Weed responses to high intensity break crop rotations

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Key findings

- Controlling Group A and B herbicide resistant annual ryegrass and Group B resistant common sowthistle in break crops is becoming increasingly challenging.
- Resistance in ryegrass to pre-emergence herbicides such as Boxer Gold® and Sakura® has been confirmed in high break crop intensity systems.
- Paddock survey results showed common sowthistle from paddocks with high IMI-use history had high incidence of IMI resistance. However, IMI resistance levels in paddocks where only sulfonylureas had been used, raises concern for resistance development to IMIs in other broadleaf weeds.
- The Group B tolerant faba bean PBA Bendoc⊕ provides a new opportunity for managing broadleaf weeds.
- Crop competition has the potential to reduce seed set of broad leaf weeds in some break crops.

Why do the research?

A number of improved herbicide tolerant break crop options are available such as triazine tolerant (TT) canola, imidazolinone (IMI) tolerant (Clearfield) canola and lentils e.g. PBA Hurricane XT. Their relatively high market prices, improved agronomic and disease characteristics and harvest efficiency have resulted in an expansion of the area sown to pulses and canola in South Australia. Growers using break crops can use a more diverse range of herbicide chemistry compared with that used in the cereal phase, particularly for grass weeds. This uptake has largely occurred in the Mid-North (MN), Yorke Peninsula (YP) and Lower Eyre Peninsula (LEP), where the total area under break crops is higher than the national average (Figure 1).

Ryegrass control in break crops relied heavily on Group A chemistry (fops and dims). This has contributed to increased herbicide resistance, in particular to the dim chemistry, making ryegrass control challenging. Consequently, herbicides with different modes-of-action (Groups D, J and K) have been adopted to manage dim-resistant ryegrass in high break crop intensity (HBCI) rotations. Careful management of Group D, J and K herbicides is required to minimise selection for resistance to any single mode of action. The introduction of TT canola, IMI tolerant canola and lentil have also improved broadleaf weed control options with triazine and IMI herbicides. However, they have resulted in a decreased frequency of other weed control tactics in these break crops. Over-reliance on triazines and IMI herbicides in herbicide tolerant break crops for improved broadleaf weed management could result in shifts in the weed spectrum and increase the incidence of herbicide resistance. This has occurred in Canada with the evolution of sulfonylurea (SU) and IMI resistant wild mustard (Warwick et al, 2005) as a result of high intensity use of ALS inhibiting herbicides. Resistance in broadleaf weeds presents a big challenge for IMI tolerant lentils.

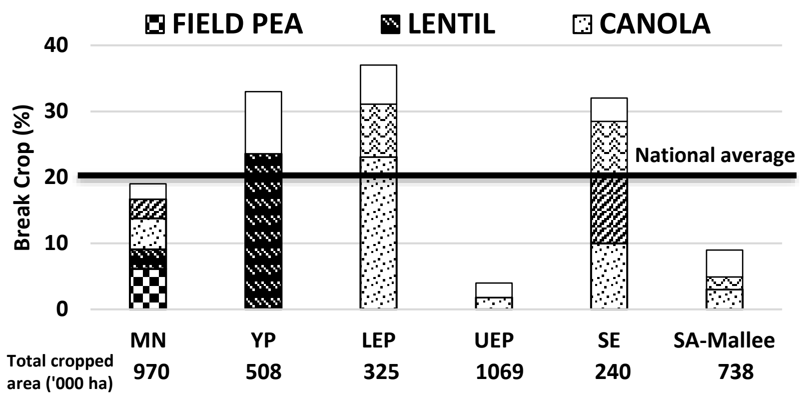

Figure 1. Distribution of break crops across different regions of South Australia. Source: PIRSA crop estimates 2017

A more sustainable approach is to include herbicide tolerant break crops as part of an overall weed management strategy, rather than focussing on short-term weed control in individual crops and seasons. Introducing strategies such as crop-topping to reduce seed set can significantly reduce weed seed banks (Preston, 2014). The adoption of effective diverse strategies will therefore aid in reducing the risk of resistance developing in high break crop intensity rotations.

Paddock survey

A paddock survey was initiated in 2017 to understand changes in weed and herbicide resistance, in response to low or high use of IMI herbicides in high intensity break crop rotations (at least two break crops in the last 5-6 years) across different regions of South Australia. A total of 45 focus paddocks were selected [MN-16, YP-11, LEP-8, Upper Eyre Peninsula (UEP)-2, South East (SE)-4, SA Mallee-4]. The selected paddocks had IMI tolerant break crops such as PBA Hurricane XT lentil (at least twice in the last five years) or Clearfield canola (twice in the last five to six years) sown as a dominant break crop. In addition to these, paddocks with two non-IMI break crops (conventional lentil, conventional canola/TT canola, field pea, chickpea, faba bean, lupin) were included. Seeds from ryegrass and two dominant broadleaf weed species were collected from these paddocks prior to harvest in 2017. They were screened for resistance in outdoor pot trials by Plant Science Consulting (Tables 1 and 2).

Ryegrass and common sowthistle were the dominant weed species encountered in the focus paddocks (Tables 1 and 2). Ryegrass resistance to SU and Dens (Axial) was detected in almost all paddocks (Table 1). A high incidence of ryegrass resistance to IMI was observed in both high IMI-history paddocks (56% of samples) and no-IMI history paddocks (63% of samples). In addition, a total of 46% of ryegrass populations were found to be resistant, and 21% had started developing resistance to clethodim in high break crop intensity paddocks (Table 1). This has started to limit the effectiveness of break crops as rotational tools.

Resistance to the Group J and K herbicides Boxer Gold and Sakura, albeit at low levels, was confirmed in ryegrass and is a concern (Table 1). One quarter of the ryegrass populations exhibited resistance to Boxer Gold (≥20% survivors). Half of the ryegrass biotypes resistant to Boxer Gold originated from high break crop intensity paddocks on Lower Eyre Peninsula where canola was the dominant break crop. Biotypes with ≥ 20% survival to Sakura® were not detected, although 1 to <20% survival in pot trials (developing resistance) was confirmed in one third of ryegrass populations, predominately from Lower Eyre Peninsula. The increase in resistance to pre-emergence herbicides highlights the need for careful and strategic use of these chemistries, particularly in the break crop phase. This might include rotational use of Group D herbicide propyzamide with Group J and K herbicides in the break crop phase.

Table 1. Herbicide resistance in annual ryegrass collected from high break crop intensity paddocks in SA. Resistance (where ≥ 20% survival was confirmed in pot tests) and developing resistance (where 1 to <20% survival was confirmed in pot tests) is presented below.

Resistant ryegrass populations									
Weed	**Samples tested**	**Trifluralin***	**Propyzamide**	**Boxer Gold**	**Sakura**	**Clethodim**	**Glean**	**Axial**	**Intervix**
Ryegrass	24	17 (71)	0	6 (25)	0	11 (46)	22 (92)	22 (92)	14 (58)
Ryegrass populations with developing resistance									
Ryegrass	24	3 (13)	0	4 (17)	8 (33)	5 (21)	1 (4)	1 (4)	2 (8)

** numbers (percent)*

Table 2. Percent resistant broadleaf weeds (≥ 20% survivors) observed in high break crop intensity paddocks of South Australia, samples taken in 2017.

Weed	Ally	Intervix	Imazapic	2,4-D	Brodal	Bromoxynil	MCPA	Imazethapyr	Glean	Lontrel
Common sowthistle (17) *	88	65	88	6	0	-	-	-	-	-
Bedstraw (3)	-	0	0	-	-	0	0	0	-	-
Bifora (3)	-	0	0	-	-	0	0	0	0	-
Marshmallow (4)	0	0	0	50	0	-	-	-	-	-
Wild turnip (2)	0	0	0	0	0	-	-	-	-	-
Wild radish (1)	0	0	0	0	0	-	-	-	0	-
IHM (1)	0	0	0	0	0	-	-	-	-	-
Medic (1)	0	0	0	0	-	-	-	-	-	0

** Figures in brackets are the number of samples tested*

In common sowthistle, over half of the biotypes exhibited resistance to SU and IMI herbicides (Table 2). The majority of SU resistant populations exhibited cross-resistance to imazapic (93% of samples) and Intervix® (imazamox + imazapyr) (73% of samples). Only one population was confirmed to be susceptible to both SU and IMI. All common sowthistle populations from paddocks with high IMI-use history were resistant to imazapic, and 69% were resistant to Intervix. Fifty percent of populations from paddocks with non-IMI history were resistant to both IMI herbicides.

The target site of all Group B herbicides is the enzyme acetolactate synthase (ALS). Multiple target-site mutations in the ALS gene have been confirmed in resistant weeds, conferring resistance across chemical families of ALS-inhibiting herbicides (Tranel and Wright 2002). ALS target site cross-resistance to SU and IMI was observed in common sowthistle and is of concern for the sustainability of HBCI rotations dominated by IMI tolerant PBA Hurricane XT lentil and Clearfield canola varieties. One population of common sowthistle from the Mid-North was also found to be resistant to the Group I herbicide 2,4-D and exhibited weak cross-resistance to IMI.

The herbicide resistance screening results identified that IMI herbicides were still effective in controlling other broadleaf weed species such as bedstraw, bifora, marshmallow, wild radish, wild turnip, Indian hedge mustard and medics (Table 2). However, an increased reliance on herbicide tolerant break crops, including IMI-tolerant pulse and canola varieties, without incorporating alternative weed control strategies, could result in weed species shifts and increased resistance in existing species. To address these issues, a project with joint investment of GRDC and SARDI has been initiated to develop effective management strategies, including integrated weed management practices for grasses and broad leaf weeds, to maintain the sustainability of HBCI systems.

Managing dim-resistant ryegrass in lentils – field trials

Two research trials were conducted during 2017 at the Hart (Mid-North) and Maitland (Yorke Peninsula) investigating the pre-emergent herbicide Ultro® (1700 g/ha with active carbetamide, Group E) which is currently in development. Ultro® was compared to propyzamide (900 g/kg @ 1000 g/ha), Sakura (118 g/ha) and Boxer Gold (2500 mL/ha) in controlling dim-resistant ryegrass in lentil. PBA Hurricane XT lentils were sown on 31 May 2017 at Hart and on 6 June 2017 at Maitland. At Hart, dim-resistant annual ryegrass seed was broadcast at 160 seeds/m^2 ahead of seeding and incorporated prior to herbicide application. The Maitland site had a background population of dim-resistant annual ryegrass.

The effectiveness of pre-emergent herbicides was investigated at both sites. Herbicide strategies including propyzamide resulted in the lowest ryegrass heads and seed set at both locations. Ultro® provided a 98% reduction in ryegrass seed set over unweeded control at both sites, and was similar to propyzamide, Sakura and Boxer Gold (Table 3). Additionally, Ultro® did not impact yield of lentil compared to propyzamide, Sakura and Boxer Gold. The pending registration of this new mode of action herbicide (Group E) is expected in 2020 and is likely to be an important tool, along with Group D propyzamide, in reducing selection pressure for existing Group J and K pre-emergent and dim chemistry post emergent herbicides for ryegrass control in break crops.

¤*Unregistered herbicide was included for experimental purposes only. It has been submitted to the APVMA for registration.*

Table 3. Ryegrass seed heads and seed set at maturity, and lentil yield at Hart and Maitland, in 2017. Numbers with different letters are significantly different averages (P<0.05).

Herbicide	Hart 2017			Maitland 2017		
	Head counts (heads/m^2)	RG seed set (seeds/m^2)	Yield (t/ha)	Head counts (heads/m^2)	RG seed set (seeds/m^2)	Yield (t/ha)
Ultro (IBS)* + Clethodim (POST)	6.5^{b}	352^{b}	1.95^{a}	4.8^{b}	269^{b}	3.62^{a}
Boxer Gold (IBS) + Clethodim (POST)	9.4^{b}	440^{b}	1.98^{a}	28.1^{b}	1697^{b}	3.39^{a}
Sakura (IBS) + Clethodim (POST)	10.2^{b}	549^{b}	2.02^{a}	9.6^{b}	585^{b}	3.85^{a}
Propyzamide (IBS) + Clethodim (POST)	4.9^{b}	120^{b}	1.86^{a}	0.5^{b}	23^{b}	3.71^{a}
Control	203.8^{a}	15364^{a}	1.38^{b}	179.6^{a}	13595^{a}	2.66^{b}

** Unregistered herbicides were included for experimental purposes only. The results within this document do not constitute a recommendation for that particular use by the author or author's organisation.*

Herbicides and crop-competition for managing vetch in Group B tolerant faba bean

A trial was established at Turretfield Research Centre in 2017, focusing on control of vetch and medic in Group B tolerant faba bean variety PBA Bendoc⁽ᵗ⁾. This trial was sown on 19 June 2017 in factorial randomised block design and included all combinations of three herbicide management strategies [H_1: Simazine (1100 g/ha) post-sowing pre-emergent (PSPE), H_2: Simazine (1100 g/ha) PSPE + Intervix® (750 ml/ha) at 5-6 crop node stage, and H_3: no herbicides] and three faba bean densities (12, 24 and 36 plants/m^2). Vetch seeds were broadcast prior to sowing @ 50 seeds/m^2 to contribute to the existing background medic weed population. The main effects of herbicide management strategies and faba bean densities are summarised in Table 4, and the interactions between these two factors were non-significant.

The Group B tolerant faba bean PBA Bendoc⁽ᵠ⁾ provided an opportunity to selectively use post-emergent Intervix® at 5-6 node stage. Application of simazine (PSPE) + Intervix® (post-emergent) resulted in a reduction in vetch seed and medic pod density by 97% and 100% respectively over grower practice (simazine 1100 PSPE) (Table 4). Improved broadleaf weed control with simazine (PSPE) + Intervix® (post-emergent) also resulted in the highest faba bean yield. These results indicate the availability of PBA Bendoc⁽ᵠ⁾ will benefit in selectively controlling vetch, medic and potentially other broad leaf weeds with post-emergence applied IMI in a strategy to minimise selection for resistance.

Table 4. Vetch and medic management in Group B tolerant faba bean (Bendoc) at Turretfield Research Station in 2017. Numbers with different letters are significantly different averages (P<0.05).

Treatment		Crop biomass at flowering (t/ha) 100 DAS	Plant height at flowering (cm) 100 DAS	Vetch pods/ plant 120 DAS	Medic pods/ plant 120 DAS	Vetch seed set/m²	Medic pod set/m²	Grain yield (t/ha)
Herbicide								
H_1	Simazine 1100 (PSPE)	2.46^{ab}	59.3^{b}	11.7^{b}	19.2^{b}	930^{b}	61^{b}	2.66^{b}
H_2	Simazine 1100 (PSPE) + Intervix* 750 (at 5-node stage)	2.78^{a}	58.4^{b}	1.8^{c}	0.0^{c}	25^{c}	0^{c}	3.19^{a}
H_3	Unweeded control	2.17^{b}	62.0^{a}	15.9^{a}	75.3^{a}	1399^{a}	2421^{a}	2.14^{c}
Density (m^{-2})								
D_1	12	1.13^{c}	52.2^{c}	12.4^{a}	53.0^{a}	772^{a}	745^{a}	1.92^{c}
D_2	24	2.55^{b}	59.1^{b}	9.7^{b}	27.1^{b}	660^{a}	289^{b}	2.83^{b}
D_3	36	3.72^{a}	68.4^{a}	7.3^{b}	14.3^{c}	380^{b}	161^{b}	3.25^{a}

**Unregistered herbicides were included for experimental purposes only. The results within this document do not constitute a recommendation for that particular use by the author or author's organisation. Currently there is a permit (PER14726) to use imazamox (700 g/kg product @ 45 g/ha or 350 g/kg product @ 90 g/ha at 3-6 node stage) in Group B tolerant faba bean (Bendoc).*

Crop competition has been shown to complement other weed control strategies. An increase in break crop plant density can lead to early ground cover, thereby reducing the competitiveness and seed production of weeds (Lemerle et al. 2006). The implementation of such a strategy can be especially effective in crops such as faba bean that have low plant densities and slow initial growth. In the present study, increasing faba bean density from 12 to 36 plants/m² resulted in improved crop competition with weeds due to significant increase in crop biomass and plant height (Table 4). The increased crop competitiveness significantly reduced vetch pods and seed set, and medic pod set, and subsequently led to increased crop yield (Table 4). A faba bean density of 36 plants/m² resulted in 42% and 44% reduction in vetch seed and medic pod set respectively, compared to standard grower practice of 24 plants/m². There was no disease incidence or lodging with an increase in faba bean density at the trial site in 2017. This practice requires further investigations across different seasons and locations.

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