CROP SCIENCE SOCIETY OF SA INCORPORATED

Welcome to the April issue of the Crop Science Society of SA newsletter; issue 346

Dear CSSSA Members,

Welcome to the April issue of the Crop Science Society of SA, issue 346.

In this month's newsletter we explore:

- Member in focus – Dr Michael Nash
- Frost Mitigation through variety selection and management of wheat: Genevieve Clark, BCG Shared Solutions
- Invertebrate crop threats due to mixed species cover crops: Dr M A Nash

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 – Dr Michael Nash

I grew up on the family farm located on "*pleurisy plains*" in Western Victoria, with the Salt Creek running close by through my uncle's farm.

The former volcano Mt Shadwell provided the only relief to an otherwise flat, treeless landscape. Succeeding my father after leaving school, I changed the enterprise from grazing to farming. Revegetation continued in areas too difficult to crop.

Twelve years on and frustrated by the lack of research for high rainfall cropping, I returned to university while continuing to farm. Seven years, nine months, two weeks and three days later a PhD was complete at the University of Melbourne.

Post-doctoral research led me to study alpine invertebrates' response to climate change, then a position at SARDI. Standing on the shoulders of giants at the Waite, my research focused on snails and slugs ("*snugs*"). Crop Science Society's connection to researchers saw me join in 2014. My continued passion to deliver useful research to growers is cultivated by CSSSA; hopefully I can help this tradition continue.

An applied invertebrate ecologist, I look for crop protection solutions that are based on how species within agriculture interact with each other and their environment. Discovering the unseen fauna in nature keeps me busy when I am not consulting to industry. I am a strong advocate for conservation of native species in productive landscapes.

Dr Michael Nash

FROST MITIGATION THROUGH VARIETY SELECTION AND MANAGEMENT OF WHEAT

Genevieve Clarke (BCG)

TAKE HOME MESSAGES

Late grazing delayed flowering by up to three weeks.

- With adequate recovery conditions, grazed spring wheats yielded similarly to ungrazed.
- Grazing can shift flowering out of a high-risk window however, frost timing is unpredictable.

BACKGROUND

Frost damage is a risk to all winter cereals across the Wimmera and Mallee and can cause significant yield losses. No crop is resistant to frost damage so management is the only way to reduce this risk.

It is difficult to predict when frost will occur and a number of complexities come into play when understanding severity and whether it will cause crop damage. Damage can occur at all stages of development however crops are most susceptible to frost damage at flowering. While frost does not occur at the same time every season, avoiding flowering in a higher risk window is a good risk management tool. The optimal flowering windows for wheat—a window of reduced risk of frost and heat damage—have been defined for different locations (Table 1).

Table 1. Optimal flowering windows and soil types for locations across western Victoria, adapted from Flohr et al 2017. (a) and (b) refer to different soil types in the same location.

Location	Start of window	End of window	Soil type
Hopetoun (a)	7 September	11 September	Loamy sand
Hopetoun (b)	4 September	9 September	Clay loam
Walpeup	8 September	17 September	Swale loamy sand
Charlton	21 September	30 September	Clay loam
Longerenong	6 October	10 October	Clay

Targeting flowering for these optimal windows lowers risk in most years. Manipulation of flowering and spreading flowering timing across a wider window across a cropping program will also help to reduce the overall risk of frost damage. This can be achieved through variety selection, sowing date and management.

Matching phenology to sowing timing is one way to target these lower risk flowering windows. Maturity drivers of different wheat varieties will determine optimal sowing windows to align with flowering. Driven by either day length, temperature or a combination, spring wheats have the ability to be sown across a two to four week window. Winter wheats have an additional vernalisation requirement and a much wider sowing window. This is due to the need to accumulate cold temperatures before switching from vegetative to reproductive growth, providing a more stable flowering timing across a wider sowing window (Clarke et al, 2018).

Late grazing, or mechanical defoliation of early sown spring wheat after initiation of stem elongation, has been found to manipulate this flowering timing by up to two weeks, delaying maturity through removing biomass and apical growing tips (Porker et al, 2021). Yield recovery in some cases was equivalent to yields of early sown winter wheats that were not defoliated. While this is an uncertain result in low rainfall environments, there may be opportunity in some seasons to use it as a tool to manipulate flowering timing to avoid frost risk without the need to carry a winter wheat variety to provide an opportunity to open up the sowing window without risking early flowering (Porker, 2019).

This work further investigates the manipulation of flowering timing through sowing timing, variety selection and late grazing for frost mitigation in a low rainfall, frost-prone environment.

AIM

To investigate the effect of variety selection, late grazing and time of sowing on flowering timing of wheat production in a frost-prone environment.

PADDOCK DETAILS

Location: Watchupga

Crop year rainfall (Nov – Oct): 234mm

GSR (Apr – Oct): 172mm

Soil type: Sandy clay

Paddock history: Vetch hay

METHOD

A replicated field trial was sown using a split plot design with time of sowing (TOS) as whole plots. Irrigation (10mm) was applied following TOS1 to ensure early establishment. TOS2 was established after rainfall. Simulated crash grazing was applied using a lawn mower on 21 June (TOS1) and 5 August (TOS2) at growth stage Z31/32 for spring wheats and tillering for winter wheats. Assessments included establishment scores, phenology observations, grazing biomass and feed value, hay yield and biomass at growth stage 71 just post-flowering, frost induced sterility scoring and grain yield and quality assessments.

Table 2. Trial treatment outline. Grazing simulated as defoliation by lawn mower.

Variety	Maturity	Time of sowing (TOS)	Grazing
Vixen	Quick spring	TOS 1: 15 April	Grazed
Razor CL Plus	Quick-mid spring	TOS 2: 7 May	Ungrazed
Scepter	Mid spring		
Catapult	Mid-slow spring		
Illabo	Quick winter		
DS Bennett	Mid winter		

RESULTS AND INTERPRETATION

Phenology

Maturity drivers differed across varieties in this trial (Table 3). Wheats are sensitive to thermal time, and increased development rate with increased temperatures, but can also have sensitivities to photoperiod (day length) and vernalisation (winter wheats). In the case of the spring wheats there is very weak photoperiod sensitivity so growth is dictated through temperature. Catapult has a weak sensitivity to photoperiod but a larger thermal requirement and is therefore slower to mature. The winter wheats require vernalisation to be satisfied, with DS Bennett having a larger requirement than Illabo, before a switch to vegetative growth and therefore were further behind in maturity at grazing timings than the spring wheats (Table 3).

Late grazing, after the initiation of stem elongation, delayed flowering timing by up to three weeks in the spring wheats (Table 3). Grazing had little effect on the flowering time of Catapult (long spring wheat) DS Bennett and Illabo (winter wheats) from either of the sowing times. This could be expected in the winter wheats as at the time of grazing they were not at elongation growth stages.

Table 3. Flowering dates, growth stage at grazing and delay in flowering from grazing across all treatments. TOS1 grazing applied with lawn mower on 21 June and TOS2 grazing applied 3 August.

Variety	TOS	Growth stage at grazing	Ungrazed flowering date	Grazed flowering date	Flowering delay from grazing (days)
Vixen	1	GS32	16 August	6 September	21
Razor	1	GS31	16 August	6 September	21
Scepter	1	GS31	26 August	10 September	15
Catapult	1	GS31	2 September	6 September	4
Illabo	1	GS23	23 September	23 September	0
DS Bennett	1	GS24	7 October	7 October	0
Vixen	2	GS32	10 September	1 October	21
Razor	2	GS32	10 September	23 September	13
Scepter	2	GS32	17 September	1 October	14
Catapult	2	GS31	21 September	27 September	6
Illabo	2	GS30	27 September	1 October	4
DS Bennett	2	GS27	12 October	15 October	3

Early biomass and grazing quality

Although irrigated after sowing, dry and warm early growing conditions limited biomass production, while phenology progressed quickly on TOS1 treatments. Early biomass (taken at grazing timing) found TOS2 produced much greater biomass than TOS1 at the time of grazing with an average of 1.7t/ha and 0.3t/ha respectively ($P<0.001$).

TOS1 had higher feed quality at the time of grazing (Figure 1) however the amount of biomass available at this growth stage would realistically not have been enough to warrant grazing.

Decline in feed quality with progression of wheat maturity was evident, with lower feed value from varieties that were further along at the time of grazing.

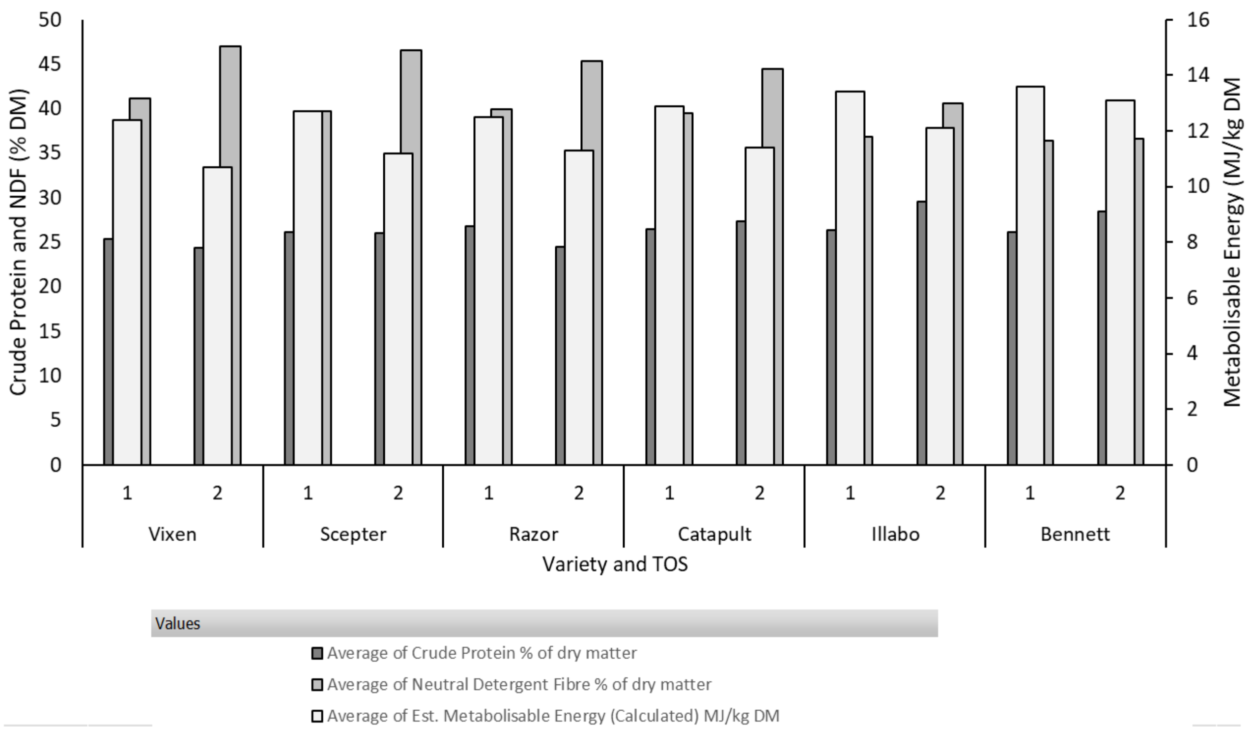

Figure 1. Crude protein, Neutral detergent fibre (NDF) (%DM) and Metabolisable energy (MJ/Kg DM) of early biomass at grazing timing of respective sowing timings.

Hay yield and quality

Hay cuts were taken just after flowering (GS71) from ungrazed plots to assess hay as a salvage option. Cut date differed between time of sowing and variety. Time of sowing had no effect on final yield, however variety was a determinant of hay yield. The faster maturing varieties, Razor CL Plus and Vixen ultimately produced less hay than other trialed varieties (Table 4).

Table 4. Hay yield (t/ha) and cut timing (of each TOS) for different varieties.

Variety	Hay yield (t/ha)	TOS1 Cut date	TOS2 Cut date
DS Bennett	4.6[a]	19 October	26 October
Scepter	4.2[ab]	14 September	28 September
Catapult	4.2[ab]	14 September	1 October
Illabo	4.1[ab]	4 October	12 October
Razor CL Plus	3.8[b]	6 September	23 September
Vixen	3.7[b]	6 September	21 September
Sig. diff.	0.019		
LSD (P=0.05)	0.5		
CV %	12		

While there was some difference in hay quality indicators across varieties and sowing timing, all hay was high quality and would have received high quality results (Table 5).

Table 5. Hay yield (t/ha) and quality results from cuts taken as treatments reached Z71.

Variety	TOS	Hay yield (t/ha)	Crude Protein (% of DM)	Neutral detergent fibre (% of DM)	Digestibility (% of DM)	Metabolisable Energy (MJ/kg DM)	Water soluble carbohydrates (% of DM)
Vixen	**1**	3.6	12.5	50	67.7	10.0	19.8
Scepter	**1**	4.3	13.2	46.7	70.0	10.4	22.9
Razor CL Plus	**1**	3.5	12.0	49.2	67.4	10.0	20.9
Catapult	**1**	4.2	12.7	47.5	69.1	10.3	23.1
Illabo	**1**	3.9	13.3	43.5	74.2	11.2	27.3
DS Bennett	**1**	4.2	11.5	45.8	69.7	10.4	26.8
Vixen	**2**	3.8	12.5	43.4	72.0	10.8	27.7
Scepter	**2**	4.1	13.1	39.2	76.2	11.5	30.4
Razor CL Plus	**2**	4.0	12.7	43.1	73.5	11.0	28.7
Catapult	**2**	4.1	12.6	42.6	73.6	11.0	28.8
Illabo	**2**	4.8	13.2	44.7	72.4	10.8	25.0
DS Bennett	**2**	4.9	10.7	43.6	70.9	10.6	27.2

Grain yield and quality

Yield and grazing recovery were better in the earlier sown and earlier grazed treatments. At the first time of sowing, all varieties recovered and yielded similarly to ungrazed treatments. Grazing recovery in TOS2 was not as good, with larger differences in grazed and ungrazed yields seen in faster maturing varieties that were grazed at GS32 and did not have as long to recover before reaching maturity. DS Bennett benefitted from late season rains, yielding higher from later sowing and maturing. Illabo is a winter wheat but matures quickly after vernalisation and therefore TOS2 treatments did not benefit from late rains to the same degree as DS Bennett (Figure 2).

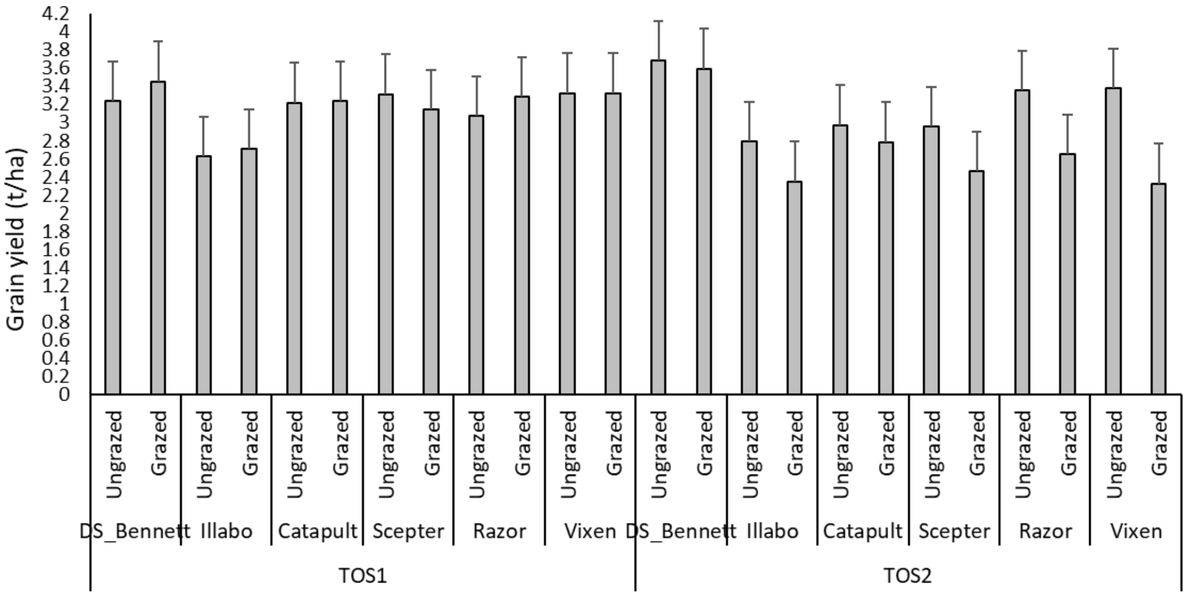

Figure 2. Mean grain yield (t/ha) of all trial treatments. TOS*Var*Graze. Stats: P=0.007, LSD 0.487t/ha, CV 6.1%.

Ungrazed treatments returned higher grain protein than grazed treatments (Table 6). This is likely due to nitrogen being used for grazing recovery in those treatments where it was needed and mobilised in grain for treatments that did not have to recover from grazing. Grazing also resulted in higher test weights (Table 6).

Table 6. Mean protein (%) and test weight (kg/hL) of grazed and ungrazed treatments across the times of sowing.

Treatment	**Protein (%)**	**Test weight (kg/hL)**
Grazed	13.1[a]	78.4[a]
Ungrazed	13.8[b]	77.8[b]
Sig. diff. LSD (P=0.05) CV %	<0.001 0.3 5.0	0.002 0.3 1.1

Protein was high across the trial. Lower yields in TOS2 treatments can be linked to higher protein with the exception of the winter varieties that yielded similarly across the sowing timings. Screenings were higher in TOS1 spring treatments, likely attributed to moisture stress during grain fill, however no treatments were above thresholds. Test weights were similar between sowing timings within a variety with the exception of winter wheats that returned a higher test weight from TOS2, displaying their ability to take advantage of late rains during grain fill (Table 7).

Table 7. Mean protein (%), test weight (kg/hL) and screenings (%) for varieties at different sowing times.

TOS	Variety	Protein (%)	Test weight (kg/hL)	Screenings (%)
1	Illabo	15.4^{a}	73.8^{e}	1.1^{b}
2	Illabo	14.6^{ab}	76.8^{d}	0.9^{a}
2	Vixen	13.9^{bc}	77.5^{d}	1.4^{cd}
2	Scepter	13.7^{cd}	78.5^{c}	1.5^{de}
1	Vixen	13.4^{cd}	77.6^{d}	2.0^{f}
1	Scepter	13.2^{cde}	78.9^{c}	2.0^{f}
2	Catapult	13.1^{cde}	78.7^{c}	1.4^{cd}
1	DS Bennett	13.1^{cde}	80.3^{b}	1.3^{bc}
1	Catapult	13.0^{cde}	78.7^{c}	1.6^{e}
2	Razor	13.0^{cde}	77.2^{d}	1.4^{cd}
2	DS Bennett	12.7^{de}	81.6^{a}	1.4^{cd}
1	Razor	12.4^{e}	77.2^{d}	1.9^{f}
	Sig. diff. (TOS* Var)	0.033	<0.001	<0.001
	LSD (P=0.05)	0.7	0.4	0.2
	CV %	5	1.1	13.6

Frost timing and damage

The site experienced 191 hours at or below zero degrees at canopy height across 33 events throughout the growing season. Significant events occurring regularly through September placed crops flowering in that window at risk of experiencing frost (Table 8).

Table 8. Notable frost events at the trial site throughout September around the optimal flowering window for this environment.

Date	Minimum temperature at canopy height reached (°C)	Consecutive hours below zero
7 September	-0.4	0.5
8 September	-2.6	6.5
14 September	-4.9	7.75
15 September	-4.6	6.75
16 September	-3.4	8
19 September	-0.9	6.5
21 September	-0.1	0.25
24 September	-1.4	2.75
26 September	-5.1	8.5

Higher levels of frost induced sterility were seen across the second time of sowing at an average of 13.2% compared to 10.3% in earlier sown treatments (P=0.021). Although flowering within the lower risk window, the timing of frost events this season resulted in greater damage which was reflected in final yield (Figure 3).

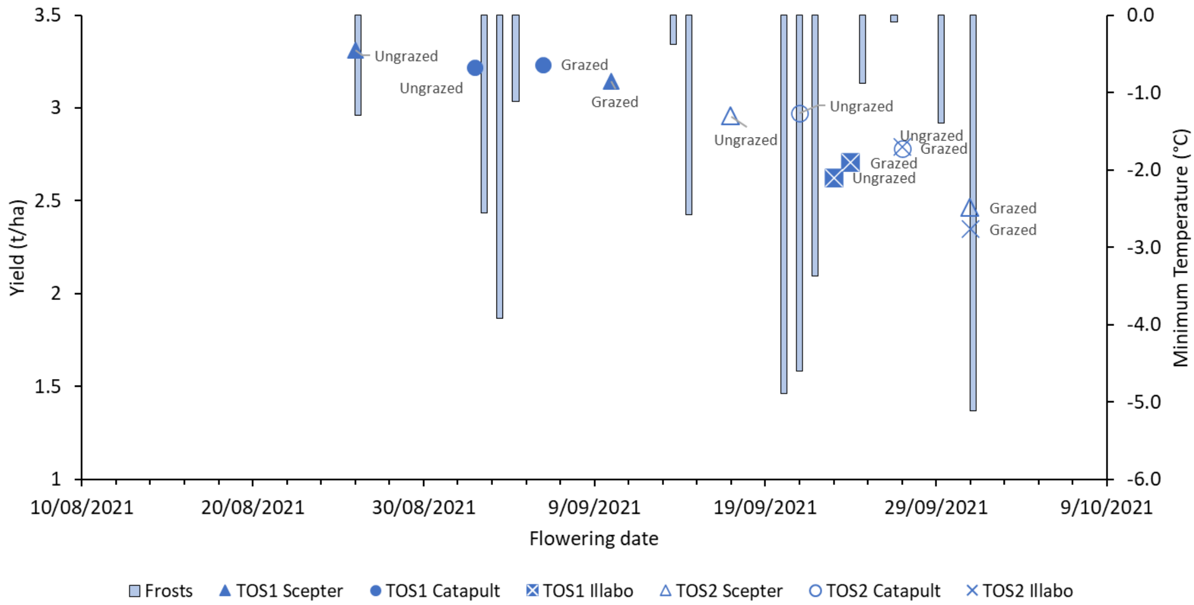

Figure 3. Yield (t/ha) of a selection of varieties and their respective flowering dates overlayed with frost events (°C). TOS*Var*Graze. Stats: P=0.007, LSD 0.487t/ha, CV 6.1%.

Grazing reduced sterility levels due to delaying flowering timing in TOS1, mostly to the first week of September and the beginning of October which, in this season meant frost events experienced in the second and third week of September caused less sterility in these grazed treatments on average, at 9.6% compared to 13.8% sterility (P<0.001).

COMMERCIAL PRACTICE AND ON-FARM PROFITABILITY

Time of sowing, grazing after stem elongation and variety selection all proved to be tools for manipulating flowering timing in wheat. The exception was winter wheats that retain a more stable flowering period regardless of sowing timing due to their requirement for vernalisation. Grazing after stem elongation delayed spring wheat flowering time by up to three weeks, pushing early sown treatments into an optimal flowering window.

Understanding how to manipulate the time of flowering in wheat can be an important risk management tool, allowing the targeting of a reduced risk flowering window. This window is identified as an optimum period for flowering, providing conditions in the majority of seasons where a crop is flowering in the ‘sweet spot’ between frost risk and heat shock. Frost events during September 2021 presented a high risk of yield loss in varieties flowering within the identified optimal window for this environment.

While the 2021 season has proven time of sowing isn’t always a frost avoidance tool if frosts occur late, grazing can provide an option to slow the maturity of a quick variety that for one reason or another – for example, unexpected rain after dry sowing – is moving too quickly to promote flowering in a less risky window. Simulated grazing with a lawn mower is much more even and more representative of crash grazing with a high stocking rate over a short period. This may provide some feed to stock during the autumn feed gap.

In some cases grazing improved the gross margin compared to grain production, particularly where no yield loss occurred as a result (table 9).

Table 9. Grazing gross margin, dual purpose gross margin and ungrazed grain gross margin.

TOS	Variety	DSE grazing days	Gross margin prime lamb/ merino ewe enterprise grazing value ($/ha)*	Grazed treatment yield (t/ha)	Yield loss from grazing (t/ha)	GM dual purpose graze grain ($/ha)	GM Grain only (ungrazed) ($/ha)
1	Vixen	199	43	3.3	0.0	1240	1197
1	Scepter	200	43	3.1	0.2	1176	1192
1	Illabo	200	43	2.7	0.0	1017	945
1	Catapult	201	44	3.2	0.0	1209	1158
1	Razor	216	47	3.3	0.0	1092	978
1	DS Bennett	192	42	3.5	0.0	1416	1030
2	Vixen	1436	311	2.3	1.1	1148	1216
2	Illabo	1136	246	2.3	0.4	1091	1004
2	DS Bennett	1255	272	3.6	0.0	1416	1171
2	Scepter	1216	263	2.5	0.5	1150	1064
2	Catapult	1294	280	2.8	0.2	1282	1070
2	Razor	1022	221	2.7	0.4	1065	1067

A mower or slasher may be used to achieve even defoliation, but this doesn't allow for feed value from biomass removed to be realised.

Grazing recovery requires suitable growing conditions, ample nutrition and time. After early sowing and grazing in June, spring wheats were able to recover without losing yield. Grazing on later sown treatments in August did not reflect these results with large differences in yield seen between grazed and ungrazed early maturing, slightly further progressed varieties due to warming temperatures, tough conditions and a lack of time to recover before grain fill. Results suggest late grazing, by about 20 June, allows time for yield recovery in quick spring wheats but should ideally occur before GS32.

Enterprise diversification is another way to manage risk. If a crop is frosted at flowering there may be the opportunity to cut it for hay as a salvage option. A good understanding of the breadth and severity of damage is required before making this decision, along with considering economics. The return from hay this season was not as profitable as grain, largely because of prices (Table 10).

Table 10. Gross margin for hay and grain production across treatments. Prices taken from *The Weekly Times* 22 December 2021 based on cereal hay at $170/t, assuming three bales per tonne and GrainFlow website (AWB cash price) for wheat Birchip 23 December 2021.

Variety	TOS	Hay yield (t/ha)	Gross margin ($/ha)	Gross margin grain (ungrazed) ($/ha)	Grain quality
Vixen	1	3.6	612	1197	H1
Scepter	1	4.3	731	1192	H1
Razor	1	3.5	595	978	ASW1
Catapult	1	4.2	714	1158	H1
Illabo	1	3.9	663	945	H1
DS Bennett	1	4.2	714	1030	ASW1
Vixen	2	3.8	646	1216	H1
Scepter	2	4.1	697	1064	H1
Razor	2	4.0	680	1067	ASW1
Catapult	2	4.1	697	1070	H1
Illabo	2	4.8	816	1004	H1
DS Bennett	2	4.9	833	1171	ASW1

Yield trends highlighted the loss of potential with later sowing/flowering, particularly in spring varieties. While early sowing opens the potential of flowering in a high frost risk window (but with low heat shock risk), it allows for time to build early biomass and yield potential where later sown crops don't have the same opportunity.

Grazing or defoliation may provide a tool to delay flowering in certain situations, however yield potential can be lost, depending on timing, seasonal conditions and fertiliser management. Increasing machinery sizes will result in larger seeders covering ground more efficiently and offering the ability to tighten sowing windows. In frost-prone environments, particularly frost-prone paddocks, steering a crop to flower in the optimal window will aid overall farm business risk management.

Research suggests frost damage is likely to occur when tissue temperatures reach -3.5˚C and will be more significant at lower temperatures and when plants are moisture stressed (NSW DPI, 2008). The dry and frosty spring experienced this season did not favour later sown spring wheats in this trial. There is no genetic resistance to frost so it is impossible to avoid frost all the time but risk can be minimised with variety selection and careful management.

ACKNOWLEDGEMENTS

This research was funded by the Yitpi Foundation and Hugh DT Williamson Foundation.

Invertebrate Crop Threats due to Mixed Species Cover Crops

Project: **Warm and cool season mixed cover cropping for sustainable farming systems in south eastern Australia.**

Author: Dr. M A Nash

Background

To increase crop diversity in water limiting environments, growing two or more crop species together (intercropping) has been evaluated by growers in Australia. Intercropping is defined here as either multiple crop species mixed within or between rows. Recent studies of intercropping of canola (*Brassica napus*) with faba beans (*Victa faba*) on separate rows were evaluated, with significantly ($P < 0.05$) lower numbers of cabbage aphid, (*Brevicoryne brassicae*), compared to the monoculture, while a significant increase in the predator diversity and parasitism rate was observed. An Australian review concluded legume-oilseed intercropping reduce the incidence of disease in comparison with sole crops, minimising the need for pesticides. Peaola (pea [*Pisum sativum*] and canola) intercrop reduced incidence of pea aphid (*Acyrthosiphon pisum*) infestation and infection from *Mycosphaerella* fungi compared with monocropped peas. Many oilseed species, such as sesame (*Sesamum indicum*), sunflower (*Harpalium*), and mustard (*B. juncea*), have demonstrated allelopathic properties, supressing the growth of soil-borne pathogens and pests, such as nematodes, fungi and some weeds.

Aim

The aim of this study was to test if threats from invertebrate pests were different between multispecies cover crops or intercrops and traditional monocultures that included a short summer fallow. The focus was on temperate sites across south-eastern Australia where moisture was often limited. The provision of increased crop diversity must be quantified to link the perceived benefits of pest control to both economic and environmental outcomes. That is, will growers be able to decrease input cost whilst maintaining production?

Methods

Ad hoc quantification of pest numbers was done, when they threatened crops, as part of a larger project where 20 demonstration sites were setup from 2018 - 2021 to evaluate the effects of rotations that increase plant diversity had on various soil properties. What constituted a mixed species cover crop varied according to farmer management. Project guidelines included warm or cool season cover crops, intercrops, pasture, or pasture crops: the only requirement was it had to have two or more species. The treatments were grouped as: one or more seasons of mixed species cover crop – monoculture (Multi), traditional short fallow – monoculture (Fallow), and single species cover crop – monoculture (Single). The trial design was in most cases a randomised block design with 4 replicates. Exact treatments where pests were quantified are given in the results. The significance of treatment was tested using ANOVA in MSExcel. Demonstrations were generally the width of the farmer's seeder, which excluded evaluation of many migratory pests, such as native budworm (*Helicoverpa punctigera*). A paired field design was used to test differences between migratory moths' species, with the significance of differences tested using T-Tests.

Results

Grey field slugs – *Deroceras reticulatum*

A demonstration site located at Rokewood, south west Victoria, was setup after a canola crop in 2019 using a fully replicated randomised block design with 12 m wide treatments. Tillage radish sown Jan 2020 as the single species and the mixed species summer cover crop composed of tillage radish, sorghum, millet, forage rape (SummerMax from AGF seeds Smeaton VIC). Faba beans (Zara) was the winter cash crop in 2020. Dec 2020 summer cover crop treatments were: Fallow – faba bean stubble Single – soybeans (*Glycine max*), Multi – soybeans, sunflowers, sorghum (*Sorghum bicolor*), forage rape (*Brassica*), leafy turnip (*Brassica rapa* var. *rapa*), tillage radish (*Raphanus sativus*), millet (*Panicum miliaceum*). Wheat (Revenue [*Triticum*]) was the cash crop sown in 2021. The rainfall was above average over the two summers cover crops were grown.

The number of slugs was quantified using surface refuge traps that consisted of 500 by 500 mm carpet mats in tillering wheat following a summer cover crop to test the grower's assumption more slugs would be carried over in the mixed species cover crop over summer. This was not the case with no differences between treatments detected (Fig 1). The wheat established successfully with final yield also showing no response to cover crop treatments: $F_{2,6} = 1.5$; $P = 0.296$.

A North American study evaluating slug damage to soybean crops following winter cover crops found when terminated two weeks before soybean planting, slug damage was greater in the single species rye cover crop compared to the 3-way mix and the no winter fallow. Planting green with termination a week after planting resulted in a significant, though small, reduction in slug damage, but not pest populations: seedling damage was not closely related to slug active density. Multi species cover crops probably do not make slug damage worse, despite increased numbers (https://extension.umd.edu/resource/slug-damage-soybeans-do-cover-crops-help-or-hurt accessed 10/4/2022).

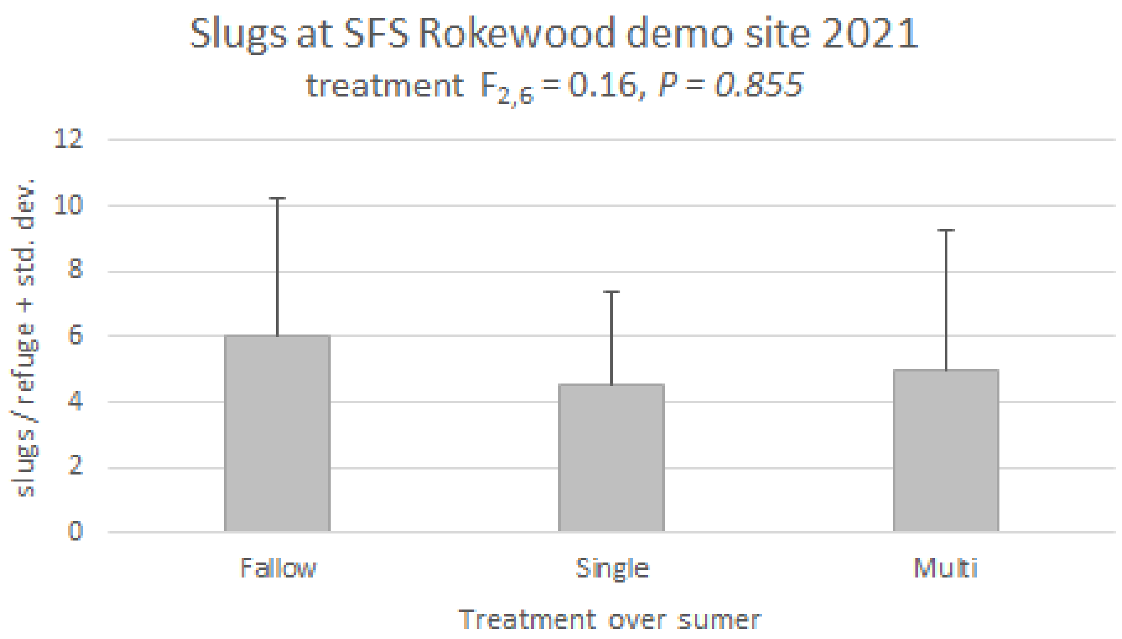

Figure 1. Mean number of grey field slugs under a refuge in wheat south west Victoria June 2021 in each of the three summer treatments: Fallow – faba bean stubble, Single – soybeans, Multi – soybeans, sunflowers, sorghum, forage rape, leafy turnip, tillage radish, millet.

Russian Wheat Aphid (RWA) - *Diuraphis noxia*

A demonstration site located at Ungarra, Eyre peninsula South Australia, was setup in 2019 using a repeated paired design. The 36 m by 300 m multi treatment was sown within a barley (Compass) crop. The 2019 winter cover mix was composed of vetch (*Faba sativa*), barley (*Hordeum vulgare*), winter canola, tillage radish, peas, and lentils (*Lens culinaris*). Treatments sown Jan 2020 were: Fallow – stripper stubble 24 m wide by two strips, single – Millet 12 m wide by two strips, Mutli -millet, tillage radish, winter canola, and sunflowers 36 m wide. Faba beans (Bendoc) was the winter cash crop in 2020, with the middle 26 m Multi treatment sown to faba beans and canola (Stingray). Dec 2020 summer cover crop treatments were: Fallow – bean stubble, Single – millet and sunflowers, Multi – Shirohie millet (*Echinochloa esculenta*), white millet (*E. frumentaceae*) sorghum, sunflowers, buckwheat (*Fagopyrum esculentum*), tillage radish, purple top turnip, mung beans (*Vigna radiata*), and 3 cultivars of clover (*Trifolium*). Wheat (Scepter) was the cash crop sown without insecticide dressings in May 2021.

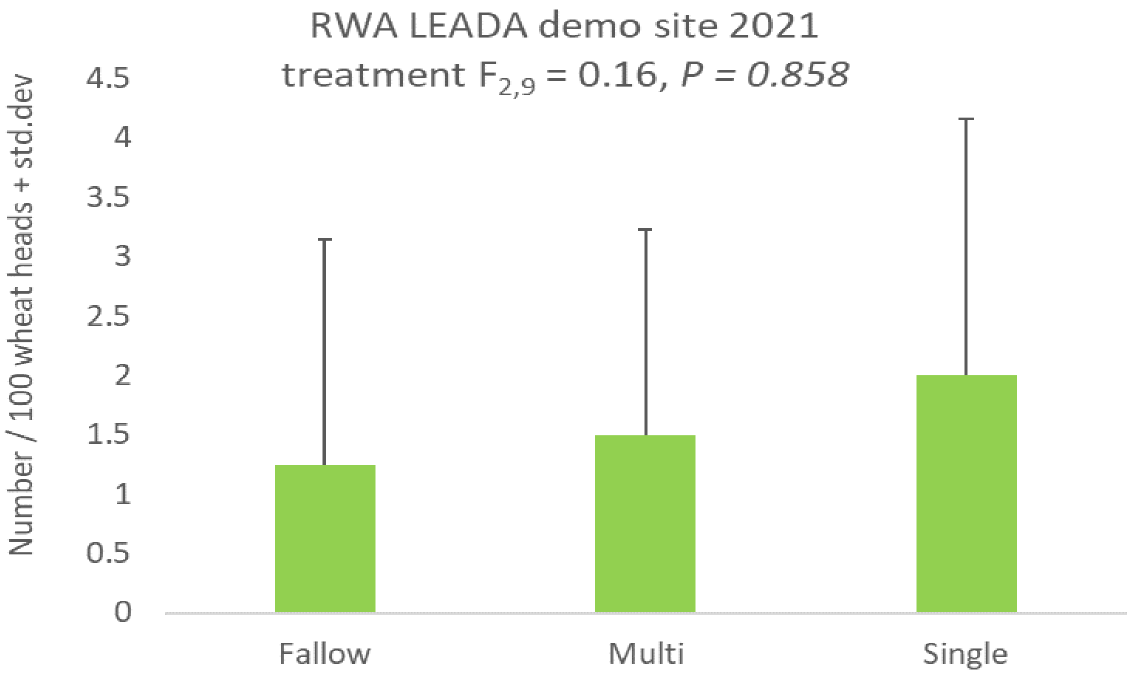

Figure 2. Mean number of Russian Wheat Aphids (RWA)/ 100 wheat stems scored Oct 2021, Ungarra, South Australia in each of the three summer cover crop treatments: Fallow – faba bean stubble, Single – millet & sunflowers, Multi – millet, forage sorghum, sunflowers, buckwheat, tillage radish, purple top turnip, mung beans, and 3 cultivars of clover.

The number of RWA was quantified by randomly selecting 100 wheat heads/tillers per sampling point, 10 m by 10m, and counting the number of aphids on that "head". Four sampling points were randomly chosen per treatment. No significant differences were detected between treatments (Fig. 2). These results are concordant with the literature: millet is a poor over summer host for RWA. Favoured summer grass hosts are: *Bromus* spp.; Barley grass, *Hordum* spp.; native grasses, *Enneapogon*, *Rytidosperma*, and *Austrostipa* spp. (13).

Round snails – vineyard (Cernulla virgata) & Italian (Theba pisana)

Experiment 1

At the same demonstration site, Ungarra, Eyre peninsula South Australia, round snails were also quantified by counting the number found on 100 randomly selected wheat head/tillers per 10 m by 10 m sampling point. No significant differences were detected between treatments, although numbers were numerically greater in the Multi species treatment (Fig. 3).

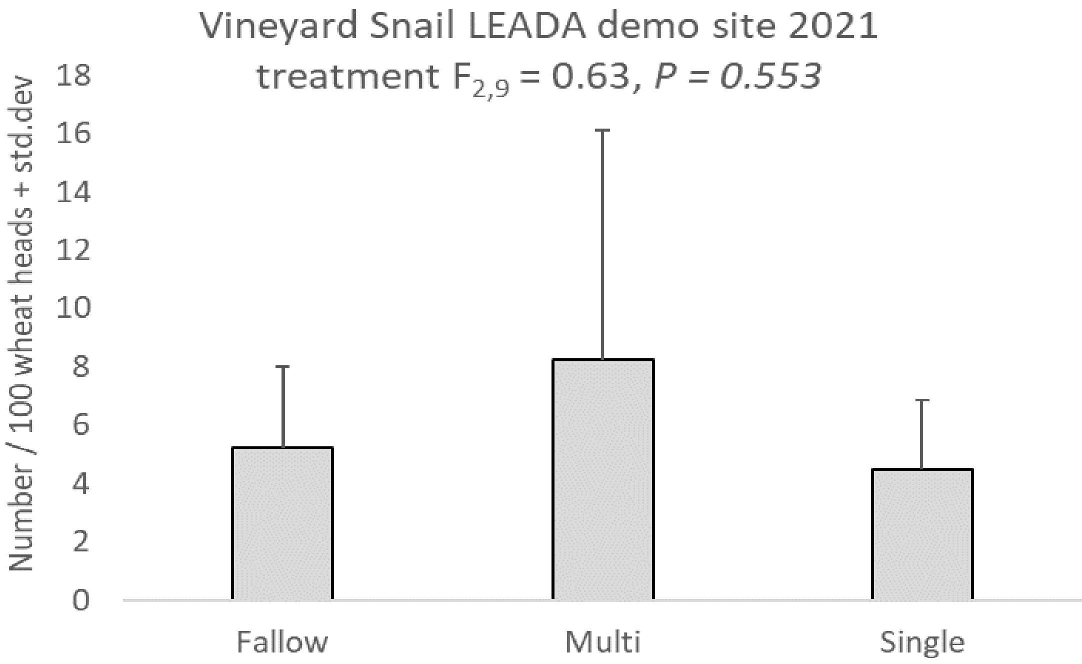

Figure 3. Mean number of Vineyard snails on 100 wheat stems scored Oct 2021, Ungarra, South Australia in each of the three summer cover crop treatments: Fallow – faba bean stubble, Single – millet & sunflowers, Multi – millet, forage sorghum, sunflowers, buckwheat, tillage radish, purple top turnip, mung beans, and 3 cultivars of clover.

Experiment 2

A replicated (n=6), randomised block experiment was established (June 2021) at Warooka, Yorke Peninsula, South Australia, to test what species (Fig. 4) may cause an increase in snail numbers when sown as part of a mixed cover crop. Species were sown individually and in combination, with a mixed species treatment either including or excluding brassicas. The full mix of species was lentils, phacelia (*Phacelia tanacetifolia*), saia oats (*Avena strigose*), marigold (*Tagetes patula*), linseed (*Linum usitatissimum*), turnip, tillage radish. Combinations of a legume (lentils) or wheat (Scepter) and various individual species were also included in the treatments.

Snail numbers were scored by counting the number per 1.8 by 10m plot. The results indicate what species are included in cover crops can have a significant effect on snail numbers ($F_{19,95} = 6.2$; $P < 0.001$), with the most snails observed where tillage radish was grown, either as a single species or as part of a mix. Snail population increase due to the growing of brassica species was expected because snail population increases are often observed in canola crops. In areas where snails are present, growing a winter cover crop that contains brassicas, in particular tillage radish and/or canola, should be avoided, else additional management of snails will be required.

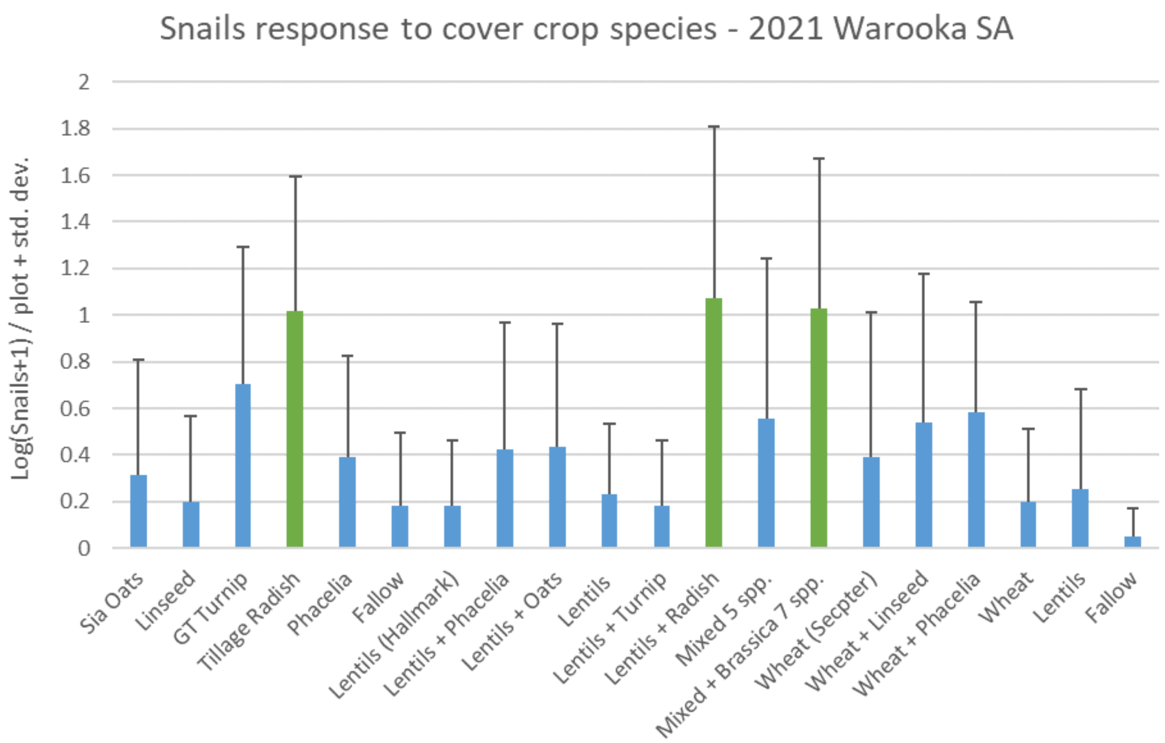

Figure 4. Mean number of Italian snails per plot scored Oct 2021, Warooka, South Australia to test what cover crop species increased populations. Green bars represent treatments where tillage radish was included in the mix. Mixed species treatment either including (Mixed + Brassica 7 spp.) or excluding brassicas (Mixed 5 spp.) and was made up of the following species: lentils, phacelia, sia oats, marigold, linseed, turnip, tillage radish. The marigold failed to establish.

Moths – Various species

Due to scale limitations replicated experiments could not be conducted to test the likelihood of increased moth numbers in mixed species crops. Paired paddock observations from seven sites using pheromone traps found varied response with either no difference in moth numbers, or significantly less in the mixed species crops (Table 1). Some results were based on real time data generated by smart traps (DTN.com) that record images of moths daily, hence were not spatially replicated (n=1, Table 1). These traps often failed to upload data resulting in missing data that could not be analysed. Results did not investigate actual damage caused so should be treated with some caution. The in season monitoring of moth flights was not followed up with monitoring in the following season, nor was the level of natural enemy function assessed. Further research is required to tease apart the often interactions occurring when plant diversity is increased.

Table 1. Experiments testing the influence of crop diversity on moth numbers, assessed using pheromone traps. A positive mean difference indicates more moths were recorded in the multispecies crop, hence a negative value indicates lower numbers. Significance of observed differences (bold) were based on T-tests (*P* < 0.05). The frequency of sampling and number of replicates (n) is indicated in Location column. NA indicates not analysed due to missing data due to technological issues.

Location	Pest	Single	Multi	Date	Sig.	Mean/day difference
Bairnsdale VIC daily n=1	Native Budworm	forage rape	Various plots of mixed species	7 Mar – 8 Apr 2020	NA	-0.4
Yorke Peninsula SA weekly n =3	Native Budworm	faba beans	faba beans, lentils – alleys	Aug - Nov 20	*0.599*	0.27
	Etiella	lentils		Sep – Nov 20	*0.769*	0.11
Mid North SA weekly n =3	Etiella	lentils	lentils, oats, linseed, barley, tillage radish	Sep – Oct 20	*0.307*	-0.53
Kangaroo Is. SA monthly n = 3	Diamond Back Moth	canola	canola, faba beans – mixed rows	9-Sep 20	*0.267*	7.1
				28-Sep 20	*0.183*	2.1
				26-Oct 20	*0.841*	-0.4
				29-Nov 20	*0.205*	3.2
Kangaroo Is. SA daily n=1	Diamond Back Moth	volunteer canola	tillage radish, fodder rape, sorghum, shirohie millet, french white millet, kikuyu & sunflowers	Mar – May 21	<0.001	**-1.2**
Minnipa SA varied n = 3	Native Budworm	peas	peas, canola	27-Aug-21	*0.356*	-1.67
				28-Sep-21	*0.272*	-0.15
				15-Oct-21	*0.037*	**-1.04**
Yorke Peninsula SA monthly n=1	Native Budworm	faba beans	tillage radish, mustard, canola, barley, vetch, medic, phacelia	5-Oct-21	NA	-0.1
				15-Nov-21	NA	0.2

Conclusions

From the twenty demonstration sites where single species cash crops were grown following a rotation that included cover crops, either a single or multiple species (Multi), only three had pest threats in 2021. Results from two of those found no difference in pest numbers, nor damage. Observations from the other site in 2021, and other sites in 2020 indicate Red Legged Earth Mite was more prevalent following multi species crops. However, the opposite was also observed, with no damage recorded in clover being established after a mixed species summer cover crop when compared to a traditional summer fallow to control weeds. These observations, and results presented here, highlight the complex responses invertebrates demonstrate to crop diversity. The growing of summer cover crops did not create a “green bridge” as some have suggested: in some cases, summer cover crops provide resources for generalist predators that regulate invertebrate communities including pest populations. The observations from this study are supported by a North American study where the build-up of predators in the cover crops subsequently resulted in reduction in the level of heliothines in no-till cotton.

The inclusion of polycultures, such as inter-cropping or cover cropping, may have multiple benefits under Australian conditions where fields are large, and there is a need to diversify crop cultivars, type and flowering time to minimise the risk of crop failures in dryland systems. This study aimed to link increased crop diversity to pest suppression or reduced risk of pest outbreaks, however only isolated observations demonstrated this. What was clear is management needs to understand the context in which it is being applied and its tolerance to sporadic risk if pest threats are less where plant diversity is increased on farm.