from a survey of break-crop experiments. The standard deviations are shown.

Comparisons	Canola only	juncea canola only	Canola & juncea canola
Number of comparisons	180	42	36
Mean yield of wheat after wheat	3.45±1.53	2.93±1.50	3.12±1.53
Additional yield after canola	0.84±0.93		0.60±0.76
Additional yield after juncea canola		0.56±0.79	0.60±0.82

Farm survey

Paddock surveys in the Harden district during the 1990s examined variables and factors that were associated with wheat yield in a linear model. In these surveys the sowing date for wheat after canola was no earlier than for wheat after cereals or pasture. Averaged over four years of surveys, wheat grown after canola yielded 0.66 t ha^{-1} more than wheat grown after cereals or pasture By the last year of the survey there were relatively few paddocks where wheat was not grown after a break crop so the quality of these data are questionable.

Table 2. Wheat yield (t ha^{-1}) in relation to previous crops from farm surveys in the Harden district. Number of paddocks are in brackets.

	Yield after	
Year	Canola	Wheat, oats or pasture
1994	1.77 (18)	1.38 (12)
1995	5.43 (31)	4.57 (8)
1996	4.98 (27)	4.39 (11)
1998	3.69 (66)	2.90 (3)

DISCUSSION

In the review of experimental crops, the yield increase of wheat following a *Brassica* break crop was not a percentage of yield, as was previously reported, but the increase, although variable, did not change in relation to yields. There was no difference in break-crop benefit between canola and juncea canola. The reason that the mean response did not vary with yield level may be because the healthy roots of wheat following a break crop are able to extract more soil water and nutrients than wheat after wheat (Angus et al. 1991; Kirkegaard et al. 1994). The amount of available water and nutrients in the soil presumably limits additional yield.

The mean size of the break crop benefit in the Harden paddock survey was comparable with the value found in the experiments (Table 2). However the relatively small break crop effect in the survey of 1994 drought is not consistent with the relatively large effect shown at low yields in the experiments. This inconsistency may be due to disparities in the surveyed numbers of different crop sequences.

The reason for the variation in the wheat yield response to brassicas is not clear. It may be partly due to measurement errors, since a yield difference is a stern test of field data. Other reasons may be variation in level of pathogens, nitrogen status or mycorrhizal inoculum levels but data for these is not available for this data set. The wheat yield reduction after brassicas seemed, for the Australian experiments, to be associated with dry summer and autumn periods when loss of soil water by evaporation may have been greater from *Brassica* stubbles than wheat stubbles.

A consequence of the constant mean increase in response to *Brassica* break crops is that the profitability of *Brassica* break-crop sequences is relatively greater at low yield levels of the following wheat crop. Table 3 shows gross margin (gross returns less variable costs) for wheat-wheat and *Brassica*-wheat sequences at two yield levels. The gross margin for the *Brassica*-wheat sequences are calculated with the new assumptions of a mean increased wheat yield of 0.8 t ha^{-1} (BW+0.8) or the old assumption of a 20% increase (BW+20%). With the new assumption the additional gross margin is similar at the two yield levels when expressed in absolute terms, but is much greater in percentage terms (85%) at the low yield level than at the high yield level (3%). With the old assumption a *Brassica* break crop reduces gross margin at a low yield level. The source of the additional gross margin for a *Brassica*-wheat sequence at the low yield level is the additional wheat yield which more than compensates for a negative gross margin for a *Brassica*.crop.

This result has implications for the place of brassicas in cropping systems in dry seasons. The area of *Brassica* crops decreases when sowing is delayed, the soil is unusually dry or there is an expectation of low rainfall. There is a cutoff date after which it is unprofitable to sow a *Brassica* crop (James Hunt, this conference). The generally small areas of Brassicas grown in Australia since 2000 reflects the judgement of many growers and advisers that that these cutoff dates had passed. Growers and advisers presumably consider the expected yield of the following wheat crop when they decide on a cutoff date for sowing. If their expectations are based on a 20% yield response to wheat growing after a *Brassica*, they should be reconsidered taking account of the result that brassicas increased mean wheat yield by 0.8 t ha^{-1}. When that is considered, a lower-yielding *Brassica* crop can be tolerated in the expectation of compensation from increased yield of the following wheat crop. This conclusion is supported by the results of Heenan (1995) who found that the break-crop benefit of brassicas was not diminished when they were sown late and produced low yields.

Table 3. Gross margin for 2-year sequences at low and high yield levels for wheat-wheat (WW), *Brassica*-wheat (BW+0.8 and BW+20%) (see text). Price and variable costs assumptions are from 2011 budgets for short-fallow crops in the NSW central (east) zone (www.dpi.nsw.gov.au/agriculture/farm-business/budgets/winter-crops)

	First crop yield (t/ha) and gross margin ($/ha)	Second crop yield (t/ha) and gross margin ($/ha)	2-year gross margin ($)/ha)
Low yields			
WW	2.0 ($50)	2.0 ($50)	$100
BW+0.8	1.0 ($-117)	2.8 ($302)	$185
BW+20%	1.0 ($-117)	2.4 ($200)	$83
High yields			
WW	6.0 ($1070)	6.0 ($1070)	$2140
BW+0.8	3.0 ($883)	6.8 ($1322)	$2205
BW+20%	3.0 ($883)	7.2 ($1424)	$2307

Another implication of these results is that the impact of including brassicas in a sequence with wheat may be greater in drier environments than has been previously believed, after the additional yield of a following wheat crop is considered.

REFERENCES

Angus, J.F., J.M. Desmarchelier, P.A. Gardner, A. Green, P.J. Hocking, G.N. Howe, J.A. Kirkegaard, S. Marcroft, A.J. Mead, G.D. Pitson, T.D. Potter, M.H. Ryan, M. Sarwar, A.F. van Herwaarden and P.T.W. Wong, 1999: Canola and Indian mustard as break crops for wheat. Proc.10th International Rapeseed Congress, Canberra (http://www.regional.org.au/au/gcirc/2/333.htm#P0_0)

Angus, J.F., J.A. Kirkegaard and M.B. Peoples, 2001: Rotation, sequence and phase: research on crop and pasture sequences. Australian Agronomy Conference, Hobart. (www.regional.org.au/au/asa/2001/plenary/4/angus.htm#TopOfPage)

Angus, J.F., M.B. Peoples, J.A. Kirkegaard, M.H. Ryan and L. Ohlander, 2008: The value of break crops for wheat. Proc. 14th Conference, Australian Society of Agronomy, Adelaide www.regional.org.au/au/asa/2008/concurrent/rotations/5786_angusjf.htm

Angus, J.F., A.F. van Herwaarden and G.N. Howe, 1991: Productivity and break-crop effects of winter-growing oilseeds. Aust. J. Exp. Agric. 31, 669-677.

Heenan, D.P. 1995. Effect of broad-leaf crops and their sowing time on subsequent wheat production. Field Crops Res. 43, 19-29.

Kirkegaard, J.A., P.A. Gardner, J.F. Angus and E. Koetz, 1994: Effect of Brassica break crops on the growth and yield of wheat. Aust. J. Agric. Res. 45, 529-545.

Kirkegaard, J.A., G.N. Howe and P.M. Mele, 1999: Enhanced accumulation of mineral-N following canola. Aust. J. Exper. Agric. 39, 587–593.

Kirkegaard, J.A., O. Christen, J. Krupinsky and D.B. Layzell, 2008: Break crop benefits in temperate wheat production. Field Crops Res. 107, 185-195.

Robertson, M.J., R. A. Lawes, A. Bathgate, F.Byrne, P.White and R. Sands, 2010: Determinants of the proportion of break crops on Western Australian broadacre farms. Crop Past. Sc. 61, 203-213.

Ryan, M.H., A.F. van Herwaarden, J.F. Angus and J.A. Kirkegaard, 2005: Reduced growth of autumn-sown wheat in a low-P soil is associated with high colonisation by arbuscular mycorrhizal fungi. Pl. Soil 270, 275-286.

Ryan, M.H., J.A. Kirkegaard and J.F. Angus, 2006: Brassica crops stimulate soil mineral N accumulation. Aust. J. Soil Res. 44, 367-377.