CROP SCIENCE SOCIETY
OF SA INCORPORATED

Welcome to the February issue of the Crop Science Society of SA newsletter

Dear CSSSA Members,

Welcome to the February issue of the Crop Science Society of SA.

In this month's newsletter we explore:

- Member in focus – Ben Munzberg
- Movement, breeding, baiting and biocontrol of Mediterranean snail
- Weed Resistance management and optimising glyphosate update
- Nodulation of chickpea with P- Pickel T seed-dressing

We hope you are keeping well. Please contact us if you have any requests for content of information.

Kind regards,

Dan Petersen
President, Crop Science Society of South Australia

Member in focus – Ben Munzberg

I'm not your traditional Crop Science member and have tried my hands at a few things.

I grew up on a vineyard in McLaren Vale, attended Urrbrae and eventually went on to study Ag Science at Adelaide Uni. I shifted to Victoria after graduating, where I first worked at Hamilton Research Centre for Agriculture Victoria in the lamb production team before relocating to Birchip to work on a sheep and cropping farm. After this, I moved back to SA and took on a cropping manger role on the Yorke Peninsula and had a crack a growing most things. I now am working in the Ag tech industry looking to drive industry forward into the future.

I decided to join CSSSA to expand my cropping knowledge so we could make informed decisions on farm, while also keeping updated with the latest information and research. This society has been great at providing opportunities to network, ask questions and listen to many industry leaders. Meetings have always provided great access to a wide range of speakers, which has not only broadened my knowledge of agriculture, but also the wider industry. This makes it pretty unique when compared to other grower groups. I often take a note pad into the meetings and walk out with only one or two sentences on it, but this is enough to encourage further research or ask the agronomist a few curly questions at the next crop inspection.

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Movement, breeding, baiting and biocontrol of Mediterranean snails

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Keywords

- Albumen gland, reproduction, movement, behaviour, biocontrol, parasitoid fly, guidelines, molluscicide

Take home messages

- Extensive datasets highlight that baiting programs should be focused during March to June
- Snails move in response to increases in relative humidity at ground level from late summerthrough autumn, providing early baiting opportunities
- Rule-of-thumb guidelines for movement of vineyard, Italian and small pointed snails weregenerated from analysis of time lapse video data
- An introduced parasitoid fly, *Sarcophaga villeneuveana*, parasitises up to 48 % of conical snailsin local areas of SA near favourable species mixes of native vegetation

Introduction

This paper reports selected findings from GRDC research projects focused on improving molluscicidal control (DAS00160) and biocontrol (UOA1903-014BLX (9177340), CSE00061-PYC106)) of Mediterranean pest snails. Molluscicidal baiting is an important component of integrated snail controlbut provides variable levels of control despite high cost (Baker et al. 2017). An introduced parasitoidfly, *Sarcophaga villeneuveana*, attacks two conical snail species, *Cochlicella acuta* and *C. barbara*, withlimited impact to date. Developing improved management tactics for snails remains a priority to improve growers' profitability and reduce market access risks caused by snail contamination of thegrain harvest.

The GRDC project "Biology and management of snails and slugs in grain crops" (GRDC project: DAS00160, 2017–2020), led by SARDI in collaboration with DPIRD, generated new biological knowledge of pest snails and slugs, specifically their movement behaviour and reproductive activity, to assist growers to optimise the timing of baiting programs. Efficient baiting must target adult snailsbefore most reproduction occurs. Effective baiting to ensure snails encounter pellets requires snail movement, which must be predicted before application. This project investigated the environmentaltriggers for mollusc movement to provide better predictive capacity. This paper presents the resultsfor snails.

The GRDC project, "Snail biocontrol revisited – Phase II" (GRDC project: CSE00061-PYC106; 2019 – present), led by CSIRO in collaboration with SARDI, is investigating whether strains of the parasitoidfly, *S. villeneuveana*, sourced from Mediterranean regions more closely aligned with the geographicorigins of Australian *C. acuta*, can improve biocontrol of this species. Project results are presented elsewhere. New data generated by SARDI describing existing levels of biocontrol of *C. acuta* by *S.villeneuveana* in SA (SARDI-GRDC project: UOA1903-014BLX (9177340)) are presented here.
This paper summarises selected findings with relevance for management. Comprehensive datasetsand analyses are presented elsewhere and in project final reports (Perry *et al*. 2020a, Perry *et al*. 2020b, Caron *et al*. 2020; see Further Reading).

Snail breeding seasons

The reproductive cycles of three snail species were studied at four SA and four WA locations between 2017 and 2020 for periods from 2–4.5 years. Target species were the vineyard snail (*C. virgata*) atthree SA sites and one WA site, the white Italian snail (*T. pisana*) at one SA site, and the small pointed snail (*C. barbara*) at three WA sites (Table 1). Nine-month datasets were collected for *C. virgata* and *C. acuta* at three additional SA sites (for brevity, not

presented). Samples of ≈ 50 adult-sized snailswere collected approximately monthly, then measurements of shell height and albumen gland length (after dissection) recorded for each individual snail, yielding observations for 12,914 snails. Snails in a reproductive state have swollen albumen glands.

The three snail species, *C. virgata*, *T. pisana* and *C. barbara*, demonstrated strongly seasonal reproductive cycles with breeding seasons extending from autumn to spring (Table 1). On average,the main breeding seasons were March to late September for *C. virgata*, late February to late July for *T. pisana*, and March to October, sometimes extending into late November, for *C. barbara* in WA (Table 1). Limited data at three SA sites (4–8 months between July 2019 and March 2020) for theconical snail, *C. acuta,* suggested most breeding commenced sometime after March in 2020.

For each snail species, the timing of reproductive activity varied between seasons and/or locations,reflecting that species' activity depends to some extent on local environmental conditions. However, relationships between reproductive activity and prior rainfall or other measured climate and microclimate variables (such as soil water content, soil surface wetness, and relative humidity andtemperature at different heights above ground level) were not always clear, suggesting that reproductive cycles have an underlying seasonal basis. We found no evidence of significant breeding activity from late spring to summer for any snail species during this study, even when substantial movement occurred following spring or summer rainfall.

Table 1: Breeding seasons by species

Species	Study location		Study years	Breeding season ***average***	Breeding season ***range***
Vineyard snail, *Cernuella virgata*	SA	Palmer	2015 – 2018	Mar to Sep	Feb/Mar to Jul/Oct
	SA	Manoora	2015, 2017, 2018	Mar to Oct	Mar/Apr to Oct/Nov
	SA	Urania	2018 – 2020	Apr to Sep	Mar/May to Aug/Oct
	WA	Gairdner	2017, 2018	Mar to Oct	Feb/Mar to Oct/Nov
		4 sites	*12 years*	***Mar to Sep***	
White Italian snail, *Theba pisana*	SA	Warooka	2015 – 2018	Feb to Jul	Jan/Feb to Jul/Aug
		1 site	*4 years*	***late Feb – late Jul***	
Small pointed snail, *Cochlicella barbara*	WA	Esperance Marshall	2018	Jan to Sep	
	WA	Esperance Perks	2017, 2018	Mar to Sep	Feb/Apr to Sep/–
	WA	Woogenellup	2017, 2018	Mar to Nov	Mar/Apr to Nov/–
		3 sites	*5 years*	***Mar to Oct***	

Snail movement and microclimate

Movement behaviour of snails was studied at ten locations in SA and WA (seven sites in Table 1 with exception of Manoora, plus three other SA sites) between 2015 and 2020 for periods from 9 monthsto 4.5 years. Time lapse video footage was collected continuously at 1-minute intervals and microclimate variables (e.g. soil water

content at 10 cm depth, soil surface wetness, ground level relative humidity and temperature, and others) were logged at 30-minute intervals. Video footage was analysed using computer vision techniques developed by collaborators at University of SouthAustralia (Ivan Lee *et al*.), yielding 103,228,235 observations of individual movement distance perframe. Manual ground-truthing estimated that autodetection accuracy was ≈ 85 % for the round snail species but < 40 % for small pointed snails due to greater detection challenges. Movement data were statistically analysed to determine microclimate conditions that best explained low or high snail movement at different times of the year.

In general, snails became increasingly responsive (moved) to increases in ground level relative humidity from late summer through autumn. Other microclimate variables and interactions betweenvariables were associated with high/low movement, however these relationships were less clear (Perry *et al*. 2020b). For simplicity, rule-of-thumb guidelines for snail movement with respect to relative humidity were generated from the data (Table 2). These guidelines are simply a set of hypotheses generated from the available data and should be tested and refined over time under field conditions. There is greater confidence in the information for the round snails, *C. virgata* and *T. pisana*,than for small pointed snails, based on higher detection accuracy.

Table 2: Rule-of-thumb levels of relative humidity at ground level associated with the *highest* observed movement.

Species	Feb	Mar	Apr	May	Autumn
Vineyard snail	**> 95 %**	**> 90 %**	**> 80–85 %**		**> 85–95 %**
Italian snail	**> 90 %**	**> 90 %**	**> 85–90 %**		**> 88 %**
Small pointed snail		**> 95 %**	**> 95 %**	**> 95 %**	**> 95 %**

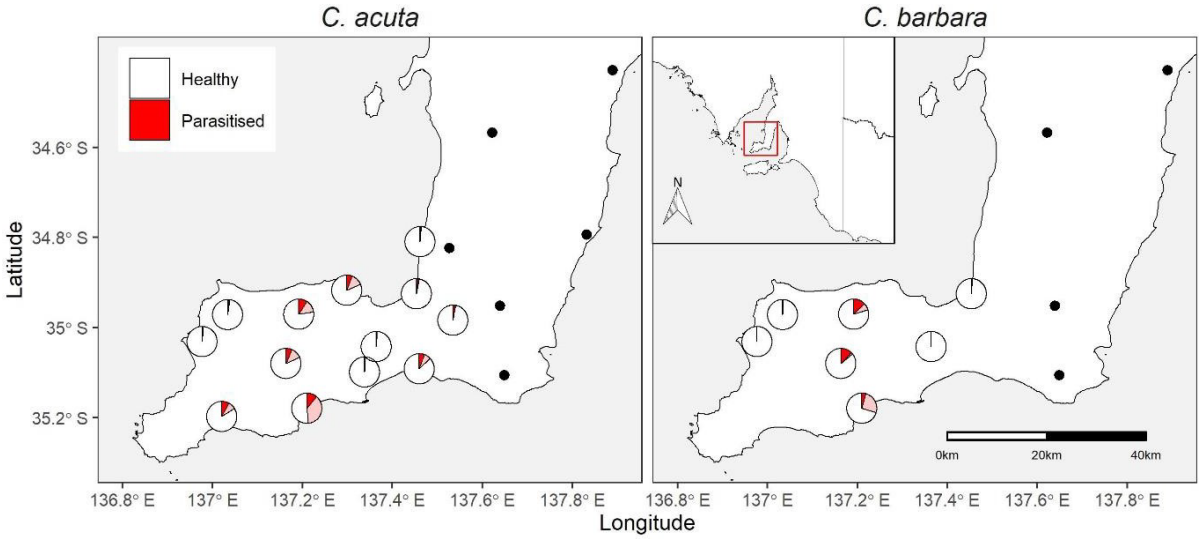
Implications for bait timing

All datasets together highlighted that baiting programs targeting *C. virgata*, *T. pisana*, and *C. barbara* should be concentrated during the autumn and early winter period, from approximately March to June, prior to most reproduction, to maximise cost-efficiency. There are several reasons for this recommended timing: (1) Snails showed higher susceptibility to bait toxins during this period than during non-reproductive periods (see Brodie *et al*. 2020, Perry *et al*. 2020b, and presentation slides);
(2) Snails feed voraciously on baits immediately after exiting summer aestivation; (3) Most offspringare produced during the early phase of the breeding season; Targeting adult snails before most eggs are laid minimises offspring production; (4) Baiting prior to crop sowing minimises soil surface obstacles and alternative food sources (e.g. crop seedlings), thereby increasing the chance of baitencounter.

We recommend that growers commence monitoring for baiting opportunities from late summer, approximately February onwards, as snails move opportunistically in response increased moisture or relative humidity at this time. Baiting from January or earlier is likely to be less efficient because: (1)Snails may be less susceptible to bait toxins than during their reproductive periods; (2) Exposure ofbait pellets to high temperatures (>35 °C) can cause loss of active ingredient (Baker *et al*. 2017); (3)Baiting too early increases the chance of killing some snails that would otherwise die naturally fromheat/dry stress (e.g. Perry *et al*. 2020a), wasting bait. We suggest baiting programs should generally cease by mid-winter or earlier as later applications are less efficient. Instead, baits should be usedearlier in the season or in the following season during the optimal windows.

Time lapse video showed that initial increases in movement during late summer through autumn occurred mostly overnight (not shown). To detect this movement and confirm whether snails are feeding, growers can deploy small areas of bait in infested areas prior to widespread application.

Figure 1: Parasitism levels of conical *C. acuta* and *C. barbara* by the parasitoid fly, *S. villeneuveana*.



Pies show the proportion mean overall parasitism (red shading) or maximum parasitism observed ona single sampling date (pink shading) at sites where *S. villeneuveana* was present, while black dotsindicate absence of *S. villeneuveana* at a sampled site

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Biocontrol of conical snails

The fly, *Sarcophaga villeneuveana*, is a specialist parasitoid of the conical snail, *C. acuta* and smallpointed snail, *C. barbara*. Strains of *S. villeneuveana* were sourced from the Montpellier region, France, and introduced into South Australia by SARDI and CSIRO between 2001–2004 for biocontrolof *C. acuta* (Leyson et al. 2003). The fly successfully established on southern Yorke Peninsula butexhibited limited spread and impact, with pre-2018 levels of *C. acuta* parasitism estimated at < 2%(SARDI unpublished). A current GRDC project (CSE00061-PYC106, 2019–present), conducted by CSIRO and SARDI, has focused on enhancing biocontrol success by introducing *S. villeneuveana* sourced fromareas of Spain and Morocco better matching the geographic origins of Australian *C. acuta* (Jourdan *et al*. 2019). In 2020, Moroccan fly strains were imported by CSIRO and reared in quarantine facilities at SARDI for evaluation of host specificity prior to seeking approval for a rear-release program.

To enable assessments of the impact of future fly releases, SARDI generated baseline data on thecurrent level of conical snail parasitism by *S. villeneuveana* (project: UOA1903-014BLX (9177340)). In January and April of 2019 and 2020, *C. acuta* and *C. barbara* were collected from 19 sites on Yorke Peninsula and from four different microhabitats: 1) ground-level, in quadrats; 2) elevated (e.g. on plants, stubble and fence posts); 3) at the base of tussocks, plants and grasses; and 4) under refuges (e.g. logs and rocks). Snails were returned to the laboratory, reared and examined for parasitism.

From 85,673 *C. acuta* and 2,412 *C. barbara* of suitable size (> 5mm) assessed for parasitism, *S. villeneuveana* was detected in snails from 13/19 sites (Fig. 1). At sites where *S. villeneuveana* wasdetected, overall parasitism was 2.8 % for *C. acuta* and 3.4 % for *C. barbara*. Mean parasitism rateswere significantly higher for *C. acuta* snails on elevated substrates (10.8 %) than at the base of plants (4.1 %), at ground level (4.4 %) or under refuges (1.7 %) (Fig 2.). At individual sites and sampling dates,parasitism ranged from 0–48% for *C. acuta* and 0–27% for *C. barbara*. Higher parasitism levels were observed at sites adjacent to native vegetation flowering during periods of fly activity (spring/summer), suggesting vegetation provides food and/or shelter resources.

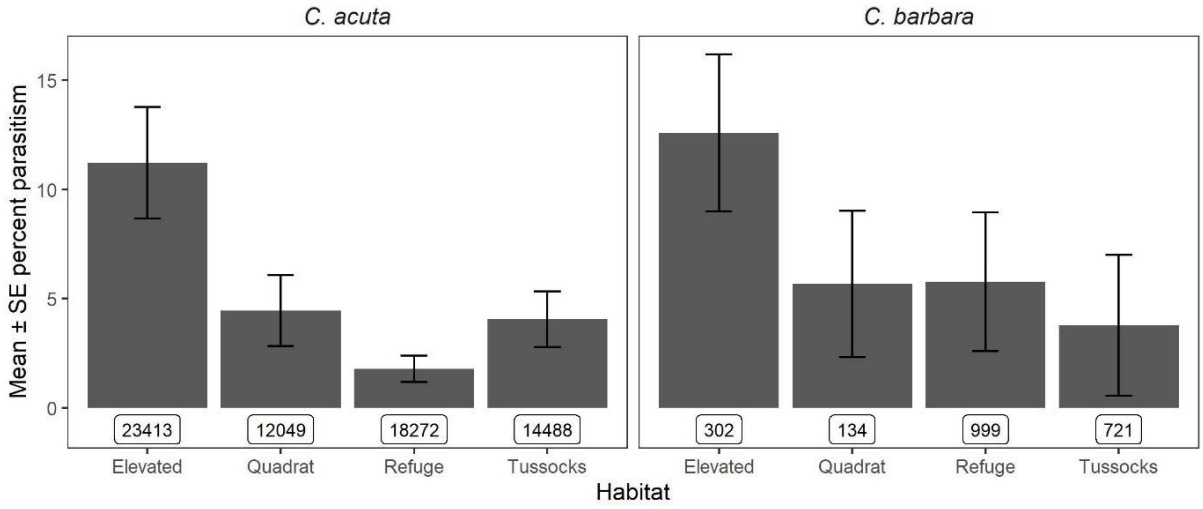

Figure 2: Parasitism of conical snails by *S. villeneuveana* in four microhabitats in 2019 and 2020.Sample sizes per category are shown in boxes.

Conclusions

Findings from DAS00160 generated a sound evidence base underpinning best practice snail management and provided growers with new information to refine their baiting strategies. Additionally, novel infrastructure (methods, analyses) for mollusc movement studies were also developed for future use. Further development is required to improve computer vision detection accuracy for conical snail species, and to generate deeper understanding of their movement and management. It was discovered that the introduced parasitoid fly, *S. villeneuveana*, performs well inthe Yorke Peninsula climate in local areas with suitable habitat. Furthermore, *S. villeneuveana* attacks *C. barbara* at similar rates to *C. acuta* and is therefore suitable for release in other regions (e.g. including Western Australia) for biocontrol of either species.

Acknowledgements

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Weed Resistance management and optimising glyphosate update.

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Keywords

- Resistance, national random weed survey, ryegrass, brome, barley grass, wild oats, wild radish, mustard, sowthistle, wild turnip, glyphosate, paraquat.

Take home messages

- Resistance to pre-emergence herbicides in ryegrass is low.
- Resistance in brome, barley grass, wild oats low, but high in broadleaf weeds to Group 2 herbicides.
- Weed control failures not always due to resistance and optimising application and timing will improve weed control.
- Glyphosate resistance most prevalent in ryegrass.
- Use of alternative strategies including glyphosate to combat glyphosate resistance.

National herbicide resistance weed survey 2020-2023

A national GRDC funded weed survey commenced in 2020. In a national collaboration between universities, over 1500 paddocks were sampled across WA, SA, Vic, Tas, NSW and Qld in 2020 and 2021. Farmer paddock details were supplied by agronomists and each university randomly selected a set number of paddocks in their respective state. After sampling, all the ryegrass was sent to the University of Adelaide for testing, barley grass, brome and wild radish to AHRI, wild oats and sowthistle to CSU. Using this approach, the national collection of each species will be tested together. In 2021, the national ryegrass collection was tested with pre-emergence herbicides with the post-emergence testing to be conducted in 2022 (Table 1).

Table 1: Percent of paddocks detected with resistant ryegrass treated with the recommended label rate of pre-emergence herbicides. Resistance is defined as a sample where ≥20% plant survival was detected in the 2021 pot trials.

State			**Herbicides**			
	Trifluralin	BoxerGold	Sakura	Propyzamide	Luximax	Overwatch
National	12	2	0	0	0	0
SA	38	1	0	0	0	0
VIC	21	9	0	0	0	0
NSW	0	1	0	0	0	0
WA	4	2	0	0	0	0
TAS	0	0	0	0	0	0

Table 2: Nr of paddocks where ryegrass was collected and tested from each state.

State			**Herbicides**			
	Trifluralin	BoxerGold	Sakura	Propyzamide	Luximax	Overwatch
National	1353	1202	1202	1202	1202	1202
SA	279	266	266	266	266	266
VIC	183	179	179	179	179	179
NSW	317	273	273	273	273	273
WA	554	465	465	465	465	465
TAS	20	19	19	19	19	19

The trends in resistance to pre-emergence herbicides in ryegrass supports the findings from previous surveys. The greatest incidence of resistance to trifluralin was detected in SA (38%) followed by Victoria (21%), WA (4%) and 0% in NSW and Tasmania. The only other resistance detected was to Boxer Gold, the highest (9%) in Victoria. No resistance to field rates of Sakura, Propyzamide, Luximax and Overwatch was detected. These results suggest several herbicide options for the pre-emergence control of ryegrass remain.

Herbicide resistance weed to other species 2017-2019 from SA random weed surveys

Other key weed species that were surveyed and resistance tested in the latest SA surveys include brome, barley grass, wild oats, wild radish, sowthistle, Indian hedge mustard and wild turnip.

Table 3: Percent of paddocks detected with herbicide resistant brome and barley grass between 2017-2019.

Herbicide	brome Eyre P 2019	brome Mid-North 2018	brome Mallee 2017	barley grass Eyre P 2019	barley grass Mid-North 2018	barley grass Mallee 2017
Quizalofop	0	2	0	6	4	0
Mesosulfuron*	0	36	48	1	49	41
Imidazolinone	0	3	0	0	0	0
Glyphosate	0	0	0	-	-	-

Resistance is defined as a sample where ≥20% plant survival was detected in the following seasons pot trials.
* suppression,

Table 4: Percent of paddocks detected with herbicide resistant wild oat between 2017-2019.

Herbicide	Eyre P 2019	Mid-North 2018	South-east 2017
Clodinafop	7	6	0
Mesosulfuron	0	9	0
Triallate	0	0	0

Resistance is defined as a sample where ≥20% plant survival was detected in the following seasons pot trials.

Grass weeds: The incidence of resistance to the grass weeds barley grass, brome and wild oats was much lower than to ryegrass. Group 1 herbicides remain effective on brome, barley grass and wild oats with few exceptions. These results indicate that in most cases, good control should be expected under optimum spray conditions. Despite the ubiquitous use of imidazolinone tolerant crops for almost two decades, resistance to imidazolinone herbicides not been detected in barley grass or wild oats with resistance detected in only 3% of brome samples from the Mid-North (Table 3). The activity of mesosulfuron is often suppression rather than mortality in brome and barley grass. In the Mid-North and Mallee between 36%-49% of brome and barley grass was suppressed, with the remainder killed (Table 3). Under strong crop competition, suppressed grass weeds rarely yield significant seed numbers. Mesosulfuron was effective on brome and wild oats from the Eyre Peninsula on wild oats from the South-East and on 91% of samples from the Mid-North (Table 4). No triallate resistant wild oats or glyphosate resistant brome was detected.

Table 5: Percent of paddocks detected with herbicide resistant broadleaf weeds (mustard, wild radish and wild turnip) between 2017-2019.

Herbicide	mustard Eyre P 2019	mustard Mid-North 2018	wild radish South East 2017	wild turnip Mallee 2017
Chlorsulfuron	82	43	46	19
Imidazolinone	27	29	23	16

Atrazine	0	0	0	0
Diflufenican	0	0	0	0
2,4-D	0	7	38	0
Glyphosate	-	-	0	-

Resistance is defined as a sample where ≥20% plant survival was detected in the following seasons pot trials.

Table 6: Percent of paddocks detected with herbicide resistant sowthistle between 2017-2019.

Herbicide	Eyre P 2019	Mid-North 2018	South East 2017	Mallee 2017
Chlorsulfuron	72	90	66	92
Imidazolinone	61	88	76	91
2,4-D	0	0	25	3
Glyphosate	0	-	0	0

Resistance is defined as a sample where ≥20% plant survival was detected in the following seasons pot trials.

Broadleaf weeds: resistance to Group 2 (B) sulfonylurea herbicides was prevalent across the 4 species tested (Tables 4, 5). Resistance to imidazolinones was lower in mustard, wild radish and wild turnip compared to chlorsulfuron. In contrast, the incidence of sowthistle resistant to Intervix was similar to that of chlorsulfuron. Where tested, no resistance to glyphosate or diflufenican was detected. Resistance to 2,4-D was detected in mustard from the Mid-North (7%), wild radish (38%) and sowthistle (25%) from the South-East, respectively.

Improving weed control

Resistance levels within individuals in a population can vary and in many cases a resistant plant can be killed with a robust field rate under optimum spray and growth conditions. This is most common in plants with weak resistance mechanisms particularly at early growth stages with herbicides such as 2,4-D, diflufenican, clethodim and glyphosate. Young plants possess thinner cuticles making herbicide entry easier. However, plants with strong resistance mechanisms, particularly to Group 2 (B) herbicides are difficult to control even at young growth stages. The high frequency of Group 2 target site resistance in certain weed species such as *Brassica* spp. (mustard, wild radish, wild turnip) and sowthistle confirms why these weeds are difficult to control with this mode of action. Fortunately, control with alternative diverse mode of action pre-emergence herbicides is available to combat Group 1 and 2 resistance. Overuse of any mode of action herbicide can lead to multiple resistance such as in the case of the 2,4-D resistant sowthistle and wild radish (Tables 5, 6).

Optimising glyphosate performance.

In order to maximise the efficacy of glyphosate consider the below:

1. use high quality glyphosate products and surfactants where recommended,
2. avoid combining glyphosate with too many other active ingredients to reduce the likelihood of antagonism, particularly with low water volumes,
3. always use ammonium sulphate to condition the water and improve efficacy of glyphosate. The concentration of ammonium sulphate required can depending on the water hardness (see useful resources at end of paper)
4. avoid applying glyphosate during periods of high temperature and low humidity, to avoid the the rapid loss of glyphosate in solution from leaf surfaces,
5. consider using higher label rates if there is considerable shading or leaves are covered with dust,
6. maximise application by adhering to lower speeds and using the correct nozzles, pressure and boom height,
7. any combination of the above factors can reduce control thereby increasing the selection for resistance.

Living with glyphosate resistance.

Across southern Australia the most important species developing glyphosate resistance is annual ryegrass. It is very important to test for glyphosate resistance to ensure the correct weed control strategies are implemented. Even if glyphosate resistance is confirmed it can still be used strategically. Unlike resistance to Group 2 (B) herbicides where the level of resistance in an individual can be high, glyphosate resistance often starts as weak resistance in a low number of plants and if left uncontrolled can increase over time, particularly for cross-pollinating species such as ryegrass.

If a resistance test was conducted and it confirmed a high survival rate don't panic! If the sampling for resistance comprised of very few individuals identified in the paddock after the glyphosate application, whether plants (Quick-Test) or seeds (Seed Test) then the true incidence of resistance is very low. Management in the subsequent season should actively target to control any survivors. That doesn't necessarily imply not to use glyphosate. A double knock approach involving glyphosate (to control the majority of susceptible individuals) followed with a robust rate of paraquat 1-5 days later is ideal (Figure 1). Over relying solely on paraquat as the only knockdown can impose strong selection pressure for the development of resistance A low number of paraquat resistant ryegrass cases have however recently been confirmed in cropping paddocks in South-Western Victoria and South-Eastern SA.

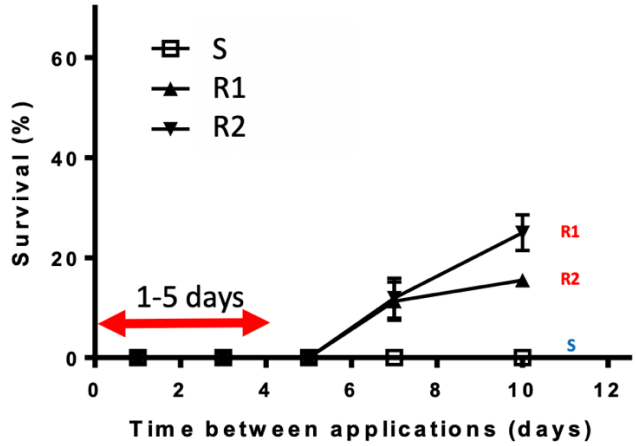

Figure 1: Double knock timing. Glyphosate applied onto a susceptible (S) and two glyphosate resistant ryegrass biotypes (R1 & R2) followed by paraquat 1, 3, 5, 7 and 10 DAA. Trial work conducted by Dr Christopher Preston (The University of Adelaide).

The use of an effective pre-emergent herbicide or combination is recommended to control any subsequent germination. With delayed germination becoming more prevalent in some ryegrass biotypes, a resistance test would aid in the identification of whether there were effective post-emergent herbicide options available to control potential glyphosate resistance. It is not advisable to grow a GM canola crop unless clethodim/ butroxydim is effective, so clethodim/ butroxydim (or clethodim + glyphosate) can be used to control the ryegrass and glyphosate to control susceptible ryegrass and other target species.

Crop topping with glyphosate where glyphosate resistance has been confirmed is not advisable as it may serve to sterilise susceptible ryegrass seed and leave resistant plants behind to preferentially cross pollinate and fast-track glyphosate resistance (Figure 2). A seed-sterilisation field trial was conducted in 2016 at a site with confirmed glyphosate resistance. Viability testing of the seed after maturation revealed that the reduction in seed germination was between 9-22% indicating that at least 80% of the seed remained viable. Glyphosate was therefore not effective in sterilising glyphosate resistant ryegrass.

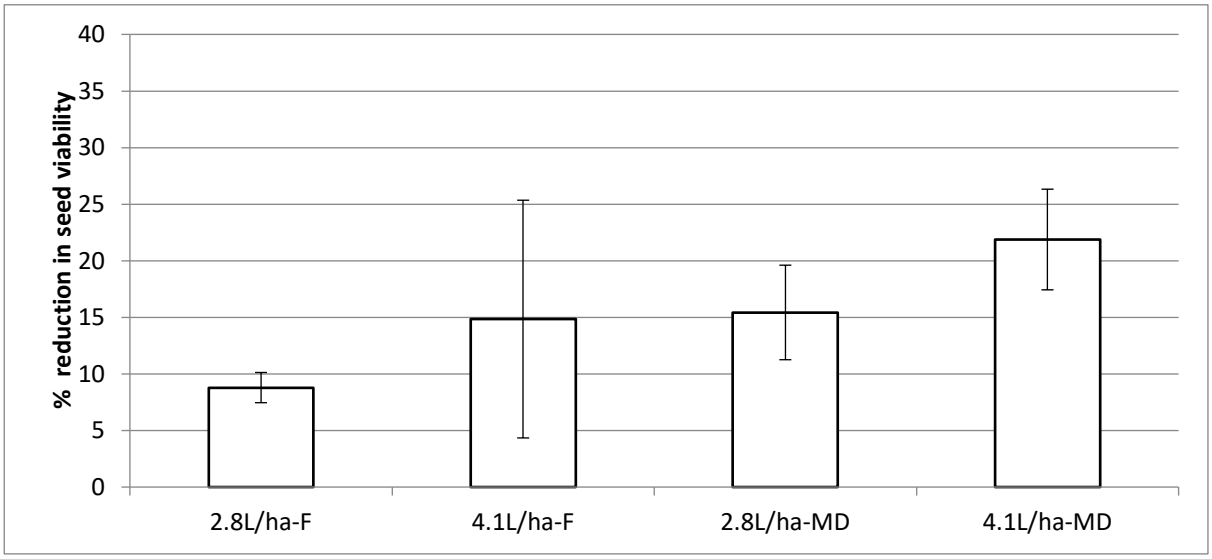

Figure 2: Reduction in viability of ryegrass seed after crop-topping with Weedmaster DST at two timings, F - flowering and MD = milky dough. Trial conducted at Roseworthy SA in 2016.

Crop rotation: There are several robust herbicide options available for combatting glyphosate resistance in a pulse crop such as propyzamide, carbetamide, higher Group 1 (DIM) registered rates and crop-topping with paraquat.

Summary
Several pre-emergent herbicide options remain to control multiple-resistant ryegrass as indicated by recent national weed surveys. Resistance in other key grass weed species remains low. However mustard, wild turnip, wild radish and sowthistle resistant to Group 2 herbicides is significant. There are several factors that can contribute to poor weed control with resistance being only one of them. Optimising application equipment, timing and understanding environmental factors that reduce herbicide efficacy is important. Glyphosate resistance is most prevalent in ryegrass across southern Australian. Glyphosate and paraquat can be used strategically even if resistance is present.

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Nodulation of chickpea with P- Pickel T seed-dressing

Judy Rathjen, Maarten Ryder, Thang Lai and Matthew Denton – University of Adelaide
GRDC 9176500

Take home messages

- P Pickel T is toxic to rhizobia and decreases nodulation in chickpea and other pulses in the field
- Using granular inoculant can reduce the fungicide effect and improve nodulation

Background

Laboratory and glasshouse experiments revealed that P Pickel T (PPT, active ingredients thiram and thiabendazole) is toxic to rhizobia. *In vitro* tests showed that rhizobia were killed when placed on a Petri dish with PPT and nodulation was reduced in a glasshouse experiment, with both group N (chickpea) and group E/F (pea, bean, lentil) rhizobia. Currently growers, especially chickpea growers, are recommended to coat PPT fungicide on the seed and then inoculate, which may affect nodulation and N fixation in the field.

Methods

Field trials were conducted over four sites and two years in soil with with low rhizobial backgrounds in high to low-rainfall environments in Victoria and SA. Soil types ranged from sandy (Angas Valley), loam (Mallala and Ouyen) to clay (Gymbowen). Chickpea seeds were coated with PPT and then inoculated with a peat slurry, or the inoculant was separated from the fungicide-coated seed by using a granular or a freeze-dried liquid inoculant (Angas Valley only). Control treatments were peat slurry and no PPT, and no inoculant or PPT coating. Nodulation rating was assessed at 12 weeks after sowing (Corbin et al, 1977). All experiments were conducted as small plot trials with three replications.

Results and Discussion

Nodulation was reduced when inoculant was applied to seed over PPT at three of four sites (Figure 1). At Angas Valley, there was low nodulation in plants where seeds were not coated with PPT (Figure 1). This may have been due to the dry conditions after sowing; nodulation was less than adequate (where adequate = rating of 3 or above) at all sites except Gymbowen.

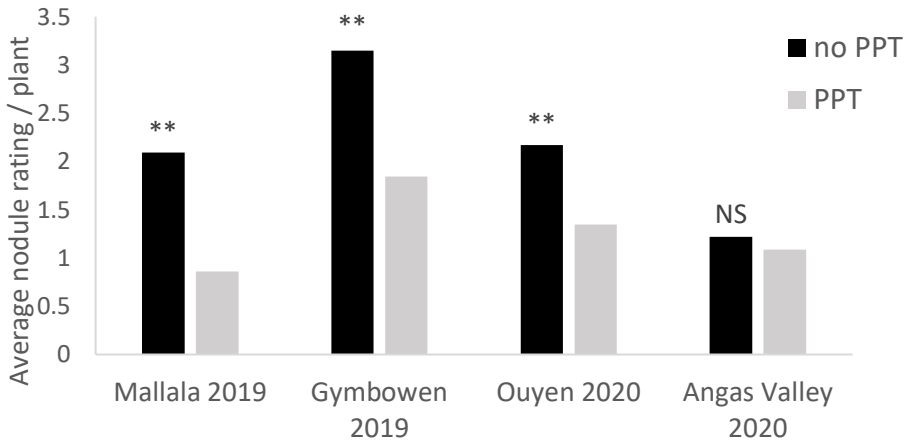

Figure 1. Average nodulation rating of chickpea plants coated with PPT or not coated and then inoculated with a peat slurry. Field trials were conducted at Mallala SA (2019), Gymbowen Vic (2019), Ouyen Vic (2020) and Angas Valley SA (2020). ** = significant at $P < 0.01$

Figure 2 shows that when granular inoculant was used, separated from seeds coated with PPT, there was not a significant reduction in nodulation in contrast to the peat inoculant together with PPT (Figure 1). However,

the nodule rating was sometimes lower (Gymbowen) in the control treatment without PPT, with granular compared to peat inoculant. At Angas Valley, nodulation was reduced when seeds were coated with PPT and inoculated with a liquid freeze-dried solution, but the freeze-dried solution applied in-furrow to seeds without PPT did not induce adequate nodulation. In general, separating the seed from the rhizobia by using granules or liquid inoculant can reduce the toxic effect of PPT.

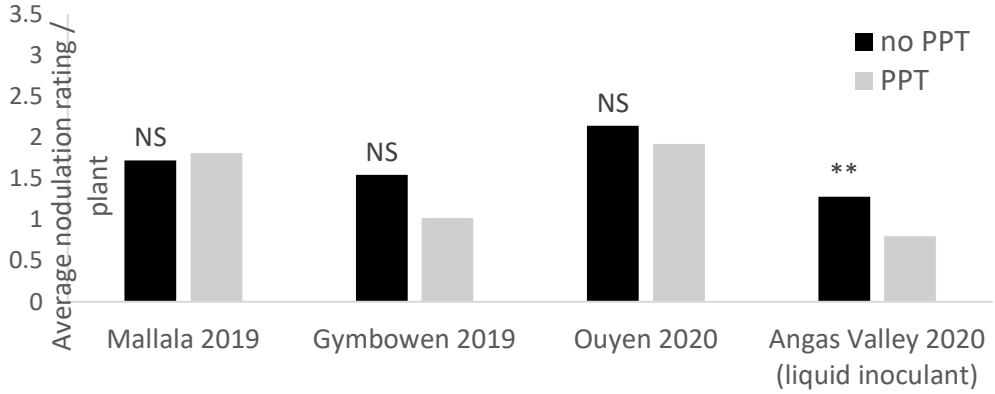

Figure 2. Average nodulation rating of chickpea plants coated with PPT and inoculated with granules or a liquid freeze-dried inoculant (Angas Valley only). Field trials were conducted at Mallala SA (2019), Gymbowen Vic (2019), Ouyen Vic (2020) and Angas Valley SA (2020). ** = significant at $P < 0.01$