Report Two

Break crop research with FarmLink to manage grass weeds

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Introduction

There is substantial evidence indicating wide-spread resistance or partial resistance of annual ryegrass (ARG; Lolium rigidum Gaudin) to a wide range of herbicide groups across south eastern Australia. Consultation with FarmLink members and agribusiness collaborators identified difficulties in managing grass weeds as a major constraint to wheat production, and the primary driver of decisions to grow broadleaf break crops.

Can a break crop be as profitable as a cereal?

Eurongilly Exp 1

In 2012, an on-farm break crop experiment was established in a paddock near Eurongilly that had been identified as having a herbicide-resistant ARG population. The most profitable crops were RR and TT canola which returned grain yields and gross margins of 3.5t/ha (GM =$1259/ha) and 3t/ha (GM = $1166/ha), respectively. The next most profitable crops were lupins (grown for grain) @ $683/ha (yield = 3.1t/ha), wheat (High input) @ $257/ha (yield = 3.2t/ha), wheat (Low input) @ $250/ha (yield = 2.0 t/ha), with the brown manure or fallow treatments having negative returns (-$45 to -$250/ha). It was shown that in the presence of a high weed burden, there were multiple broadleaf options that were more profitable than wheat in a single year.

This experiment, also aimed to test whether or not you can 'buy your way out of needing a break crop' in the presence of a high weed burden. In addition to the standard herbide treatments used to control grasses in wheat (nominated as 'low' input), a 'high' input wheat treatment was included in the design along with various broadleaf crops grown for grain or brown manure (Bm), and a fallow treatment. It was found that using the latest and most effective ryegrass control options in wheat was very expensive relative to those used in the other treatments. See Table 1 below to compare the costs of the herbicides alone used to control ryegrass.

Eurongilly Experiment 2

In 2013 a second trial was established on another farm with a herbicide-resistant AGR population. The wheat yield in high input treatment represented about twice the canola yield, but was considerably lower in the wheat low input treatment due to competition with ARG. The lupin-grain crop proved to be the most profitable crop with a profit/cost ratio of 2.5 (profit of $2.50 for each $1 spent). Nitrogen was applied to the wheat at rates of 174 and 49 kgN/ha (high and low inputs; respectively) and to the canola at 196 and 98 kgN/ha (high and low inputs; respectively). The high rates of N reduced the gross margin in both the canola and wheat high input treatments compared to lupin in Experiment 2, or the canola and wheat treatments

Crop & Input - Year 1	Ryegrass Control Costs ($/ha)
Wheat (Low)	$56
Wheat (High)	$142
Lupin (Grain)	$65
TT Canola (Grain)	$62
RR Canola (Grain)	$46
Pea Bm	$66
Fallow	$35

Table 1: Ryegrass Herbicide Costs at Eurongilly Exp 1 in 2012

described above in Experiment 1. As the canola price was similar between 2012 and 2013 ($490/t and $476/t), the main difference in gross margin related to a lower crop yield in Experiment 2. In this case, the break crop (lupins) was still more profitable than wheat.

Crop & input	Grain yield 2013 (t/ha)	Gross income[a] 2013 (t/ha)	Variable costs 2013 (t/ha)	Gross margin 2013 (t/ha)	Profit / cost ratio
Lupin - grain	2.6	$1040	$299	$741	2.5
Wheat - high	4.0 (14.5)	$1110	$756	$354	0.5
Canola - low	1.6	$781	$442	$339	0.8
Wheat - low	2.2 (12.2)	$556	$289	$300	1.1
Canola - high	1.9	$872	$711	$161	0.2
Fallow	0	$0	$72	-$72	-1.0
Peas Bm	0	$0	$204	-$204	-1.0

Table 2: Comparisons of grain yield, income, variable costs, and gross margins of wheat and break crops grown for grain or brown manure (Bm) or fallow from Year 1 of Eurongilly Expt 2. Crops arranged in order of descending gross margin. [a] Note: Grain prices used in the calculations were current at the around the time of harvest and assumed delivery to Junee except RR canola to Stockinbingal (extra freight cost = $5/t). () brackets indicate grain % protein.

Are sequences that include break crops more profitable than continuous wheat?

Eurongilly Exp 1

In the presence of a high weed burden herbicide-resistant annual ryegrass (ARG), sequence profitability was closely related to the efficacy of weed control. Herbicides used to control the ryegrass population were a major input cost and the effectiveness of the management decisions used for the different sequences impacted the year-to-year profitability.

Break Type	Crop x Input 2012	Crop x Input 2013	Grain Yield 2012	Gross Margin 2012	Grain Yield 2013	Gross Margin 2013	Grain Yield 2014	Gross Margin 2014	Avg 3 yr Gross Margin
			(t/ha)	($/ha)	(t/ha)	($/ha)	(t/ha)	($/ha)	($/ha/yr)
S	RR Canola	Wheat (H)	3.5	$1,259	4.7	$533	4.5	$858	$883
S	RR Canola	Wheat (L)	3.5	$1,259	2.8	$489	4.1	$788	$845
S	TT Canola	Wheat (L)	3.0	$1,166	4.7	$537	3.8	$828	$844
D	RR Canola	Wheat (Hay)	3.5	$1,259	7.4DM	$533	3.7	$709	$834
D	Lupin grain	RR Canola	3.1	$683	3.2	$967	4.1	$721	$790
S	Lupin grain	Wheat (H)	3.1	$683	5.1	$726	3.9	$863	$757
D	Fallow	RR Canola	nil	-$45	3.6	$1,159	3.7	$696	$603
Nil	Wheat (H)	Wheat (H)	3.2	$257	5.0	$642	4.2	$855	$585
D	Lupin Bm	RR Canola	nil	-169	3.6	$1,146	4.1	$680	$552
S	Pea Bm	Wheat (H)	5.2DM	-$160	5.0	$707	4.3	$911	$486
S	Pea Bm	Wheat (L)	5.2DM	-$160	3.0	$525	3.8	$826	$397
Nil	Wheat (L)	Wheat (L)	2.0	$250	1.5	$170	3.3	$745	$388

Table 3: Grain yield, annual Gross Margin and 3-year average Gross Margin at Eurongilly Exp 1.

In year 1 the most profitable crops were RR and TT canola which returned gross margins of =$1259/ha (yield = 3.5t/ha), and $1166/ha (3t/ha), respectively. The next most profitable crops were lupins at $683/ha (3.1t/ha), high input wheat at $257/ha (3.2t/ha), the low input wheat at $250/ha (2.0 t/ha), with the brown manure or fallow treatments all having negative returns (-$45 to -$250/ha).

In year 2, the treatments with the highest gross margin were canola following fallow or brown manure treatments (> $1000/ha, grain yield avg = 3.5t/ha) with canola following wheat (H) or lupins returning ~$900/ha (3.2t/ha). Over the 3 years, the most profitable sequence was RR canola - wheat (H) - wheat, with an average GM of $883/ha/yr. Sequences with the highest average annual gross margins >$800/ha/yr were treatments that had canola (RR or TT) in year 1, with the next most profitable group having grain lupins in year 1 or canola year 2 (> $600/ha). The third group included the use of fallow, with the final group involving sequences with Bm crops followed by wheat (H or L).

Overall it was found that sequences that involved either canola or a spray topped lupin grain crop in year 1 followed by cereal hay or RoundupReady (RR) canola in year 2 provided the highest gross margins and significantly reduced ARG seed bank over the 3 year crop sequence. Cheaper double break combinations using a fallow or pulse Bm in year 1 followed by RR canola in year 2 resulted in lower gross margins, but were the most effective in reducing the seed bank. Continous low input wheat had the lowest gross margin and the least ryegrass control.

Eurongilly Exp 2

The lupin grain yield in 2013 of 2.6/ha resulted in the highest gross margin with a profit: cost ratio of 2.5:1. The wheat (H) grain yield in 2013 was approximately double the wheat (L) yields due to reduced competition from ARG and also double the canola (H) grain yield. However, the wheat (H) and canola (H) grain yields were lower than expected due to the dry October (14mm) and November (7mm) rainfall and high nitrogen inputs. These lower yields combined with the high inputs of nitrogen of 196kgN/ha in both the wheat (H) and canola (H) significantly reduced their respective gross margins in 2013.

The wheat-hay treatment was significantly the most profitable in 2014 with gross margins being two to three times higher than any other treatment. Wheat yield in both the high and low treatments in 2014 were similar at 2.7 and 2.6 t/ha respectively but the protein concentrations were significantly higher in the wheat (H) treatment, 16.4% compared to 14.8% in the wheat (L).

Wheat yields were significantly lower than observed in Exp 1 in 2013. The low wheat yields and high protein concentrations were due to the crop suffering from stem frost (40% stems affected) and head frost (10%), which reduced water and carbohydrate transportation and reduced the plant's ability to fill grain. This resulted in screenings of between 14% to 19% in the wheat (L) and wheat (H) treatments respectively. This had a significant negative effect on the wheat gross margins in 2014, especially in the wheat (H) treatment due to the high nitrogen inputs. The RR canola grain yields in 2014 were also lower than in Exp 1 in 2013 (1.7-1.9t/ha c.f. 3t/ha in Exp 1) resulting in low gross margins due to high input costs of herbicides and nitrogen.

At Eurongilly Exp 2, the top six sequences in terms of average annual 3 year gross margins included either the hay treatment in 2014 or lupin-grain in 2013 (due to their yearly high gross margins). If we compare the average three year gross margin in experiment 1 and 2, the first main difference is that the canola grain yields and associated gross margins were significantly lower in both the first and second year in crop sequences at Eurongilly experiment 2. The second difference is that the average 3 year gross margin in any sequence that included a wheat (H) treatment, especially in 2014 was very unprofitable. The performance of the low input wheat sequence (Wheat (L) – Wheat (L)) relative to the other sequences in experiment 2 was due to the high costs associated with unused N fertiliser used in high input wheat and canola treatments. The brown manure treatments followed by wheat (H) were the least profitable sequences in both experiments.

Crop x Input 2013	Crop x Input 2014	Grain yield 2013 (t/ha)	Gross Margin 2013 ($/ha)	Grain yield 2014 (t/ha)	Gross Margin 2014 ($/ha)	Grain yield 2015 (t/ha)	Gross Margin 2015 ($/ha)	Average 3 yr GM ($/ha/yr)
TT canola	Hay	1.6	$348	7.9	$933	3.7	$638	**$640**
RT canola	Hay	1.6	$40	8.1	$962	3.9	$708	**$568**
RR canola	Hay	1.9	$171	7.9	$937	4.3	$587	**$564**
Lupins	Wheat (L)	2.6	$724	2.1	$222	3.4	$696	**$550**
Lupins	Canola	2.6	$724	1.7	$157	4.6	$753	**$543**
Lupins	Wheat (H)	2.6	$724	2.6	$42	4.1	$697	**$487**
Wheat (H)	Wheat (L)	4.0	$359	2.7	$369	3.9	$631	**$455**
TT canola	Wheat (L)	1.6	$348	2.5	$274	4.0	$605	**$408**
Wheat (H)	Canola	4.0	$359	1.7	$163	4.1	$663	**$393**
Wheat (H)	Wheat (H)	4.0	$359	2.8	$118	4.3	$612	**$362**
RT canola	Wheat (L)	1.6	$40	2.5	$307	4.2	$733	**$362**
TT canola	Wheat (H)	1.6	$348	2.7	$23	4.4	$681	**$351**
RR canola	Wheat (L)	1.9	$171	2.5	$309	4.5	$566	**$350**
Wheat (L)	Wheat (L)	2.2	$318	2.1	$129	4.1	$547	**$331**
Wheat (L)	Canola	2.2	$318	1.7	$82	4.4	$550	**$316**
Fallow	Canola	Nil DM	-$72	1.9	$285	4.8	$705	**$305**
Pea Bm	Wheat (L)	5.7DM	-$204	2.9	$421	3.9	$695	**$305**
Fallow	Wheat (L)	Nil DM	-$72	3.0	$442	4.3	$519	**$298**
Wheat (L)	Wheat (H)	2.2	$318	2.7	-$18	3.6	$586	**$297**
RT canola	Wheat (H)	1.6	$40	2.7	$53	4.5	$745	**$279**
RR canola	Wheat (H)	1.9	$171	2.6	$36	4.1	$609	**$271**
Fallow	Wheat (H)	Nil DM	-$72	2.7	$115	4.0	$715	**$253**
Pea Bm	Canola	5.7DM	-$204	1.9	$242	4.7	$634	**$223**
Pea Bm	Wheat (H)	5.7DM	-$204	2.8	$114	4.2	$654	**$188**

Table 4: Grain yield, annual gross margin and Average 3 year Gross Margin 2013-15 at Eurongilly Exp 2.

Can a weed problem be managed more cost effectively with break crops than in a continuous cereal system?

Eurongilly Exp 1

This section describes the effectiveness at reducing seed banks of herbicide resistant annual ryegrass (ARG) through the use of different inputs and herbicides applied to canola, pulse legumes, or wheat crops.

ARG panicles per m2 in the spring year 1 in untreated areas were 1,042 (with each panicle containing in the order of 30 seeds), significantly more than the low input wheat with 534 panicles/m2. By the autumn of year 2, there was a significant three-fold increase in ARG seed bank populations (5492 seeds/m2) following low input wheat (L) and by autumn year 3 a further significant 2.5 fold increase (13148 seed/m2) after a second wheat (L) treatment. The expensive herbicide costs ($142/ha) associated with consecutive high input wheat treatments resulted in a significant reduction in seed bank by November 2014 (366 plants/m2), but was not as effective as sequences involving break crops or a fallow. The most effective ARG control was achieved by fallow, pulse Bm or RR canola (see Table below). By spring in year 2, there were significant differences in panicles/m2 with four distinct categories (0-8, 14-71, 192-388 & >643 panicles/m2). Main year 2 treatment effects continued into year 3 with panicles numbers from fewest to most in order of: canola < hay = wheat (H) < wheat (L), and year 1 effects: fallow < pulses < canola = wheat (H) < wheat (L). Interactions were categorised into groups of (0-30, 60-166, 199-370, >536 panicles/m2). Generally, double break sequences or those where high input (H) wheat treatments were grown following treatments with bare soil or less stubble from year 1 had significantly

Crop x Input 2012	Crop x Input 2013	Ryegrass panicles Nov 2012	SEEDBANK March 2013	Ryegrass panicles Nov 2013	SEEDBANK March 2014	Ryegrass panicles Nov 2014	SEEDBANK March 2015	Average Annual 3yr GM
(Year 1)	(Year 2)	(panicles/m^2)	(seeds/m^2)	(panicles/m^2)	(seeds/m^2)	(panicles/m^2)	(seeds/m^2)	($/ha/yr)
Fallow	Canola	0 (NM)^	290	0	NM	2	56	$603
Lupin grain	Canola	43*	748	0	196	6	63	$790
Lupin BM	Canola	0 (NM)^	152	0	NM	1	110	$552
Fallow	Wheat (H)	0 (NM)^	290	2	NM	10	118	$539
RR Canola	Wheat (Hay)	0	208	0 (537)^	124	23	122	$834
Pea BM	Canola	0 (NM)^	464	0	210	4	142	$513
Lupin grain	Wheat (H)	43*	748	8	312	19	148	$757
Pea BM	Wheat (H)	0 (NM)^	464	2	496	14	162	$486
RR Canola	Wheat (H)	0	208	15	381	29	219	$883
TT Canola	Wheat (H)	32	505	14	NM	82	252	$844
Wheat (H)	Canola	78	777	0	259	20	267	$636
Lupin BM	Wheat (H)	0 (NM)	152	2	NM	11	279	$463
TT Canola	Wheat (Hay)	32	505	0 (790)^	NM	23	300	$844
Wheat (L)	Canola	504	5492	0	797	22	332	$582
Wheat (H)	Wheat (H)	78	777	29	1379	60	366	$585
Wheat (L)	Wheat (H)	504	5492	71	3412	121	523	$537
Fallow	Wheat (L)	0 (NM)^	290	56	NM	100	970	$530
Lupin BM	Wheat (L)	0 (NM)^	152	192	NM	308	1105	$419
Lupin grain	Wheat (L)	43*	748	200	6614	122	1167	$715
Wheat (H)	Wheat (L)	78	777	294	5508	147	2158	$513
TT Canola	Wheat (L)	32	505	383	NM	229	2222	$800
RR Canola	Wheat (L)	0	208	388	7770	200	2387	$845
Pea BM	Wheat (L)	0 (NM)^	464	237	7413	157	3118	$397
Wheat (L)	Wheat (L)	504	5492	898	13148	943	3140	$388
P value (2012)		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	
P value (2013)			NA	<0.001	<0.001	<0.001	<0.001	
P value (interaction)			NA	0.004	0.105	<0.001	0.699	

Table 5: Average annual gross margin over 3 years compared to ryegrass seedbank (April 2013, 2014, 2015) and ryegrass panicle number (November 2012-2014) in Exp 1 at Eurongilly, NSW.

Crop 2012 pre-treatments are arranged in order of descending SEEDBANK March 2015 seed counts.

**Lupins spray topped in Nov 2012 prior to ryegrass seed maturity. ^Ryegrass panicles estimated at zero in 2012 and 2013 due to either spraying or cutting of hay prior to seed set*

NM Not measured

fewer panicles.

In the presence of a high population of herbicide-resistant ARG, sequences that included a break crop were more profitable compared to continuous wheat (H or L). Canola was consistently the most profitable break crop, largely due to the high returns from canola itself, but legume grain crops were profitable and provided additional N for crops in year 2. Although the TT canola / wheat (H) sequence was profitable, it was not as effective at reducing the ARG seed bank and any sequence with wheat (L) resulted in an increase in ryegrass numbers. Break crops or fallow provided cheaper and more effective ARG control options. Two consecutive years of complete ARG control were required to reduce seed banks to managable levels. The most profitable double break sequences were RR canola followed by a cereal hay or grain lupins followed by RR canola with these sequences also very effective at reducing the seed bank. Sequences involving fallows and brown manures reduced production risk in subsequent years due to enhanced yield in the following wheat crops, but were not as profitable as continuous cropping.

Crop x Input 2013	Crop x Input 2014	Seedbank March 2013	Ryegrass panicles Nov 2013	Seedbank March 2014	Ryegrass panicles Nov 2014	Seedbank March 2015	Ryegrass panicles Nov 2015	Seedbank Feb 2016
Year 1	Year 2	seeds/m^2	panicles/m^2	seeds/m^2	panicles/m^2	seeds/m^2	panicles/m^2	seeds/m^2
Fallow	Canola	2775	0	649	1	408	22	37
RT Canola	Wheat (H)	2775	0	900	2	375	4	58
RR Canola	Wheat (H)	2775	1	670	2	350	3	59
Peas Bm	Canola	2775	108*	897	1	104	10	106
Wheat (H)	Canola	2775	30	1337	1	212	5	115
RR Canola	Hay	2775	1	670	99^	457	15	132
RT Canola	Hay	2775	0	900	78^	197	11	145
Peas Bm	Wheat (H)	2775	108*	897	3	309	8	218
Fallow	Wheat (H)	2775	0	649	2	226	5	223
TT Canola	Hay	2775	193	3358	631^	1004	47	347
Wheat (H)	Wheat (H)	2775	30	1337	6	593	23	363
Peas Bm	Wheat (L)	2775	108*	897	52	729	26	437
RT Canola	Wheat (L)	2775	0	900	23	593	20	520
RR Canola	Wheat (L)	2775	1	670	20	819	10	597
Lupins	Canola	2775	462	4505	1	892	46	638
Fallow	Wheat (L)	2775	0	649	44	1112	39	653
Lupins	Wheat (H)	2775	462	4505	47	1129	61	711
TT Canola	Wheat (H)	2775	193	3358	70	1019	51	826
Wheat (H)	Wheat (L)	2775	30	1337	173	2722	104	1316
Wheat (H)	Canola	2775	534	6748	1	1507	133	1477
Wheat (H)	Wheat (H)	2775	534	6748	130	3216	126	1567
Wheat (L)	Wheat (L)	2775	534	6748	532	4930	167	1693
TT Canola	Wheat (L)	2775	193	3358	166	3415	108	1720
Lupins	Wheat (L)	2775	462	4505	537	4251	152	1951
P value (2013)			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
P value (2014)			NA	NA	<0.001	<0.001	<0.001	<0.001
P value (interaction)			NA	NA	<0.001	0.025	0.037	0.005

* Brown manure treatment was killed prior to ARG setting seed. Effectively zero ryegrass seedset.

^ Hay treatment was cut for hay prior to ARG setting seed. Followup spray with glyphosate.

Lupins were not spray topped in 2013

Table 6: Average annual ryegrass seedbank (March 2013, 2014, 2015, Feb 2016) and ryegrass panicles (Nov 2013, 23014, 2015)

In both Eurongilly Experiments in 2013, pre- and post-emergent herbicide treatments combined with higher N and P nutrition and increased wheat density (150 plants/m2 cf 75 plants/m2) in the high input wheat treatments resulted in good control of the annual ryegrass compared to the low input wheat treatment (30 panicles/m2 cf 534 panicles/m2 and 0.1 t/ha cf 3.5 t/ha ryegrass DM). The effect of the high and low input treatments on ryegrass control and ultimately wheat grain yield can be seen in the following Figure. The high input treatment (open symbols) significantly reduced ryegrass DM and increased wheat grain yield. By contrast there was higher ryegrass DM under the low input treatments (closed symbols) resulting in a reduction in wheat grain yield of 450 kg/ha for every 1 t/ha of ryegrass DM regardless of whether the 2013 wheat followed a break crop, brown manure, fallow or wheat in 2012 (see also weeds rules-of-thumb in Appendix E in BCMG).

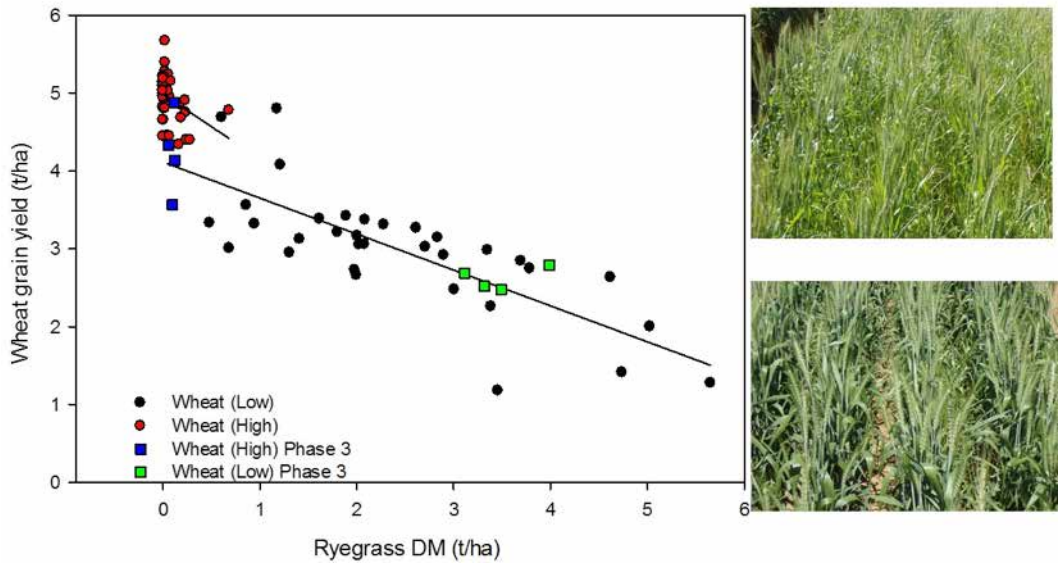

Figure 1. Relationship between ryegrass dry matter (DM) and wheat grain yield following high and low input treatments in wheat at two locations at Eurongilly, NSW

Take Home Messages

1. Wheat grain yield can be expected to be reduced by around 0.5 t/ha for every tonne of in-crop grass weed dry matter present in spring.

2. Wheat following break crops were consistently more profitable than wheat on wheat. This in part reflected the relatively low wheat grain prices experienced during experimentation, and the high returns for canola, but was also related to the efficacy and costs of ryegrass control.

3. Growing pulses for brown manure (Bm) lost money in the year that they were grown, but achieved excellent weed control, provided high inputs of N and a residual carry-over of soil water, and more ground cover than if they had been cut for hay.

4. In the presence of a high density of herbicide resistant ryegrass a 'single break' was not adequate to reduce weed seedbanks and subsequent in-crop weed competition. 'Double breaks' (two broad leaf break crops, or break crop - cereal hay sequence) reduced ryegrass seedbank numbers to manageable levels and were amongst the most profitable sequences.

5. Break crop choice and selection should be based on individual farm management and ability to manage the various break crops options in the rotation. If growers remain flexible in break crop and end-use decisions, and make suitable choices, risks associated with producing them can be greatly reduced.

6. A cropping program that includes break crops is likely to be more sustainable in terms of N inputs and risk of build-up of root diseases than continuous wheat, and provided cheaper, more effective strategies for controlling herbicide resistant grass weeds.

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