Integrated Weed Management – alternative strategies for weed control in pulses

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Summary: The increased frequency of Group 2 tolerant pulses in crop rotations is reducing herbicide diversity due to limited safe options particularly for in-crop broadleaf weed control. Therefore, developing alternative weed control methods is important for delaying imidazolinone herbicide resistance in broadleaf weeds. Experiments were established to test integrated weed management (IWM) strategies including, crop-weed competition in faba bean at Turretfield (2017-2019) and Salter Springs (2019), and wick-wiping and clipping brassica weeds at different growth stages in a lentil crop at Turretfield (2019-2020) and Tickera (2021). Increasing faba bean densities from the standard grower practice of 24 plants m^{-2} to 30 plants m^{-2} reduced vetch seed set by up to 45%, due to increased crop competition. Wick-wiping brassica weeds with Glyphosate + LVE MCPA up to two weeks after its pod initiation reduced pod set by 62-100% compared to no wick-wiping. Further, clipping brassica weeds three weeks after pod initiation (with green and squashy weed seeds) reduced pod set by 94% compared to the no clipping treatment.

Keywords: Crop competition, plant density, wick-wiping, clipping.

INTRODUCTION

With the increasing frequency of pulses in crop rotations, broadleaf weed control has become challenging due to limited safe herbicide options. While there is increasing availability of herbicide tolerance traits in new crop varieties, alternative herbicide strategies are crucial to maintaining weed control options. The development of new IWM strategies will allow greater in-crop broadleaf control and reduce in-crop weed seed set and build-up of the soil weed seed bank in pulse-based rotations. Growers are becoming more accepting of IWM programs that would help to maximise the heterogeneity of selection pressures, minimise resistance evolution, achieve satisfactory weed control and allow sustainable long-term herbicide use.

Crop competition through early closure of the crop canopy is a vital cultural strategy that plays an important role in IWM by reducing the weed biomass and their fecundity and leads to increased crop yields (Lemerle *et al.* 2004). In a survey of 130 Western Australian growers, 61% were using higher seeding rates of wheat as an IWM tactic against annual ryegrass (Llewellyn *et al.* 2004). The agronomic tactic of increasing seeding rates to increase in-crop competition over weeds can be effective especially in pulse crops that have low plant densities and slow initial growth, such as lupin and faba bean. Until now, a major effort has been made to control grass weeds with increasing cereal crop densities, but limited literature is available citing the effect of increasing plant density on increasing crop competitiveness of pulses over problematic broadleaf weeds and needs exploring. Additionally, novel weed management practices, such as wick-wiping and clipping have a role to play in controlling resistant weed seed set from plants surviving early weed control strategies, especially when weeds set seed before crop maturity. Application timing of the wick-wiping and clipping treatments is crucial for reducing broadleaf weed seed set and needs investigation.

Therefore, the present studies were carried out to develop IWM strategies for the pulse phase of the crop rotation, reducing broadleaf weed seed set by improving crop competition in faba bean, and with wick-wiping and clipping broadleaf weeds in lentil.

MATERIALS AND METHODS

Four field experiments focused on crop competition were established in the Lower North region of South Australia, with three at Turretfield Research Centre (TRC) (34°.32’38” S, 138°.50’49” E, at 116 m above sea level in medium rainfall zone with 471 mm average annual rainfall) over the growing seasons of 2017, 2018 and 2019, and one experiment at Salter Springs (34°.12’39.70” S, 138.37’50.89” E at 229 m above sea level in high rainfall zone with 501 mm average rainfall) in 2019. The soil at the TRC field sites was a light clay over medium clay (2017), clay (2018 and 2019) in texture with organic matter content of 1.1-2.0% and a pH (water) of 7.1-8.5 in 0-20 cm layer. Soil at the Salter Springs site was very heavy clay in texture with organic matter content of 1.5-2.1% and a pH (water) of 8.4 in 0-20 cm layer. Rainfall received at TRC site in 2017 and 2018 was 278 and 188 mm, respectively.

The experiments were established in a factorial randomized complete block design with three faba bean densities 12, 24 and 36 plants m^{-2} (2017), five faba bean densities 12, 18, 24, 30 and 36 plants m^{-2} (2018 and 2019), and three herbicide treatments Simazine 1100 (PSPE), Simazine 1100 (PSPE) + imazapyr + imazamox 750 (POST at 5-6 crop-node stage), and unsprayed control with three replicates. Group 2 imidazolinone resistant faba bean PBA Bendoc was sown at a depth of 5-6 cm using a no-till plot seeder fitted with knife-point openers and press wheels. Plots were 10 m long and contained six crop rows spaced 22.5 cm apart. The seed of faba bean for all experiments was obtained from the same source (Faba bean Breeder, The University of Adelaide) in all the three years, to avoid any potential influence of seed source on early vigour. Vetch seeds were broadcast prior to sowing @ 50 seeds m^{-2} to contribute to the existing background medic weed population at Turretfield. There was a background population of vetch and bifora at Salter Springs. Herbicides were applied by using a tractor mounted sprayer delivering 100 L ha^{-1} water at a pressure of 200 kPa. Crop plant emergence counts were recorded when faba bean was at approximately the 2-3 node stage. Crop biomass was sampled at faba bean flowering stage with cuts made from four rows × 1-m length in each plot starting 1-m inside from the plot end. The crop biomass was dried at 60^{o} C for 48 hours till constant weight, and weighed.

Additionally, the potential benefits from wick-wiping and clipping for reducing the seed set of brassica weeds in lentil were studied at Turretfield in 2019 and 2020, and at Tickera in 2021. These experiments were established in randomised complete block design with three replicates by using lentil cultivar PBA Hurricane XT sown at a density of 120 plants m^{-2}. Experiments tested the response of brassica weeds including wild turnip, wild radish and Indian hedge mustard to wick-wiping with Glyphosate + LVE MCPA + water mixed as 1:1:1 and the application of weed clipping just above the lentil canopy at different growth stages. The wick-wiping and clipping treatments were applied at weekly intervals, starting from pod initiation stage. A gravity-based wick-wiper was used, and clipping of weed growing parts above the crop canopy was done manually. Seed/pod set of broadleaf weeds was determined by counting the pods and seeds obtained from plants sampled in a 0.25 m^2 quadrat placed at three random locations in each plot.

Statistical Analysis. Weed and crop data were analysed with ANOVA. A square-root variance-stabilizing transformation was used for vetch and medic plant density, vetch pod and seed set, medic pod set and bifora seed set data before analysis. Least squared means were used to determine significant differences ($P < 0.05$) between herbicide application, faba bean densities, and the interaction between herbicides and faba bean densities. The interaction effects were non-significant, therefore main treatment effects are presented in this paper.

RESULTS AND DISCUSSION

A. Effect of clipping and wick-wiping (lentil)

The timing of clipping treatments was an important factor in reducing pod set of brassica weeds (wild turnip, Wild radish and Indian hedge mustard), with later clipping treatments (at two and three weeks after wild turnip pod initiation) reducing pod set compared to the earliest treatment (at pod initiation) (Table 1). However, the opposite effect was observed with wick-wiping in 2019, where earlier treatments (up to two weeks after pod initiation) resulted in reduced turnip weed pod set compared to the late wick-wiping (three weeks after pod initiation). Wick-wiping at weed pod initiation and at later stages before embryo development proved equally effective in 2020 and 2021, reducing wild radish and Indian hedge mustard pod set by up to 100% and 78%, respectively, compared to no wick wiping. Using a combination of wick-wiping and clipping resulted in reduced weed pod set compared to the control (no wick-wiping/clipping) of up to 96%. When combining the two treatments of clipping and wick-wiping, earlier timing (at pod initiation) was the most effective in 2019. All of the combined treatments resulted in reduced weed pod set compared to the control, however the combination treatments were not significantly different to the singular treatments of either delayed clipping or early wick-wiping (Table 1).

B. Crop competition studies (faba bean)

Effect of increasing faba bean density

(i) On crop growth

Crop biomass increased with increasing seeding rates in all the years and at all sites (Table 2). Plant height also increased with increasing faba bean densities, except in 2018 at Turretfield. The increase in plant height with increasing densities is an adaptive response due to the close proximity of other plants, known as shade avoidance syndrome, and is triggered by plant hormones and photoreceptor proteins (Ballaré and Pierik 2017). Increasing faba bean plant densities from standard growers' practice of 22-24 plants m^{-2} to 30-36 plants m^{-2} resulted in a 13-18% increase in grain yield at Turretfield in all three years, however, no yield advantage was seen at Salter Springs in 2019. Earlier sowing at Salter Springs (31/05/2019) might explain this result, due to the longer crop season as compared to the Turretfield site that was sown comparatively later in all three years (19/6/2017, 06/06/2018 and 18/6/2019).

(ii) On broadleaf weed seed set control

Vetch seed set was reduced by 45-88% with increasing faba bean plant density from the standard grower practice of 22-24 plants m^{-2} to 30-36 plants m^{-2} (Table 2), resulting from increased competition on weeds due to greater crop biomass and plant height. This helped faba bean in smothering vetch plants and seed set was reduced with increasing seeding rates. However, increasing faba bean density from 22-24 plants m^{-2} to 30-36 plants m^{-2} was not as effective for reducing seed set of medics in two out of three years. The medic grew in a prostrate manner between the crop rows and set the same number of seed at both high and standard crop densities. Similarly, bifora set the same number of seed in both the standard and increased faba bean densities at Salter Springs in 2019, by growing as tall as the faba bean crop in the denser canopies. Therefore, the benefits for reducing broadleaf weed seed set are dependent on the adaptations of associated weed species to differences in crop canopy structure.

Effective weed management strategies should not only focus on killing weeds when they have emerged in crop, they should also target control of weed seed set and the reduction of weed seed banks. In-crop competition has a potential application in faba bean, which is sown at low plant densities and has slow initial growth. Novel approaches to integrated weed management such as wick-wiping with low volume concentrated herbicides and mechanical clipping of weed plants growing above the lentil crop canopy, improves control of brassica weed pod set. Integrated weed management strategies incorporating the use of these agronomic tactics and other novel approaches, in combination with rotating chemistries, will reduce the overall selection pressure on weeds and delay herbicide resistance build up.

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Table 1. Brassica weed pod set at Turretfield (in 2019 and 2020) and at Tickera (in 2021) as affected by clipping and wick wiping. Bars labelled with the same letter are not significantly different (P≤0.05).

Treatment	Turretfield 2019	Turretfield 2020	Tickera 2021
	Wild turnip pods (m^{-2})	Wild radish pods (m^{-2})	Indian hedge mustard pods (m^{-2})
Clipping at early pod initiation stage	170^{ab}	145^{b}	1156^{ab}
Clipping after one week of early pod initiation	121^{bc}	15^{c}	660^{bc}
Clipping after two weeks of early pod initiation	48^{cdef}	10^{c}	182^{d}
Clipping after three weeks of early pod initiation	15^{ef}	4^{c}	-
Clipping + wick wiping at early pod initiation stage	11^{f}	-	-
Clipping + wick wiping after one week of early pod initiation	66^{cde}	-	-
Wick wiping at early pod initiation stage	56^{cdef}	0^{c}	853^{bc}
Wick wiping after one week of early pod initiation	34^{def}	15^{c}	384^{cd}
Wick wiping after two weeks of early pod initiation	91^{bcd}	10^{c}	660^{bc}
Wick wiping after three weeks of early pod initiation	-	11^{c}	-
No weed wiping/clipping	243^{a}	454^{a}	1772^{a}

Table 2. Crop growth, yield, and broadleaf weed seed set as affected by increase in faba bean densities at Turretfield in 2017-2019 and at Salter Springs in 2019. Bars labelled with the same letter are not significantly different ($P \leq 0.05$).

Location	Target faba bean density (m^{-2})	Faba bean density achieved (m^{-2})	Crop biomass at flowering ($t\ ha^{-1}$)	Plant height at flowering (cm)	Grain yield ($t\ ha^{-1}$)	Vetch seed set (m^{-2})	Medic pod set (m^{-2})	Bifora seed set (m^{-2})
A. Turretfield 2017	12 plants	12 plants	1.13^{c}	52.2^{c}	1.92^{c}	778^{a}	732^{a}	-
	24 plants	24 plants	2.55^{b}	59.1^{b}	2.83^{b}	636^{a}	356^{b}	-
	36 plants	36 plants	3.72^{a}	68.4^{a}	3.25^{a}	381^{b}	159^{c}	-
B. Turretfield 2018	12 plants	12 plants	1.52^{c}	44.1^{a}	0.77^{c}	558^{a}	146^{a}	-
	18 plants	18 plants	2.21^{b}	45.4^{a}	0.95^{b}	369^{ab}	102^{ab}	-
	24 plants	24 plants	2.49^{ab}	45.5^{a}	0.98^{b}	404^{a}	40^{bc}	-
	30 plants	30 plants	2.94^{a}	47.0^{a}	1.15^{a}	219^{c}	40^{bc}	-
	36 plants	36 plants	2.9^{a}	45.7^{a}	1.18^{a}	178^{c}	32^{c}	-
C. Turretfield 2019	12 plants	11 plants	2.67^{c}	55.0^{d}	1.15^{e}	142^{a}	9^{a}	-
	18 plants	16 plants	2.96^{c}	57.4^{c}	1.39^{d}	160^{a}	5^{ab}	-
	24 plants	22 plants	3.71^{b}	60.5^{b}	1.61^{c}	152^{a}	3^{ab}	-
	30 plants	27 plants	3.46^{b}	63.2^{a}	1.72^{b}	65^{b}	1^{b}	-
	36 plants	32 plants	4.29^{a}	63.3^{a}	1.86^{a}	84^{b}	0^{b}	-
D. Salter Springs 2019	12 plants	12 plants	2.7^{c}	82.8^{c}	2.49^{c}	153^{a}	-	237^{a}
	18 plants	14 plants	3.2^{c}	84.9^{c}	2.77^{b}	113^{ab}	-	139^{ab}
	24 plants	22 plants	4.1^{b}	88.2^{b}	2.88^{ab}	75^{ab}	-	61^{bc}
	30 plants	25 plants	4.3^{b}	88.5^{b}	2.89^{ab}	28^{bc}	-	22^{c}
	36 plants	30 plants	5.0^{a}	92.0^{a}	2.94^{a}	9^{c}	-	20^{c}