GRAINS RESEARCH UPDATE

BOOSTING PROFITABILITY – RESILIENT SOLUTIONS

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GRAINS RESEARCH & DEVELOPMENT CORPORATION

Derrinallum

Thursday 22nd August

9.00am to 1.00pm

Derrinallum Community Hall,

74 Main Street, Derrinallum

#GRDCUpdates

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GRDC Grains Research Update
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Contents

SOUTHERN/WESTERN REGION*

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- Durum crops (crown rot)

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- Take-all (including oat strain)
- Root lesion nematodes
- Cereal cyst nematode
- Stem nematode
- Blackspot (field peas)
- Yellow leaf spot
- Common root rot
- Pythium clade f
- Charcoal rot
- Ascochyta blight of chickpea
- White grain disorder
- Sclerotinia stem rot

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Program

9.00 am	**Announcements**	***Brett Symes,*** *ORM*
9.05 am	**GRDC welcome and update**	***GRDC representative***
9:15 am	**Improving the establishment of canola – what factors matter most**	***Col McMaster,*** *NSW DPI*
9:55 am	**Super high oleic oil safflower**	***David Hudson,*** *GO Resources Pty Ltd & SGA Solutions Pty Ltd*
10:35 am	***Morning tea***	
11.05 am	**Harvest weed seed control**	***James Manson,*** *SFS*
11:45 am	**Focus on earwigs**	***Matthew Binns,*** *CSIRO*
12.25 pm	**'Strip & disc' farming – a grower's experience**	***Ted Langley,*** *grower & SAGIT trustee*
1.05 pm	***Close and evaluation***	***Brett Symes,*** *ORM*
1.10 pm	***Lunch***	

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TECHNICAL WORKSHOPS


MLA INTERN PROGRAM


NEW VARIETY EVALUATION TRIALS


MANAGING HEAVY STUBBLES IN HRZ CROPPING SYSTEMS


PROBETRAX, SOIL MOISTURE PROBE NETWORK


INTEGRATED WEED MANAGEMENT


RURAL BANK CROP CHALLENGE


SOIL ACIDITY AND LIMING


PULSE AGRONOMY

Canola establishment across central NSW

Col McMaster[1], Ian Menz[2] and Alan Stevenson[1].

[1]NSW DPI Orange; [2]NSW DPI Wagga.

GRDC project code: BLG110

Keywords

- canola establishment, fertiliser placement, sowing speed, stubble management.

Take home messages

- Across 95 paddocks within the low, medium and high rainfall zones of central NSW, the average canola establishment was 48%, and ranged from 17% to 86%.
- Seed size was the main differentiating factor that improved canola establishment.
- Other key agronomic factors for improved canola establishment were stubble removal, reduced sowing speed, shallow seed placement and phosphorus (P) fertiliser separated from the seed.
- Hybrid (H) varieties were generally larger in size, and establishment was better than open-pollinated (OP) varieties.

Background

Canola establishment has become an emerging issue within central NSW over the past decade, due to increased seed costs, reduced seeding rates, unreliable autumn rainfall and sowing into marginal seedbed conditions.

Canola seed costs from 1990 to 2010 were relatively stable at 4% of total input costs, and have since increased to 14% of total input costs in 2018 (NSW DPI crop budgets). The increased seed cost is largely related to the dominance of H varieties over OP varieties since 2011 to 2018 (Figure 1). Target plant density during the era that OP varieties dominated the market place (pre-2010) was 50–80 plants m^2 (Wurst et al. 1997) and seeding rates between 3–5kg/ha. However, since the adoption of hybrids, the target plant density has been reduced to approx. 20–50 plants m^2 (Zhang et al. 2016, Matthews et al. 2018) depending on rainfall zone. Currently, best management practice is to firstly determine target plant density (plants m^2) for your rainfall region, and then determine seeding rates via knowledge of seed size, germination percentage (%) and estimate of establishment %.

Recent developments in understanding variety phenology, sowing time, and the adoption of slower developing spring varieties have brought forward the sowing window from 25 April to early April (Brill et al. 2018) for slower developing spring types. This broader, more flexible sowing window enables canola establishment to occur when seasonal conditions allow (i.e. rainfall events), rather than wait for the traditional Anzac Day trigger point to initiate sowing. This greatly improves the flexibility of the farming system, however, establishing canola in early April has the disadvantage of high seedbed moisture dry-back due to greater evaporation demands caused by higher temperatures. For example, at Parkes (medium rainfall zone), the average daily evaporation reduces from 5.9mm, 3.7mm to 2.2mm across the respective months of March, April and May (Figure 2). This means that a shallow planted canola seed is at higher risk of seedbed moisture dry-back if sown in early April compared to May, particularly in the warmer regions of NSW (i.e. Condobolin).

In summary, the margin for error in establishing canola is small, we are now sowing less seeds, they are costing more money, and we are placing those seeds in higher moisture dry-back conditions. Successful canola establishment is a significant factor, and a risk in canola production. The primary purpose of this survey was to evaluate current canola establishment rates and uniformity of plant spacings. The secondary purpose of the survey was to evaluate management practices that affect canola establishment, such as stubble management, seeding systems, fertiliser and seed quality.

Method

A field survey was conducted in 2017 across 95 commercial paddocks within the low, medium and high rainfall zones of central NSW (approx. 30 paddocks from each rainfall zone). Paddocks were selected from the following localities — Tottenham, Tullamore, Trundle, Condobolin, Bogan Gate, Parkes, Forbes, Marsden, Manildra, Cowra, Young, Boorowa and Jugiong.

Paddocks were selected to include various combinations of stubble management (burnt,

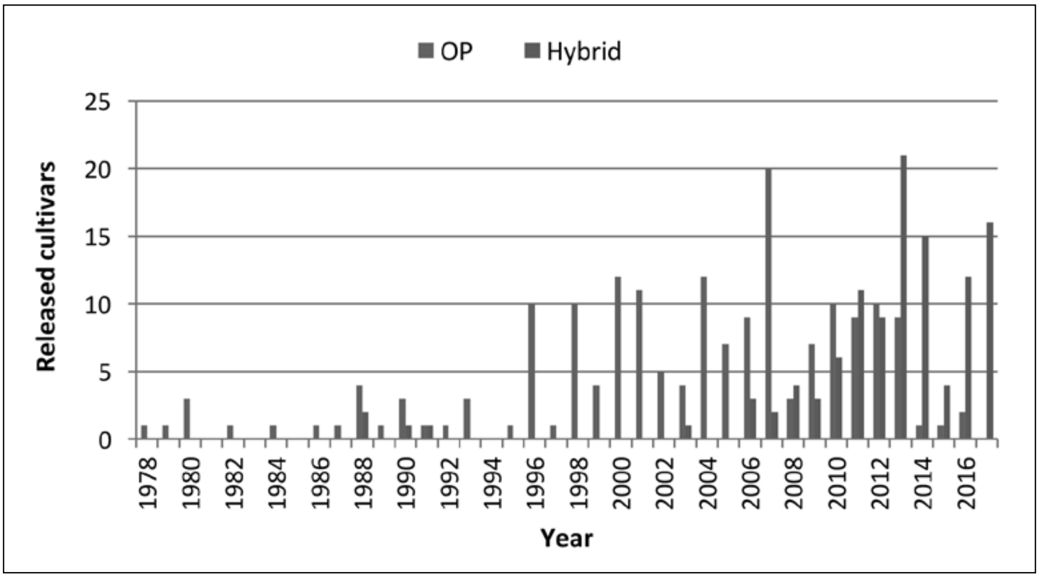

Figure 1. Year release of H or OP canola varieties in Australia from 1978 to 2017 *(Source: Steve Marcroft).*

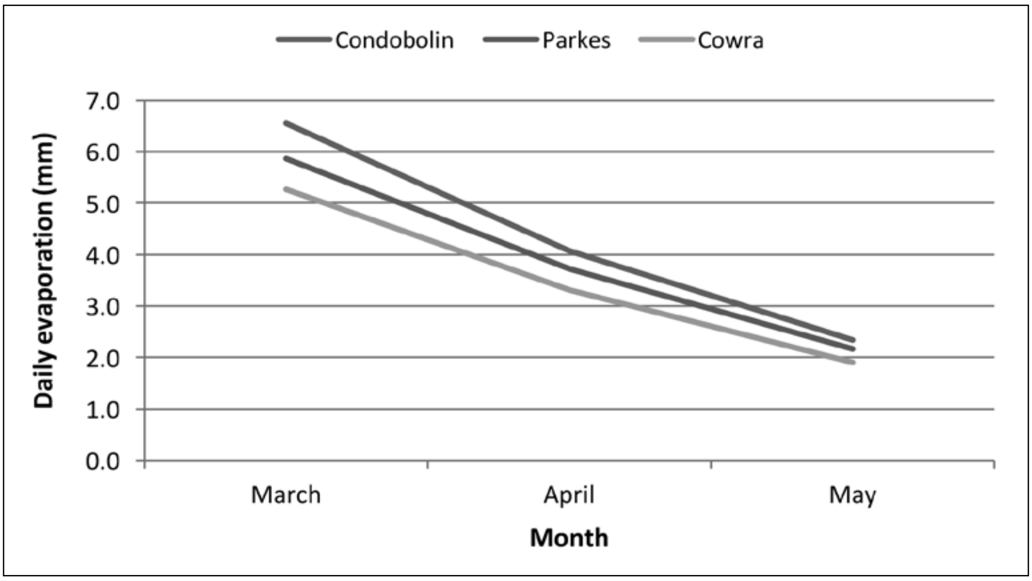

Figure 2. Average daily evaporation rates across central NSW during March, April and May *(Source: CliMate).*

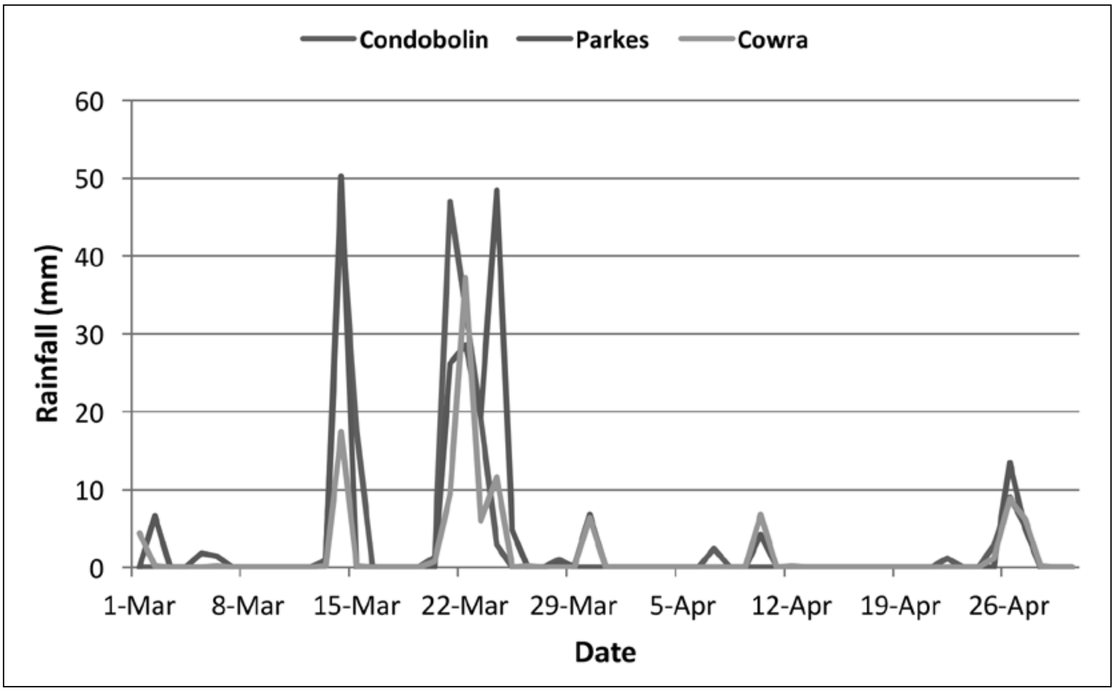

Figure 3. Daily autumn rainfall events across Condobolin, Parkes and Cowra in 2017.

retained and cultivated) and seeding system (knifepoint /presswheel, disc or scatter-plate). The survey design allowed for 10 paddocks with each combination of stubble management and seeding system from each rainfall zone (low, medium and high).

Plant establishment was measured across 15 x $1m^2$ quadrants per paddock, and from this an establishment % was determined via knowledge of seed size and sowing rate. If the seed size was unknown, a sample was taken for seed size determination. Plant population and plant uniformity were measured via the development of the 'vacancy %' method. This method relies on using a $1m^2$ section of mesh with 10cm squares. The mesh is used as the quadrant to count plants across 4 x 1m linear rows, as well as to count the total number of vacant squares within four linear metres. From this plant population and a vacancy % were determined.

Other data collected from each paddock includes sowing date, seeding depth, fertiliser rate/placement/source, variety, seeding rate, GPS coordinates, seed treatment, sowing speed, soil type, seedbed moisture conditions at sowing, and crusting events post sowing.

Results and discussion

A wet March and some timely rainfall events in April (Figure 3) allowed canola to be sown into favourable seedbed conditions across the low, medium and high rainfall zones of central NSW

Table 1. Breeding type and herbicide tolerance of paddocks surveyed across the low, medium and high rainfall zones of central NSW in 2017.

Breeding type	Rainfall region			Total
	Low	Med	High	
Hybrid	***4***	***18***	***22***	44
Clearfield®	1	9	7	17
Conventional	3	4		7
Roundup Ready®		2	2	4
Roundup Ready® + Triazine Tolerant			2	2
Triazine Tolerant		3	11	14
OP	***28***	***22***	***1***	51
Triazine Tolerant	28	22	1	51
	32	40	23	95

Table 2. Establishment, plant density and vacancy % on 95 paddocks surveyed in central NSW in 2017.

Frequency	Establishment (%)	Plants density (m^2)	Vacancy (%)
Min	17%	10	76%
1st Quartile	38%	19	56%
Mean	48%	26	47%
3rd Quartile	58%	32	39%
Max	86%	64	18%

in 2017. March rainfall was above the long-term average (LTA) at Condobolin, Parkes and Cowra, with an additional 41mm, 56mm and 49mm above the LTA, respectively. Seedbed moisture conditions were favourable at the start of April, and then started to decline from mid-April onwards. Additional rainfall around Anzac Day ensured favourable crop establishment for most of central NSW. In the paddock survey, the earliest, median and last sowing dates were 10 April, 22 April and 10 May, respectively.

Across the 95 survey paddocks, 44 were hybrid varieties and 51 were OP (Table 1). Breeding type (H or OP) was largely influenced by growing season rainfall and length of growing season, with H varieties dominating the high rainfall zone (22 H, 1 OP), OP dominating the low rainfall zone (4 H, 28 OP), and an even split between H and OP in the medium rainfall zone (H 18, OP 22). Refer to Table 1 for further details

Across the 51 survey paddocks that were OP, 16 paddocks were purchased seed and 35 paddocks were grower retained seed. Interestingly, only four of the 35 grower retained seed paddocks were not graded to seed size. Seed size grading ranged from 1.6mm to 2mm sieve size, however the sieve size was determined by the ratio of total seed graded to how much seed was required for the following sowing.

Interestingly, across all paddocks the average seeding rate was 2.5kg/ha for OP (1.6–4kg/ha), and 2.4kg/ha for H (0.9–3.2kg/ha). The average seed size from the H varieties was 4.9g/1000 seed (203,610 seeds/kg), and 3.9g/1000 seeds (257,106 seeds/kg) for the OP.

Table 2 illustrates a summary of results for establishment %, plant density and vacancy %. The average establishment was 48%, and the majority (between 1st and 3rd Quartile) of paddocks ranged between 38% and 58%. Establishment improved from low to medium to the higher rainfall zone, with the low, medium and high rainfall zones achieving a respective 43%, 47% and 55% establishment.

While each paddock had 36 pieces of information recorded, the main factor that differentiated establishment % was seed size. The mean seed size was 4.3g/1000 seeds and ranged from 3.3g to 6.6g/1000 seeds.

Figure 4 shows that establishment improved as seed size increased, however this trend was not linear and establishment decreased between the seed size of 4g and 4.5g/1000. In addition to seed size, there was an average increase in establishment by 6% (points) from selecting an H seed over an OP seed (51% establishment for H, and 45% establishment for OP).

After seed size, the top four agronomic practices that influenced canola establishment were seeding system (P=0.01), stubble management (P=0.02), sowing speed (P=0.02) and P fertiliser placement (P=0.05).

On average, reducing stubble loads via either burning or cultivation improved canola establishment by 10% (Figure 5). The main benefit appears to be from the physical removal of the stubble, rather than cultivated seedbed.

Table 2 shows that the average vacancy % was 47%, and ranged from 18% to 76%. Further research trials are being undertaken to develop calibration relationships between vacancy % and grain yield.

Interestingly, old seeding system technology such as 'scatter-plates' performed well in this survey. On average, the highest establishment of 58% was achieved with scatter-plates, and then reduced to 49% and 41% with the respective knifepoint and disc machine seeding systems. It is likely that the main benefits of the scatter-plate seeding system are due to shallow seed placement and favourable autumn conditions in 2017.

Establishment decreased as sowing speed increased, with a 16% establishment reduction if speed increased from 6–8km/hr to 13–17km/hr.

On average, there was a 7% reduction in establishment if P fertiliser was not separated from seed. There were two main groups of P fertiliser

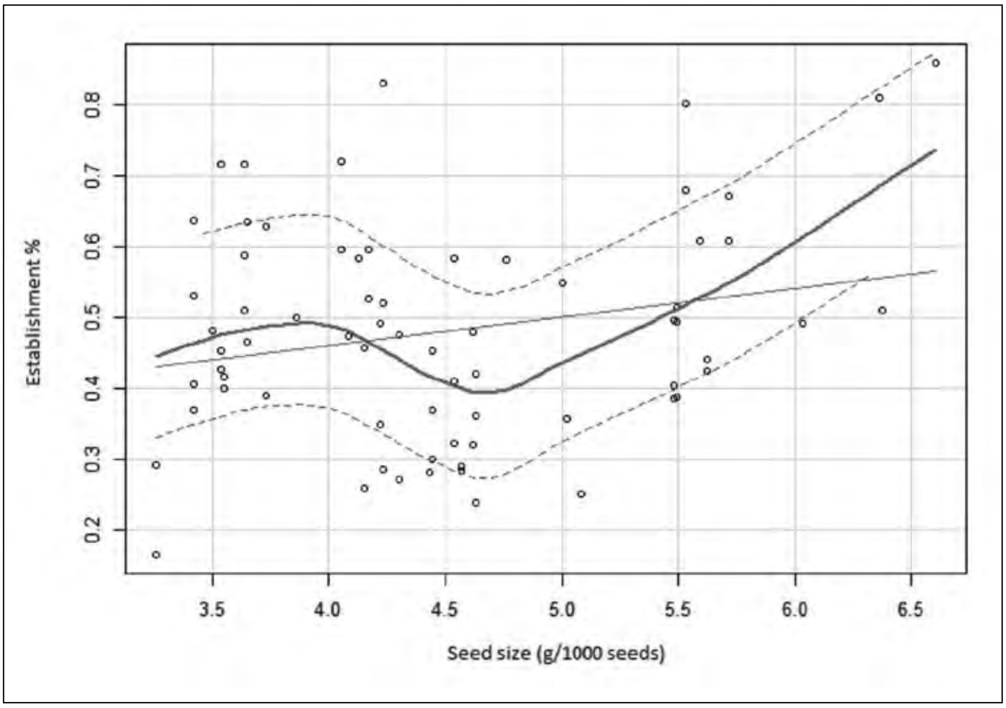

Figure 4. Fitted and observed relationship between seed size (g/1000 seeds) and canola establishment % with 95% confidence intervals.

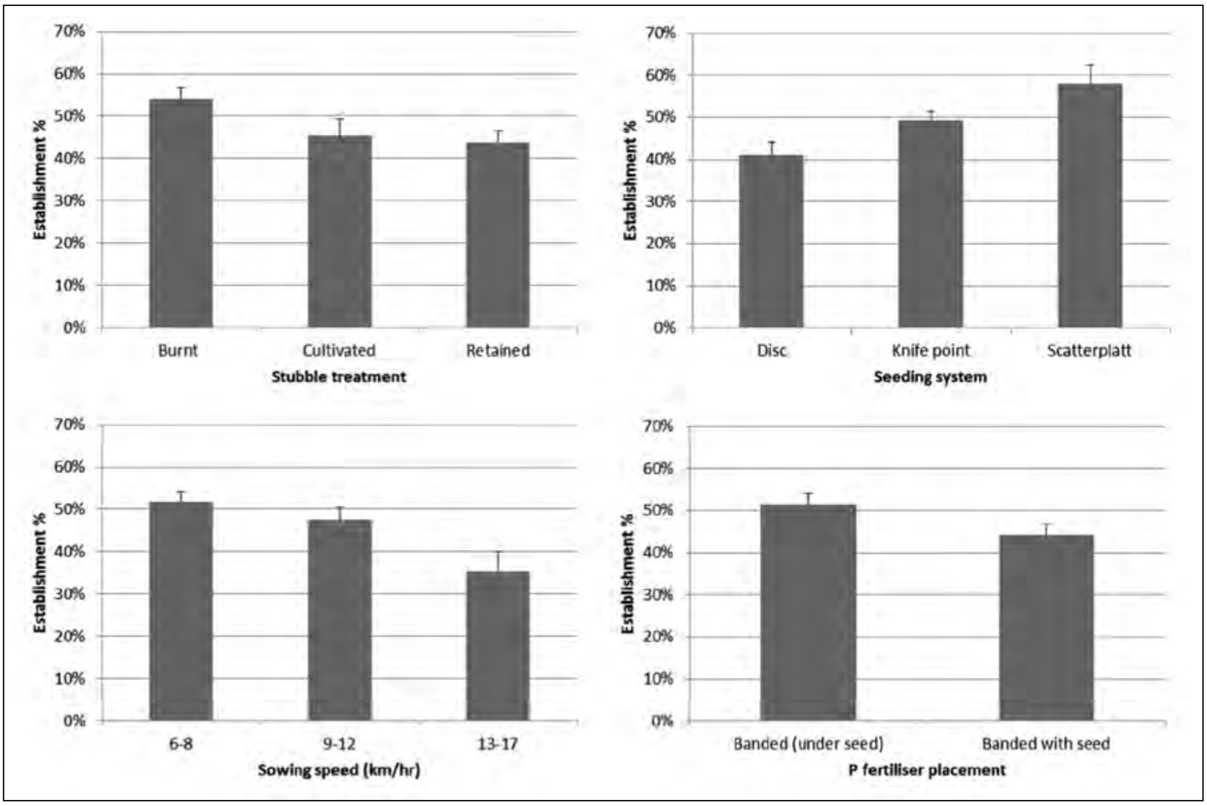

Figure 5. Effect of stubble management, seeding system, sowing speed and fertiliser placement on canola crop establishment. Standard error bars shown.

rates — 40% of paddocks had between 50–75kg/ha monoammonium phosphate (MAP) and another 40% had between 75–100kg/ha MAP.

Conclusion

Despite favourable sowing conditions in 2017, these results suggest there is an opportunity for improved canola establishment in central NSW. Effectively, growers are only establishing half of what they purchase, and if the autumn break was less favourable, it is likely to be much less. Traditionally, growers would apply an extra 1–1.5kg/ha of seed to compensate for poor sowing conditions, however this is no longer an option given the associated higher costs with hybrid seed.

Seed size was the main differentiating factor that improved canola establishment, while the other key agronomic practices were stubble removal, reduced sowing speed, shallow seed placement and P fertiliser separated from the seed. Hybrids were generally larger in size, and establishment was better than OP varieties. Further research is required to evaluate why the relationship between seed size and establishment was not linear.

The benefits of the scatter-plate seeding system in 2017 were likely to be associated with shallow seed placement combined with weather conditions that provided moist conditions for the canola seedling to germinate and establish. Canola establishment results are likely to be different if moisture seeking was required. These results highlight the importance of taking time to set up seeding equipment, particularly with the disc seeding machine as they are typically used in high stubble load paddocks, sowing speeds are higher and have limited fertiliser separation from the seed.

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Notes

GRDC™ GROWNOTES

SPRAY APPLICATION GROWNOTES™ MANUAL

SPRAY APPLICATION MANUAL FOR GRAIN GROWERS

The Spray Application GrowNotes™ Manual is a comprehensive digital publication containing all the information a spray operator needs to know when it comes to using spray application technology.

It explains how various spraying systems and components work, along with those factors that the operator should consider to ensure the sprayer is operating to its full potential.

This new manual focuses on issues that will assist in maintaining the accuracy of the sprayer output while improving the efficiency and safety of spraying operations. It contains many useful tips for growers and spray operators and includes practical information – backed by science – on sprayer set-up, including self-propelled sprayers, new tools for determining sprayer outputs, advice for assessing spray coverage in the field, improving droplet capture by the target, drift-reducing equipment and techniques, the effects of adjuvant and nozzle type on drift potential, and surface temperature inversion research.

It comprises 23 modules accompanied by a series of videos which deliver 'how-to' advice to growers and spray operators in a visual easy-to-digest manner. Lead author and editor is Bill Gordon and other contributors include key industry players from Australia and overseas.

Spray Application GrowNotes™ Manual – go to:
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GRAINS RESEARCH & DEVELOPMENT CORPORATION

Super high oleic safflower – a game changer for grain growers

David Hudson[1] and Rosemary Richards[2].

[1]GO Resources Pty. Ltd. & SGA Solutions Pty Ltd; [2]GO Resources Pty. Ltd. & Bowman Richards and Associates.

Keywords

- safflower, super high oleic safflower, super high oleic oil, cropping rotations.

Take home messages

- Safflower is a winter/spring growing crop that is:
  - ☐ heat and drought tolerant,
  - ☐ moderately tolerant of sodic and saline soils,
  - ☐ suited to both dryland and irrigation farming systems,
  - ☐ low input, low maintenance and easy to grow, and;
  - ☐ has machinery requirements similar to cereal /canola production.
- Super high oleic safflower has been developed by GRDC and CSIRO as an alternate high value cash crop with rotation benefits, that produces a minimum of 90% oleic acid in every litre of oil produced.
- Super high oleic safflower oil is being produced for a range of Australian and global industrial markets including lubricants, plastics, polymers, resins, cosmetics and biofuels.
- Following the granting of all required regulatory approvals super high oleic safflower was released in Australia for commercial production in 2019.

Introduction

Plant-derived oils are mixtures of saturated, monounsaturated and polyunsaturated fatty acids in ratios that can be less than ideal for certain industrial uses which have specific performance requirements. Large volumes of crude vegetable oil are used as feedstocks for the oleochemical industry and provide the opportunity to access the growing bio-base market segment.

Safflower (*Carthamus tinctorius* L.) seed produces oil that predominantly contains monounsaturated fatty acid (C18:1; oleic acid) and polyunsaturated fatty acid (C18:2; linoleic acid). While both have commercial uses, it is the valuable oleic acid that is used as a replacement to petroleum-based precursors in the manufacture of plastics, lubricants and cosmetics, etc.

Traditional breeding programs have developed safflower seed with oleic acid levels in the range of 75–85%. However, like other oilseeds, the remaining linoleic acid component, at 12-18%, is not desirable for industrial use because it is unstable and difficult to remove during oil processing. Therefore, it is desirable to develop a safflower seed that accumulates high oleic acid (C18:1) but contains very low linoleic acid (C18:2) and zero linolenic (C18:3) content. (Wood et al, 2018)

CSIRO scientists utilising their patented seed-specific hairpin-based RNAi to two safflower lipid biosynthetic genes, FAD2.2 and FATB have produced seed oil containing minimum 90% oleic content and at the same time less than 1.5% polyunsaturates and only 4% saturates. Due to the high level of oleic content, the oil derived from the safflower plant is referred to as Super High Oleic Safflower oil (SHOSO).

History

Safflower (*Carthamus tinctorius L.*) is an herbaceous annual and a member of the Asteraceae/Compositae (sunflower) family. It is native to parts of Asia, the Middle East, and Africa. It was grown mainly for its flowers, which were used in making dyes for clothing and food. Today, it is grown mainly for its oil. Safflower evaluations in Australia started in the 1940s amid concerns for drying oil shortages in the paint and resin industries (Smith 1996). Several cultivars were subsequently introduced from overseas, allowing small scale commercial production to commence in the mid-1950s.

The abolishment of quotas on the use of vegetable oils for margarine production in 1976 led to increased interest in oilseed production and in the following seasons record prices were paid for safflower (Smith 1996). The area sown in Australia subsequently peaked in 1979 with 74,688ha (Smith 1996). Production in the 1980s was concentrated in the south-east of South Australia, the Western District of Victoria and northern New South Wales. Following the demise of the marketing channels for safflower in the late 1980s production has since been limited to approximately 4,000 to 6,000ha per year for sale into the bird seed market.

In two studies of safflower growers in Victoria and southern NSW (Wachsman et al., 2010) and northern NSW (CSIRO 2014) growers were asked why they included safflower in their crop rotations (Table 1). Key reasons that were important in both studies were improved soil structure, improved weed and disease control, low input costs and spreading the work load.

Description

Safflower is thistle-like, with a main stem and numerous branches. It stands 0.35m to 1.2m tall at maturity. Its taproot can penetrate 2.5m to 3.0m depending on subsoil temperature and moisture (Figure 1).

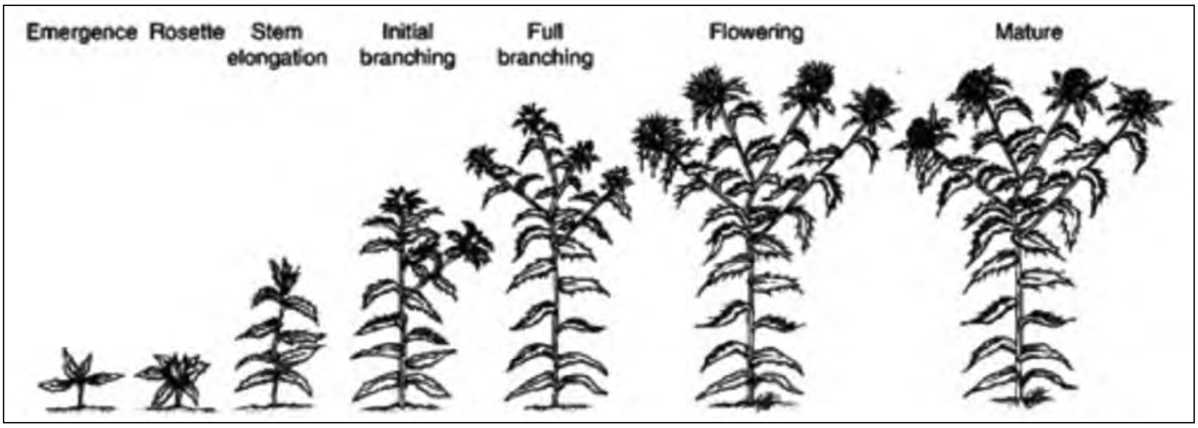

Figure 1. The development of a safflower plant (Source: Kaffka and Kearney, 1998).

Table 1. Reasons growers include safflower in their crop rotations (Wachsman et al., 2010).

Reasons for growing safflower in your crop rotation? (Victoria / Sth. NSW)	2010 Responses (%)	Reasons for growing safflower in your crop rotation? (Northern NSW)	2014 Responses (%)
Improves soil structure	24%	Opportunity crop when the sowing window for other winter crops has closed.	25%
Good weed control tool	19%	Spreads workload for both planting and harvest times.	15%
Water use/profile drainage	17%	Disease, weed or insect pest break in the rotation.	14%
Flexible time of sowing	19%	Attractive market prices.	14%
Low input/cheap to grow	12%	Low nutritional inputs needed to grow the crop.	11%
Easy to grow	12%	Breaks up a compacted profile or a hardpan.	10%
Disease break	10%	Dries out a saturated profile.	5%
Spread workloads	7%	Deters pests; pigs, kangaroos and emus.	5%
Non cereal/pulse option 2 4	2%	Other	0%

Safflower takes one to two weeks to germinate. After emergence, it stays two to four weeks in the rosette stage. Early growth and development is slow, but growth is rapid from the stem elongation stage. Each plant produces numerous flower heads. Flower petals are red, white, yellow or orange. Each head contains 20 to 100 seeds. The seed is the same size as plump barley. Seeds are glossy white, brown, or white with grey, black, or brown stripes. On average, safflower is ready to harvest about 35 to 40 days after the peak of flowering.

Super high oleic safflower end uses

Super high oleic safflower oil (SHOSO) is a renewable, biodegradable alternative to petroleum-based raw materials with multiple applications in the bio-lubricants, biochemical and bioplastics industries (Figure 2).

Recent research completed by scientists at Montana State University Advanced Fuels Centre compared the performance of a lubricant oil formulation based on GO Resources super high oleic oil versus a synthetic lubricant oil (e.g. Mobil 1). The following results for a lubricant oil formulation based on SHOSO were reported (Johnson, D. 2019 pers comm.):

- Reduced friction over synthetic oils by 83%.
- Reduced friction over conventional oils by 124% (Figure 3).
- Reduced tailpipe emissions by 48%.
- Reduced engine wear.
- Increased fuel economy >10% (actual usage in cars).
- Reduced environmental contamination.
- 100% recyclable.

The meal that remains after oil extraction can be used as a valuable feedstuff for livestock rations. The meal from dehulled seeds has a high protein content (40 percent) and low fibre.

Conditions for growing safflower

Soil

Safflower is adaptable to a wide range of soils, but the best soils for production are deep, fertile and well-drained. Safflower should not be planted in poorly drained or cool, wet soils as these conditions can delay uniform emergence.

Safflower is more tolerant of saline and sodic soils (Yeilaghi et al 2016, Hussain et al 2015, Shaki 2018, Pooran 2016, Biosalinity News July 2012, Subsoils Manual 2009) than small grains and canola because of its deep tap root. Due to its deep taproot,

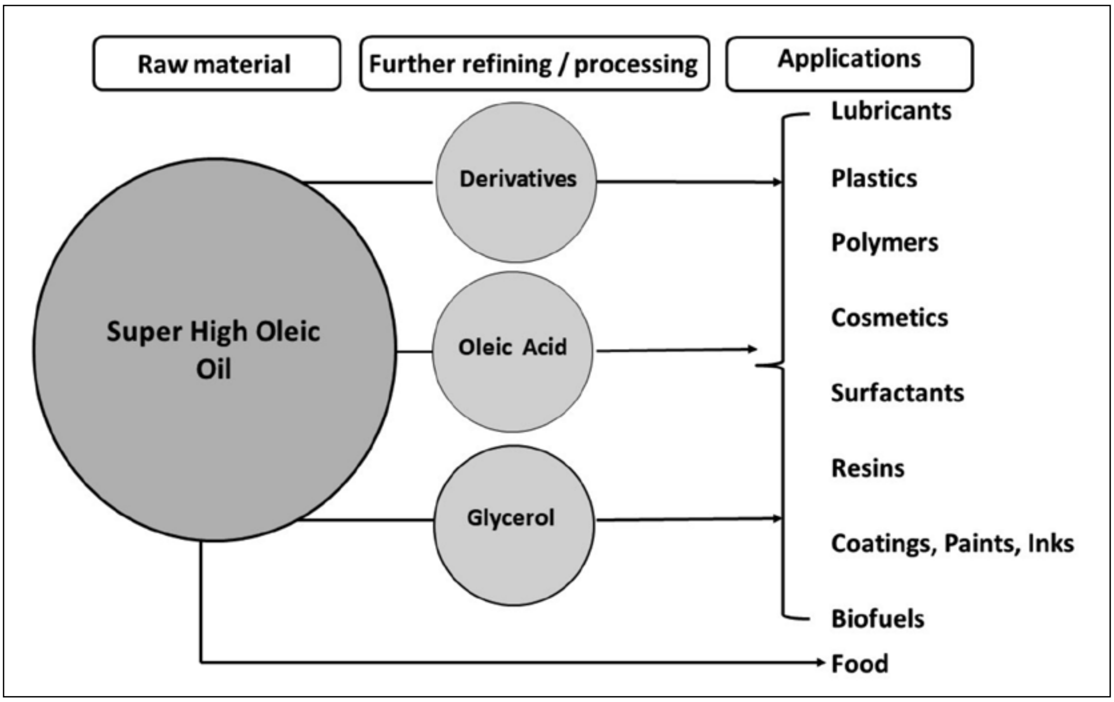

Figure 2. Market opportunities for super high oleic safflower oil.

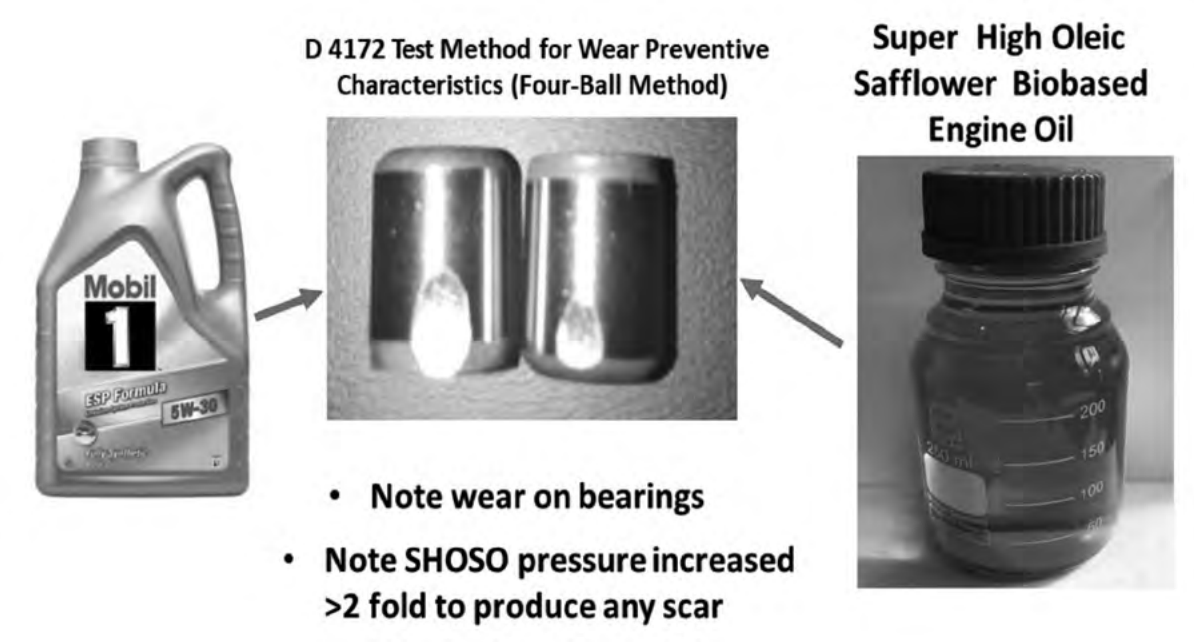

Figure 3. Reduced friction over conventional oils (Source: Montana State University Advanced Fuels Centre. June 2019).

safflower can be used in a tactical role on problem soils to break up hard pans and improve water and air infiltration into the subsoil through the creation of pores.

Climate

Safflower is a sun loving crop, and high temperatures and bright sunny days in July through to early September speeds development. Seeds germinate when soil temperatures are above 4.5°C with germination rates increasing with higher temperatures after sowing. Plants cannot withstand freezing temperatures after flowering. It grows well in both dryland and irrigated areas. It is a drought-tolerant plant though moisture is important at planting. Plants need dry atmospheric conditions during flowering and seed filling for proper head set (Figure 4).

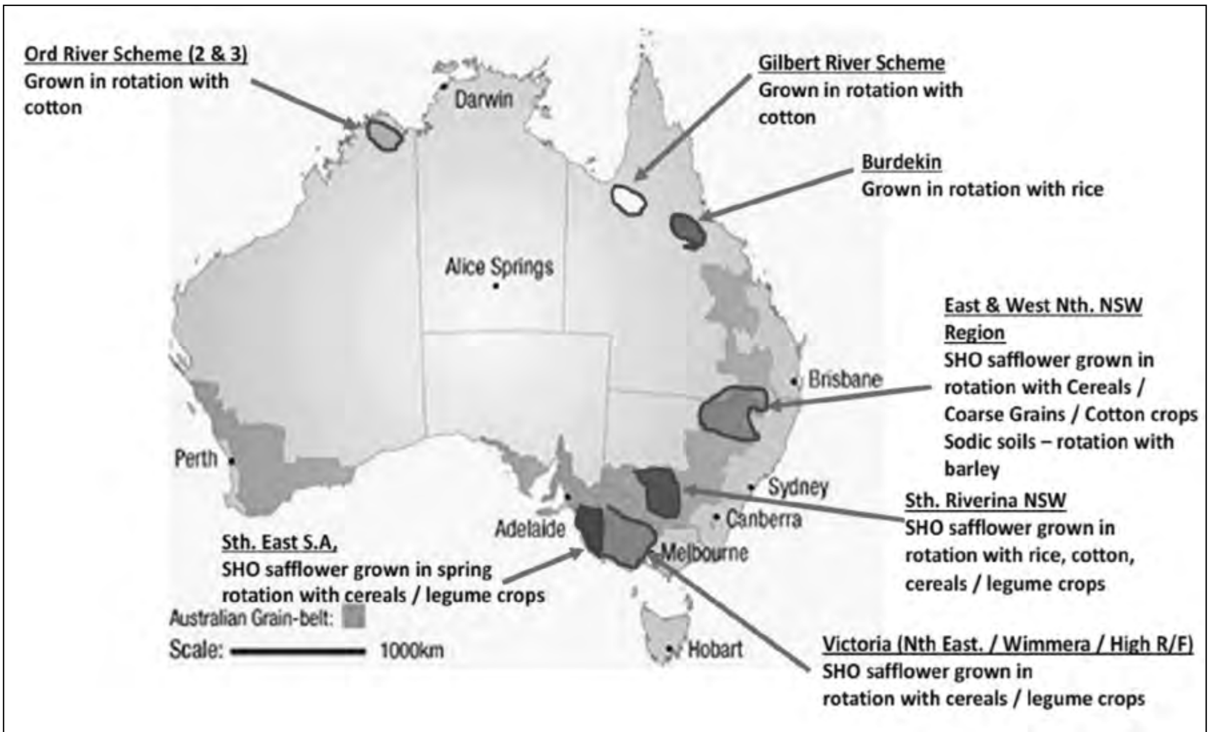

Figure 4. Safflower production locations in Australia.

Water

Although safflower is regarded as drought tolerant, it actually has a high water requirement. It survives dry conditions by developing an extensive tap root and scavenging for deep soil water, rather than relying on growing season rainfall. This assumes that deep soil water is present and that adverse soil conditions do not restrict root fill.

Safflower's relatively high water requirement is often ascribed to its relatively long growing season and some water must be available to crops during flowering and seed fill. Safflower performs best in regions that receive more than 450mm of rainfall annually but yields exceeding 1t/ha can be expected on clay soils that are wet to 1m depth at sowing, providing at least 50mm of post-sowing rainfall is received.

Temperature

Safflower will emerge at soil temperatures above 4°C, but 15°C is considered optimal. It tolerates frosts to -7°C during the rosette stage, but frosts below -4°C during stem elongation and branching can damage the growing point and split stems. Provided damage is not too extensive the plant can partially compensate by producing new shoots from below the damaged area. Safflower matures during December and January when temperatures are often high in traditional cereal growing regions. It can tolerate these temperatures providing sufficient moisture is available.

Cultural practices

Seedbed preparation

Seedbed preparation is no different from that of wheat or barley. A moist, firm, weed-free seedbed is required. Safflower doesn't do well when there is soil crusting. The crop is a poor competitor with weeds, especially in the early stages of growth, when it has not started branching. Presence of weeds at this time is detrimental. It is important to eliminate weeds before you plant the crop. Use registered knockdown herbicides and/or cultivation to control weed growth prior to planting.

Safflower is ideally sown into moist soil with equipment such as press wheels to provide good seed-soil contact. Sowing depth will vary with soil type and conditions but is normally between 2 and 5cm. Sowing deeper can delay emergence and reduce early vigour, leaving crops more susceptible to pests, diseases and competition from weeds. One advantage of safflower is that it compensates for poor emergence by producing extra branches, extra heads, and extra seeds per head.

Planting date

Safflower development is controlled by a combination of temperature and day length. Large delays in the time of sowing therefore have a much smaller effect on the timing of flowering. This is because crops progress through the vegetative fill stages much more rapidly, with only a small effect on the period between flowering and maturity (Figure 5). The development of safflower is hastened in seasons that are warm and dry due to higher temperatures in the crop canopy (Figure 6).

Seeding rate

Target plant populations and seeding rates for safflower over a range of environments are provided in Table 2.

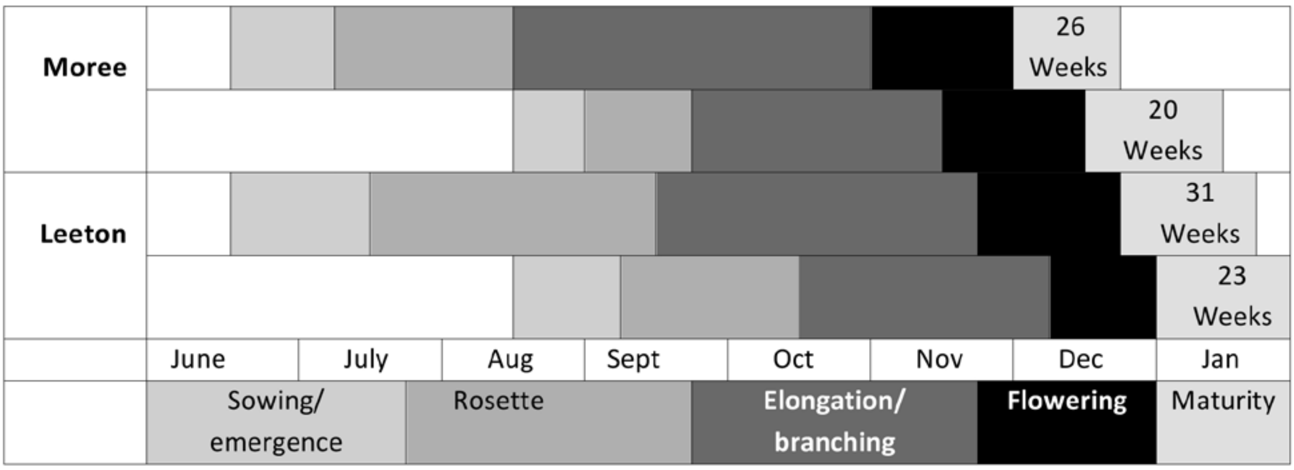

Figure 5. Effect of sowing in mid-June and mid-August on safflower development at Moree and Leeton in NSW (Source: Adapted from Colton, 1988).

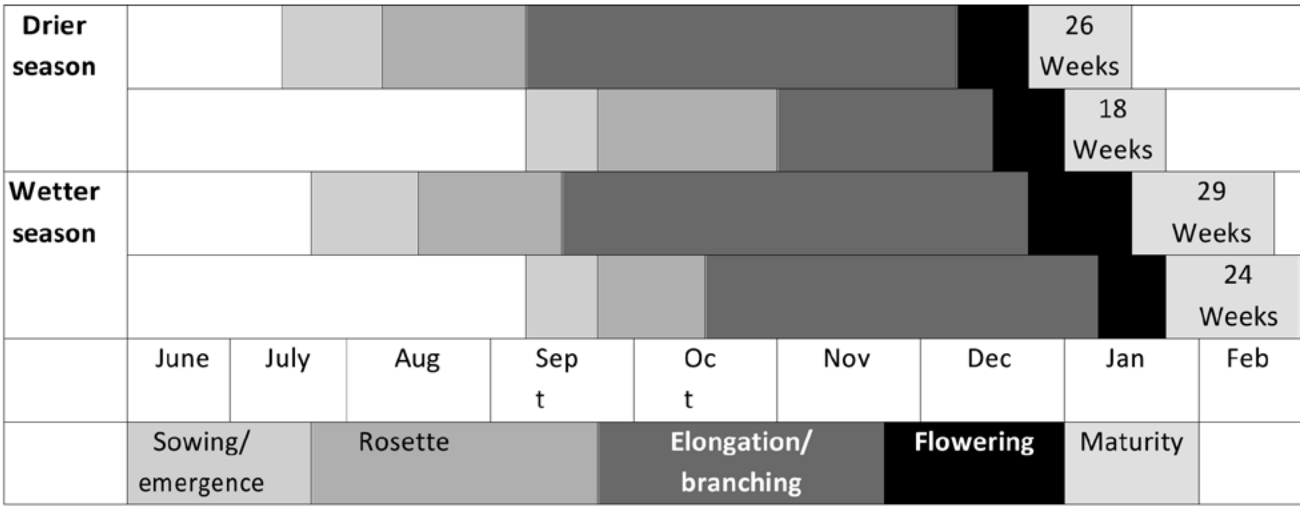

Figure 6. Effect of sowing in mid-July and mid-September on safflower development in a wetter and drier season at the same location in the Victorian Wimmera (Source: Adapted from Colton, 1988).

Table 2. Seeding rates of safflower for different regions and different climatic conditions (Source: GRDC. Raising the Bar with Better Safflower Agronomy, 2010).

	Favourable conditions	Drier conditions	Irrigated crops
Northern & central NSW	20 – 25 plants/m2	15 plants/m2	40 – 50 plants/m2 (25 – 31kg/ha)
	(12 – 15kg/ha)	(9kg/ha)	
Southern NSW	30 – 35 plants/m2	25 plants/m2	
	(18 – 22kg/ha)	(15kg/ha)	
Victoria & SA	30 – 40 plants/m2	20 – 30 plants/m2	
	(18 – 24kg/ha)	(12 – 18kg/ha)	

Fertiliser

Safflower's nutrient needs generally depend on the following:

- Yield goal
- Soil test results
- The sequence of the crop in the rotation

Safflower's deep taproot allows it to reach nutrients that may be unavailable to small grains. Growers may need to apply more fertiliser if safflower follows deep-rooted crops in rotations.

Nitrogen

At least 30kg/ha of nitrogen should be applied to most dryland crops and this can be increased to over 100kg/ha for high yielding crops under irrigation. No more than 20kg/ha of nitrogen should be drilled with seed to avoid toxicity, which will reduce crop establishment.

Phosphorus

As a general rule of thumb 12 to 20kg/ha of phosphorus is recommended on deficient soils. Responses to phosphorus are unlikely on soils with Cowell P levels above 40mg/kg, although small amounts can still be applied at sowing to improve early growth and maintain soil levels.

Potassium

Safflower uses moderate amounts of potassium, but most soils in the cereal growing regions of Australia contain adequate levels. The general exception is sandy soils, which are not best suited for safflower production unless in high rainfall regions. Potassium is not very mobile in soils, so where required it is best banded under seed.

Sulphur

Many soils contain adequate sulphur levels for safflower production. Soil sulphur levels should be monitored with soil tests and sulphur can be applied as gypsum or as a component of a blended fertiliser when necessary.

Manganese, Iron and Zinc

On certain soil types, such as the black soils in northern New South Wales or the heavy black or grey clay over limestone soils in South Australia, safflower does respond to manganese, iron and/or zinc. These are best applied as a foliar application around six weeks after sowing if necessary.

Weed control

Safflower competes poorly with weeds, especially from early growth through the rosette stage, when branching has not yet occurred. It is critical to have effective pre-plant weed control. Weeds have reduced safflower yields by up to 75 percent, depending on the species and numbers.

Due to the limited number of herbicides registered for weed control in safflower in 2016, GO Resources commenced an on-going herbicide safety screen for a range of pre-emergent and post-emergent herbicides. The research by GO Resources contributed to the Australian Pesticides and Veterinary Medicines Authority (APVMA) decision in 2019 to grant the Australian Oilseeds Federation (AOF) minor use permits for the application of clethodim (PER86859) and S-Metolachlor (PER86858) (Dual Gold®) in safflower. Current minor use applications that are being prepared for submission to the APVMA for use in safflower include the herbicides propyzamide, pyroxasulfone (Sakura®) and prosulfocarb + S-Metolachlor (Boxer Gold®). Refer to the APVMA permits portal to confirm permits are in place prior to the use of these chemicals (https://portal.apvma.gov.au/permits). Table 3 provides a summary of the current herbicides approved and being screened for use in safflower.

Diseases

In periods of higher than normal rainfall, fungal diseases such as Phytophthora root rot, Alternaria leaf spot (*Alternaria carthармi*), Pseudomonas bacterial blight (*P. syringae*) and Sclerotinia rot can cause serious losses. Fusarium and Verticillium wilts and Botrytis head rot also have caused serious losses.

To reduce disease severity, it's important to:

- Plant certified seed that has been treated with appropriate seed treatments.
- Utilise proper crop rotation practices that will reduce the risk of diseases being present in safflower.

Do not plant safflower before or after safflower, pulse crops, sunflower, mustards or canola. These crops are susceptible to Sclerotinia head rot. Leave at least four years between susceptible crops.

Insects

Safflower is most susceptible to damage by insects during establishment and between budding and harvest. Numerous insect pests have been observed on safflower and while some are widespread, others are confined to certain regions and climates.

There are a few insect problems in safflower. Red legged earth mites, wireworms and cutworms can damage seedlings. Rutherglen bug, grasshoppers and lygus bugs can damage the crop, but control is only necessary when they reach levels that cause serious losses.

If insects are present it is recommended that growers consult with their local agronomist to confirm the insects' presence and for advice on the appropriate registered insecticide that can be applied for control.

Table 3. Current herbicides approved in 2019 for use in safflower (Source: GO Resources).

Registered	APVMA Minor Use Permit in Safflower - Status	
	Granted in 2019	Applied for in 2019 for 2020 Season
Trifluralin	S-Metolachlor (PER86858)	Propyzamide
Avadex®Xtra	Clethodim (PER86859)	Pyroxasulfone
Diclofop-methyl		Prosulfocarb + S-Metolachlor
Propaquizafop		
Pendimethalin		
Metsulfuron-methyl		

Harvest and storage

The crop is ready for harvest when most of its leaves have turned brown with only a tint of green remaining on the bracts. The stem must be dry.

Moisture content should be eight percent or lower for proper storage. If the crop is cut at higher moisture content, dry it.

It is recommended to harvest a small sample and measure the moisture content. Direct heading is better than windrowing because it reduces shattering losses and seed quality is better.

Safflower can be harvested using the same machinery used for cereals. Ground speed is generally 25 percent slower than for cereals. This is mainly to reduce grain losses, but also to reduce the chance of blockages which can be time consuming and uncomfortable to rectify due to the crop's spines. Header settings will vary with conditions, crop yield and the type of machinery used.

Reels should be set to gently push the crop over the cutter bar without dislodging seed from the seed head. Drum speeds are generally slower (~500rpm), and concave openings usually wider (~16mm at front, ~13mm at back) than used for cereals. This is to prevent the cracking of seed which will deteriorate oil quality and reduce the value of the crop. Wind settings are typically about two-thirds of that required for wheat.

References and useful resources

Raising The Bar With Better Safflower Agronomy https://grdc.com.au/resources-and-publications/all-publications/publications/2011/01/raising-the-bar-with-better-safflower-agronomy

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Notes

Harvest weed seed control is less effective on annual ryegrass in the southern high rainfall zone

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GRDC project code: SFS00032

Keywords

- harvest weed seed control, weed seed retention, annual ryegrass, *Lolium rigidum*, high rainfall zone, integrated weed management, GRDC Southern Region.

Take home messages

- In the southern high rainfall zone (HRZ), harvest weed seed control (HWSC) is likely to capture 30% of annual ryegrass (ARG) seeds compared to around 70% in other regions of Australia (Walsh et al 2014). Therefore, HWSC will assist ARG control but cannot be relied upon to dramatically reduce weed seedbanks.
- It is difficult to increase the efficacy of HWSC in the southern HRZ. A harvest cut height of 15cm was no more effective than 30cm. Changing the crop cultivar and time of sowing did not manipulate ARG phenology and/or the harvest date enough to prevent high ARG seed shedding.
- Be strategic with HWSC. The extra operating costs of weed seed impact mills (up to $34 per ha) will only be covered in the long-term in paddocks where there is moderate to high weed pressure. Consider cheaper HWSC options where annual ryegrass density is lower.

Background

Harvest weed seed control (HWSC) is a term that refers to the capture of weed seeds during harvest for subsequent destruction by crushing, grazing, burning or rotting. It has been shown to be an extremely effective means of long-term annual ryegrass (ARG) control in Australia (Walsh et al 2014; Walsh et al 2017). However, while research has been conducted across all rainfall zones only a small proportion of it has been conducted in the southern HRZ. Not only is this a wet and productive environment – which changes the growth of the crop and ARG plants – it is also cooler, which prolongs the growing season and sets back harvest dates, possibly increasing the amount of pre-harvest ARG seed shedding. Therefore, the adoption of these technologies has been recommended in the southern HRZ on the assumption that HWSC has a similar fit in integrated weed management (IWM) packages as it does elsewhere. From 2015 to 2018 a GRDC investment led by Southern Farming Systems in collaboration with Riverine Plains, Mackillop Farm Management Group and FarmLink was implemented to test this assumption.

Method

The research program had three components addressing three questions:

1. *Is HWSC effective?* Small-plot experiments were conducted in Victoria (Lake Bolac, Rutherglen, Yarrawonga), South Australia (Conmurra) and Tasmania (Cressy). All trials except for Rutherglen were conducted for two to three consecutive years on the same experimental plots. Sowing date, crop cultivar choice and harvest cut height were hypothesised to affect the efficacy of HWSC. HWSC was simulated by catching all harvest trash from plot headers and taking it off-site (Figure 1).

Figure 1. HWSC was simulated on a plot header by capturing harvest trash to be discarded off-site.

2. *Is HWSC practical?* On-farm trials were conducted in Victoria, South Australia and southern New South Wales to test the practicality of using HWSC technologies, ground-truth their efficacy and measure operating costs.
3. *Is HWSC profitable?* The data from these trials were pooled to re-calibrate a farm systems model called LUSO (Lawes and Renton 2010) which was used to explore the long-term economic impact of adding HWSC to a wheat-barley-canola rotation.

Results and discussion

High shedding and lodging reduce the efficacy of HWSC in the southern HRZ

ARG populations were not controlled or reduced by HWSC in any small-plot trial in any year with any treatment. This is because much fewer seeds were captured for HWSC in the southern HRZ compared to other environments. The proportion of weed seeds that was captured was calculated for each experimental plot and pooled across the research program. The median value of this data set was 29% of seeds captured, with half of the data falling between 46% and 10%. The primary causes of this low efficacy were ARG shedding and lodging.

The season length of the southern HRZ postpones harvest dates compared to other environments in Australia, prolonging the growing season. It appears that the longer growing season gives ARG extra time to reach maturity and shed seeds before harvest. Across trial years, ARG reached anthesis in November, and shedding was first recorded from the second week of November to mid-December (Table 1). All trials were harvested at least one week after the first day of shedding was measured, but most were harvested three to four weeks after shedding began.

Table 1. Summary of annual ryegrass phenology and harvest dates from small-plot trials across the Southern HRZ in 2015 to 2017.

Site	Year	Sowing date(s)	ARG anthesis	First recorded shedding	Harvest date
Conmurra	2015	15 May, 3 June, 26 June	28 October	-	22 December
Lake Bolac	2015	20 April, 15 May, 17 June	-	26 November	4 Dec (TOS1) or 23 Dec (TOS2,3)
Conmurra	2016	17 May	23 November	19 December	4 January
Lake Bolac	2016	25 May	21 November	30 November	23 December
Yarrawonga	2016	28 April	-	11 November	11 December
Cressy	2016	12 April, 10 May	-	15 December	5 January
Conmurra	2017	22 May	10 November	24 November	4 January
Yarrawonga	2017	12 May	-	10 November	10 December

Seed shedding was measured and calculated for each individual plot and the data from all trial years was pooled. The median value of this data is 51% of seed shed, but there is substantial variation (Figure 2b). The sowing and harvest dates in the trials are appropriate for the region, so data can be taken to be representative of the likely situation for HWSC on farms in the southern HRZ.

It was hypothesised that changing the sowing date and crop cultivar would manipulate the phenology of ARG, and as a consequence, change the efficacy of HWSC. However, there were no significant differences ($P>0.05$) between sowing date treatments in any trial in any year. In other words, this research suggests that the growing season in the southern HRZ is too long to change ARG phenology to an extent that prevents its shedding in cereals. Canola was not included in the small-plot trials but given that it is harvested before cereals it is likely that it will be less affected by ARG shedding, but still more affected in the southern HRZ when compared to other environments.

Around 20-25% of ARG seeds were located below either a 15cm or 30cm harvest cut height. This was due to lodging or to mature seed heads detaching from the stem and falling to the ground. Again, there was substantial variation in the dataset and while the median value of seeds captured was slightly higher for a 15cm cut height compared to a 30cm cut height, analysis of the small-plot experiment showed that there were no long-term effects of a low-cut height. ARG plants were counted in early 2018 at Yarrawonga after applying HWSC at 15 or 30cm in 2016 and 2017. After two years of HWSC, ARG establishment remained above 100 plants/m^2 with no difference between cut heights ($P>0.05$). This suggests that while it may be beneficial in some years, cutting at 15cm may not be necessary in the southern HRZ. This supports the finding by Walsh et al (2018) who showed that greater crop biomass competition resulted in ARG setting seed higher in the crop canopy.

The high productivity potential of the southern HRZ makes HWSC a valuable weed control tool

To estimate the costs and benefits of controlling ARG with HWSC it is essential to be able to estimate the yield loss ARG causes. Several models and parameters are available in the literature, but the data set of the research program made it possible to choose parameters specifically for the southern HRZ. Remarkably, it was not necessary to adjust the parameters for weed and crop competitiveness; the values in LUSO that are used in the medium and low rainfall zones also work in the southern HRZ. As can be seen in Figure 3, yield can be predicted accurately for a given crop and winter ARG population.

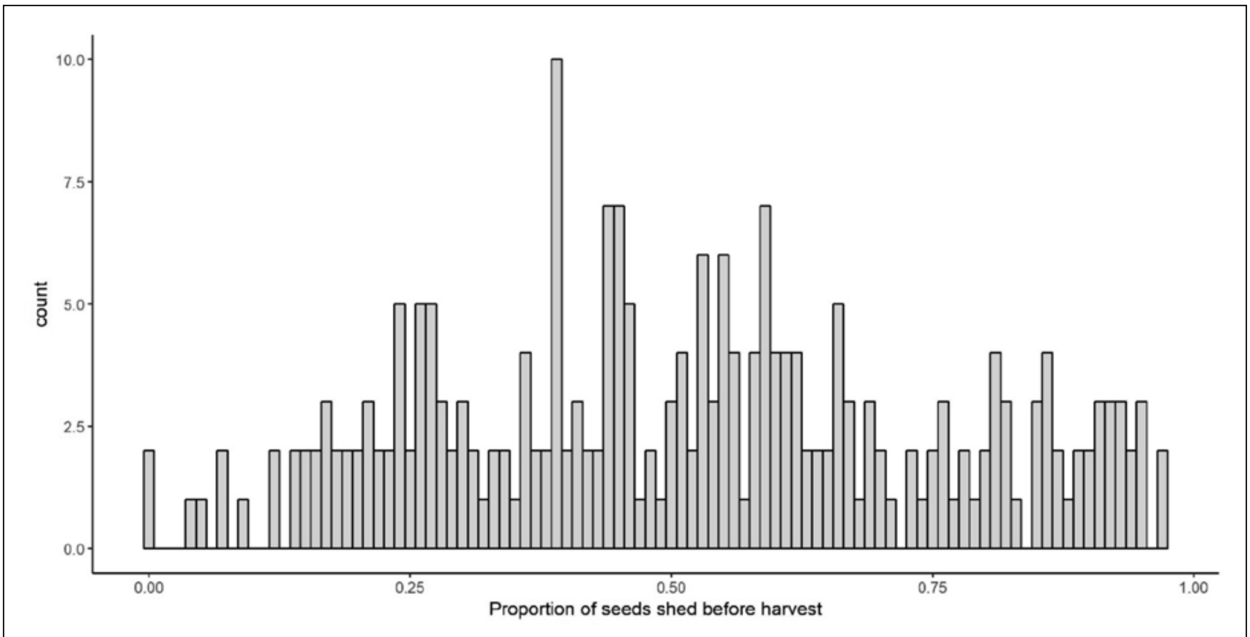

Figure 2. The incidence of pre-harvest seed shedding by annual ryegrass in cereals across the southern HRZ from 2015 to 2017, presented as the proportion of shed seed to total seed set.

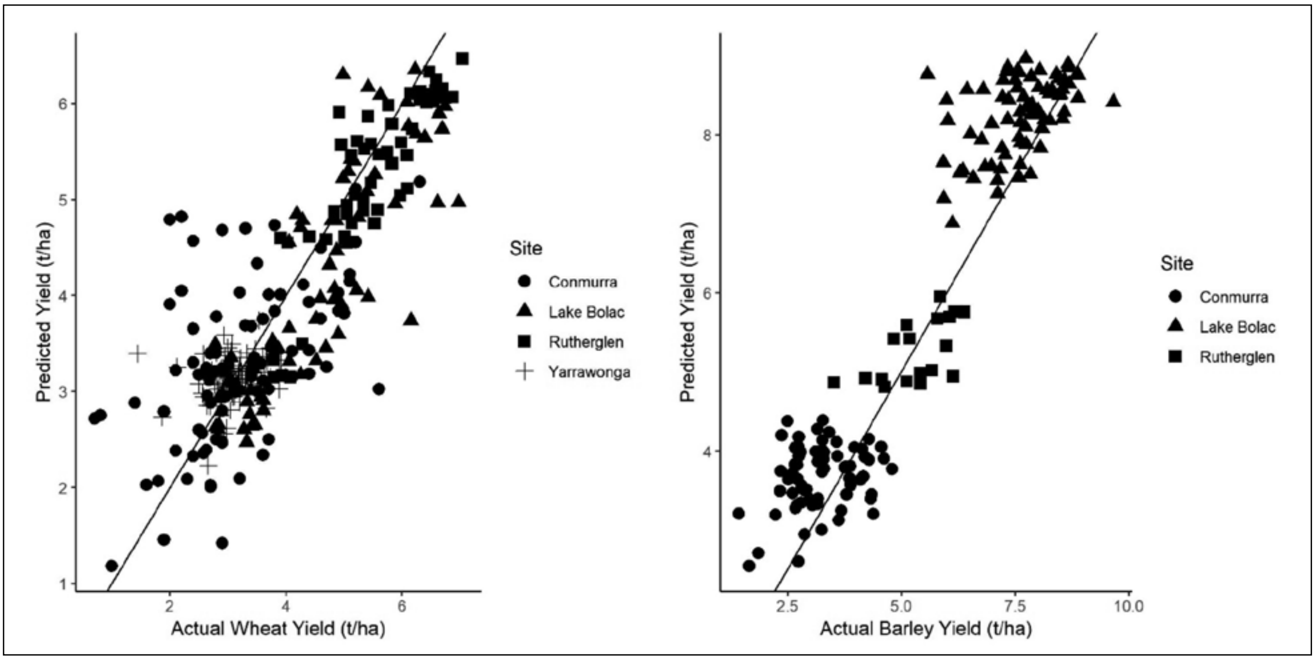

Figure 3. Actual plot yield and the yield predicted by LUSO for wheat and barley based on default weed and crop competition parameters using the number of annual ryegrass plants established in winter.

Despite very high weed burdens (>100 plants/m^2 in many plots in this data set), the relative competitiveness of weeds and crops remain similar to that recorded for other rainfall environments with lower weed pressures. The theoretical point where an ARG population would cause crop failure was not reached. Intensive cropping rotations in the southern HRZ can tolerate a higher weed burden than other environments.

On the other hand, because of the southern HRZ's high yield potential the value of ARG control is high. According to these parameters, 50 weeds/m^2 established in a cereal crop in winter reduces the yield potential by about 10%. If the yield potential of a given environment is 4t/ha, this equates to a 0.4t/ha yield loss to weed competition. If the yield potential is 8t/ha (as in the southern HRZ), this equates to a 0.8t/ha yield loss to weed competition. So, while more weeds can be tolerated in a cropping system in the southern HRZ because the penalty is cushioned by a high yield potential, the gains from controlling weeds are greater too. This makes the contribution of HWSC to ARG control more valuable for the southern HRZ than might be expected from its low efficacy rate of 30%.

Case study: A weed seed impact mill is profitable only if there is already a weed problem

Extra costs of a weed seed mill

In 2017, an on-farm demonstration was conducted at Wolesley, SA, comparing two New Holland CR8090 headers, one with an integrated Harrington Seed Destructor (iHSD) and one without an iHSD. Wheat was harvested at 15cm. The data collected from this demonstration was used to calculate the extra operating costs of using an iHSD by making use of the data from the PIRSA Gross Margin Guide 2019 (https://grdc.com.au/resources-and-publications/all-publications/publications/2019/farm-gross-margin-and-enterprise-planning-guide). The value was $34/ha, which is comparable to a value calculated by the Kondinin Group ($4.81/t, or $33.67 for a 7t/ha yield).

Table 2. Values used to estimate the extra operating costs of using an integrated Harrington Seed Destructor in a cereal crop in Wolesley, South Australia.

Costs	GM Guide 2019 ($/ha)	Conversion Factor	WSM Cost ($/ha)
Repairs & Maintenance	9.29	+15% to engine load	10.68
Fuel	6.14	+37% to fuel usage	8.41
Contractor Harvest	85	-36% to harvest efficiency	115.60
		Total extra cost:	34.36

Table 3. Values used in the economic analysis of HWSC in a wheat-barley-canola rotation in LUSO.

Enterprise	Yield potential	Grain Price	Variable cost	N required
Wheat + WSM	8	300	635	180
Wheat	8	300	600	180
Feed barley + WSM	8	260	585	150
Feed barley	8	260	550	150
Canola + WSM	3	580	635	100
Canola	3	580	600	100

Scenario analysis

The long-term impact of a weed seed mill (WSM) on ARG populations and profitability was modelled in a wheat-barley-canola rotation over 12 years using the values presented in Table 3. Fixed costs were set at $180, and the cost of nitrogen (N) was set at $1.50/unit of N. The model was run with and without HWSC at two starting weed seedbank levels. Then the model was run again with the same conditions but the proportion of weeds surviving until maturity was raised from 5% to 10%. In the small-plot trials, low intensity herbicides were used to focus on the impact of HWSC and so the average survival rate in these trials was 10%. This value was used in the scenario analysis to illustrate the role of herbicide efficacy which may be affected by numerous factors including herbicide resistance.

After 12 years, a similar pattern in ARG control was observed when the starting seedbank was 100 or 500 seeds/m^2 (Figure 4). Populations increased exponentially if 10% of weeds survived and a WSM was not used. Adding a WSM to this situation significantly reduced weed population **growth** but the final number of weed seeds in the seedbank was much higher after 12 years than the initial value. Reducing weed survival to 5%, the default LUSO value, achieved this to a greater extent. Only when a WSM was used and weed survival was 5% did ARG numbers decline in absolute terms, but they only declined by about 30% over 12 years.

Although the pattern in final seedbank was similar between the 100 and 500 seeds/m^2 scenarios, the pattern in profitability differed depending on the starting seedbank (Figure 5). With a 5% survival rate, adding a WSM did not increase profitability when starting at 100 seeds/m^2. It was, however, profitable when starting at 500 seeds/m^2. Using a WSM was always profitable when 10% of weeds survived to harvest. These results suggest that there must be enough of a yield penalty caused by high weed numbers of cover the extra costs of a WSM. It should be noted that these calculations only account for extra operating costs, and do not account for extra capital costs associated with purchasing a WSM.

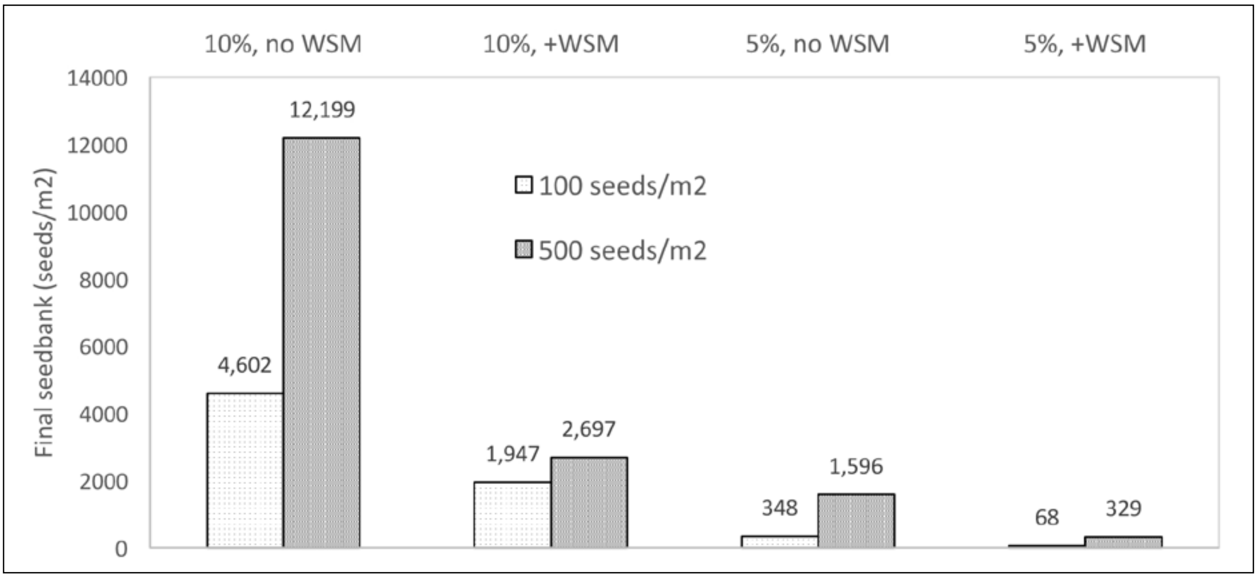

Figure 4. Final seedbank after 12 years of a wheat-barley-canola rotation with 5% or 10% weeds surviving until maturity and with or without a weed seed mill (WSM), starting at 100 seeds/m^2 or 500 seeds/m^2.

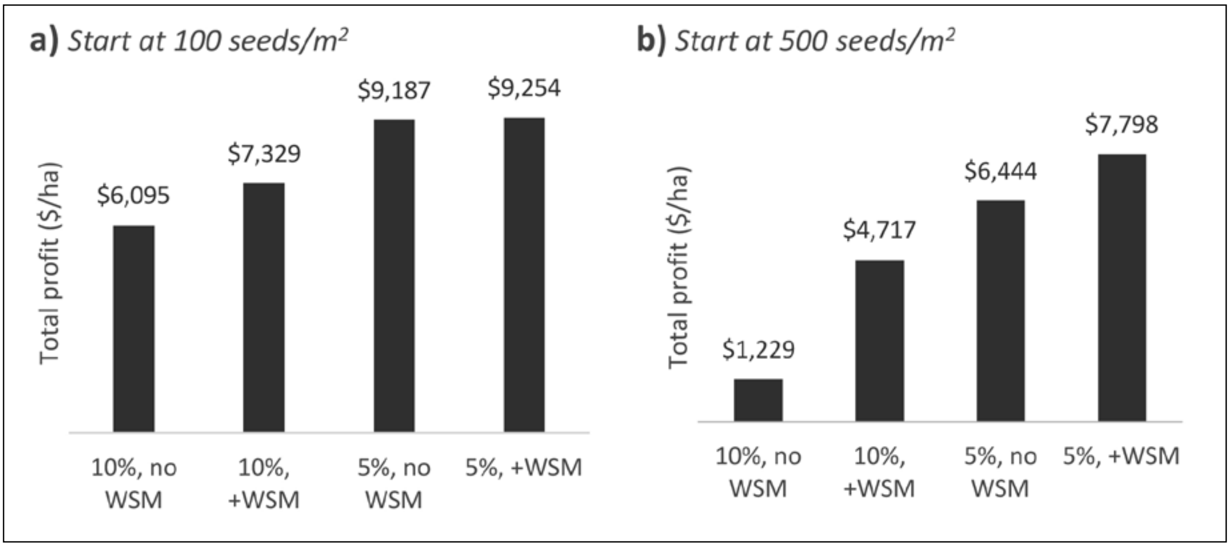

Figure 5. Total profit after 12 years of a wheat-barley-canola rotation with 5% or 10% weeds surviving until maturity and with or without a weed seed mill (WSM), starting at (a) 100 seeds/m^2 or (b) 500 seeds/m^2.

Implications

By itself, HWSC only decelerates the population growth of ARG. The final weed seedbank output from LUSO matches what was seen in the small-plot trials – ARG numbers continue to grow between seasons despite the use of HWSC when many plants survive until harvest. HWSC must be combined with consistently effective herbicide and other weed management options that reduce the number of weeds setting seed, and even then, the reduction in ARG seedbanks will be small and slow. However, with an efficacy of 30% a WSM had a large decelerating effect on ARG population growth in every scenario. Therefore, HWSC cannot be relied upon in the southern HRZ to drastically reduce ARG numbers but can support IWM packages by decelerating ARG population growth.

There must already be a weed problem for a WSM to pay for itself. A WSM was only profitable if the initial weed seedbank was high burden (i.e. 500 seeds/m^2 is equivalent to about 70 plants/m^2 in mid to late winter) or the number of weeds surviving to harvest was high (i.e. low herbicide efficacy). Therefore, expensive to use HWSC technologies like WSMs could be targeted to problem paddocks to cover the extra costs and should not necessarily be used in clean paddocks with low resistance levels.

Furthermore, **cheaper HWSC options with lower operating costs should be considered** over expensive technologies. Effort should be made to reduce the operating costs associated with weed seed mills if they are going to have a place in farm businesses in the southern HRZ. The new vertical iHSD selling for $85,000 instead of $200,000 is a step in the right direction, but ways to reduce operating costs should also be pursued.

Chaff lining or decking may be a low-cost HWSC option that fits the needs of the southern HRZ, but its efficacy has not been tested in this region. Recent findings by Broster et al (2018) in Wagga Wagga showed that high concentrations of chaff (>24t/ha) will suppress ARG germination by 40 to 80%. Large amounts of chaff would be produced in the southern HRZ, but it is unknown whether the different conditions would affect its ability to suppress weeds.

Conclusion

HWSC is likely to only capture 30% of ARG seeds in the southern HRZ, but this 30% is valuable to farm businesses because of the high productivity of the region. Therefore, HWSC has a fit in the southern HRZ farming systems, but it fits differently – it is not the 'holy grail', but it can play a supporting role for IWM packages. Adding HWSC to weed management strategies in the southern HRZ is recommended, but growers should focus on the cheaper HWSC options and/or use the expensive HWSC options strategically.

Useful resources

https://weedsmart.org.au/the-big-6/

https://ahri.uwa.edu.au/hwsc-cost/

https://ahri.uwa.edu.au/chaff-liningtoo-good-to-be-true/

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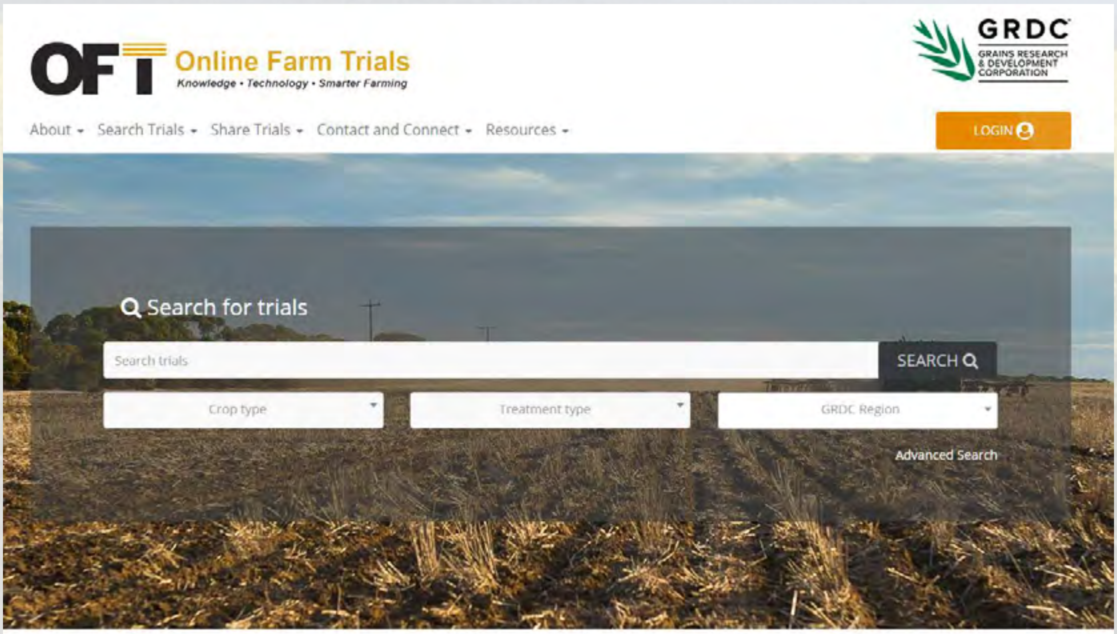

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Earwigs – latest research on these damaging pests

Matthew Binns[1], Ary Hoffmann[2], Maarten van Helden[3], Thomas Heddle[3] and Paul Umina[2,4].

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GRDC project code: CSP1805-016RTX

Keywords

- earwig, canola, lifecycle.

Take home messages

- Adult European earwigs are present all year, but eggs and juvenile earwigs are only present from April to November.
- European earwigs can cause significant damage to canola, lucerne, lupins and in some cases, lentils.
- The potential for damage to emerging crop seedlings by adult European earwigs exists, although it is dependent upon the timing of germination and egg laying. The juvenile earwigs can cause further damage as the crop develops through winter.
- Multiple earwig species have been detected in grain crops, most of which are not associated with crop damage. It is therefore important to correctly identify which species is present in a paddock before taking any action.

Background

There are at least 80 species of earwigs (Dermaptera) present in Australia (Haas 2018). Recent work using a combination of morphological and molecular data has identified ten different species of earwigs in grain crops (Stuart et al. 2019). These species are comprised of introduced and native earwigs, of which there is not a lot known. However, some of the potentially beneficial species appear to be region specific (Stuart et al. 2019). Reports of earwig outbreaks and damage to canola, cereals and pulse crops, have been increasingly recorded in Victoria, NSW, SA, and southern WA. However, the factors that influence the risk of earwig outbreaks and crop damage are not well documented.

The most dominant and widespread species in Australian crops is the European earwig (*Forficula auricularia*) (Hill et al. 2019). The European earwig consumes a variety of foods (plants, invertebrates, fungus, detritus), acting beneficially through the consumption of crop pests in orchards (Quarrell et al. 2017). However, the European earwig has been observed as an irregular pest of grain crops in Australia (Murray et al. 2013). Despite being introduced into Australia over a century ago (Quarrell et al. 2018), there has been little research conducted on crop damage from European earwigs in Australia. Furthermore, the potential beneficial activities of the European earwig in grain crops have not been explored. The two dominant native earwig species found in grain crops are *Labidura truncata* and *Nala lividipes* (unpublished data). Research has shown *L. truncata* to be predatory (Horne and Edward 1995), although this species' importance as a beneficial in grain crops has not been explored. *N. lividipes* is a pest of Queensland cereals (Hargreaves 1970), although it is unclear if this is also the case in southern Australia or if it will feed on canola at all. It is suspected that increased stubble retention and the associated increase in organic matter within the soil may be linked to greater in-field earwig populations. However, resources documenting the risk of crop damage, as well as management options to minimise the crop damage from pest earwigs, are limited.

Methods

Lifecycle monitoring of the European earwig

To establish the life cycle of European earwigs within a grains production context, grain crops (canola, wheat, oats) at five commercial farms were examined; two in Victoria and three in SA. Sampling at these sites was undertaken over a period of seven days each month from September 2016 to December 2018. During each sampling period two types of traps were used; shelter traps in the form of cardboard rolls inserted into PVC pipe, and pitfall traps containing 100% propylene glycol. Three pitfall traps were installed two meters apart at four sampling locations (>30m apart) per site, with at least one sampling location being placed at the paddock edge for a total of 12 pitfall traps. Pitfall traps were used to capture earwigs during times of activity (i.e. foraging for food at night).

At each of the four sampling locations within the field, three cardboard rolls were placed complementary to the pitfalls to determine abundance (12 rolls in total). The cardboard roll traps were placed within an inter-row parallel to the stubble row, two metres from the associated pitfall and collected seven days later. Additionally, to establish movement of earwigs into vegetation adjacent to field sites, two rolls were placed in the canopy of four trees per site (eight tree rolls) using wire to tie the rolls to branches. The use of cardboard rolls allowed the collection of live earwigs during times of inactivity (being nocturnal they use the rolls for shelter during the day).

European earwigs (*F. auricularia)* comprised 75% of earwigs collected (unpublished data), and so laboratory processing first involved separating them from the other earwig species that were captured. Part of the species separation involved confirmation via molecular work with comparisons to published sequence data (Stuart et al. 2019). The adult and nymphal stages of *F. auricularia* was identified using head width, the number of antennal segments and wing bud development as described in Crumb et al. (1941). As earwigs are dimorphic, sex was identified using the shape of the cerci (Crumb et al. 1941) and categorised into male, female and gynandromorph.

Damage and management of the European earwig in canola

The following methods are part of a larger ongoing field experiment, they give background to the data collected and presented in the results but do not cover the entire experiment.

On the 23 April 2019, 30 plots (8m by 1.8m in size) of canola were sown into wheat stubble on a 0.5ha paddock on the Ginninderra research station near Canberra ACT. The plots were randomly allocated seed with different seed treatments; fipronil, imidacloprid or untreated. All seed was planted at the rate of 2.7kg/ha, and all seed was coated with Jockey® Stayer® for blackleg control.

On the 23 May 2019, seedling establishment was measured in the fipronil/imidacloprid/untreated plots by counting the number of seedlings. At this time the European earwigs had either laid eggs or were preparing to lay, but no juveniles had hatched. By mid-June, second instar earwig nymph activity was detected using a modified wildlife camera and significant damage was seen over the next couple of weeks. On the 24 June 2019 the damage to the plots of canola was assessed by estimating biomass loss in each experimental plot.

Results and discussion

Lifecycle

Over the course of two years, 25 000 European earwigs (*F. auricularia*) were captured from five sites. This provided enough data to understand the lifecycle of the European earwig in grain crops in southern Australia.

The timing of the peak abundance of each lifestage was relatively consistent across each of the five sites, for which the data was combined to determine the proportion of each lifestage expected to be observed for each month of the year (Figure 1). The initial brood of eggs was observed in nests during April-July, with peak numbers of first and second instar nymphs observed in July. Third instar numbers peaked in October, while fourth instar numbers peaked before this in September. This is potentially due to earwigs moving out of the paddocks and into nearby trees when they reached fourth instar in September and October (Figure 2 - note the log scale abundance axis). Adult earwig numbers were shown to peak in November/December and remain abundant until the following March.

The collection of detailed lifecycle data for *F. auricularia* has enabled orchard growers worldwide to preserve or increase earwig numbers and thereby take advantage of their beneficial behaviors to protect orchards from pest insects (Nicholas et al. 2005; Quarrell 2013). Conversely, using this lifecycle data for grain crops may allow better prediction of the risk of crop seedlings to

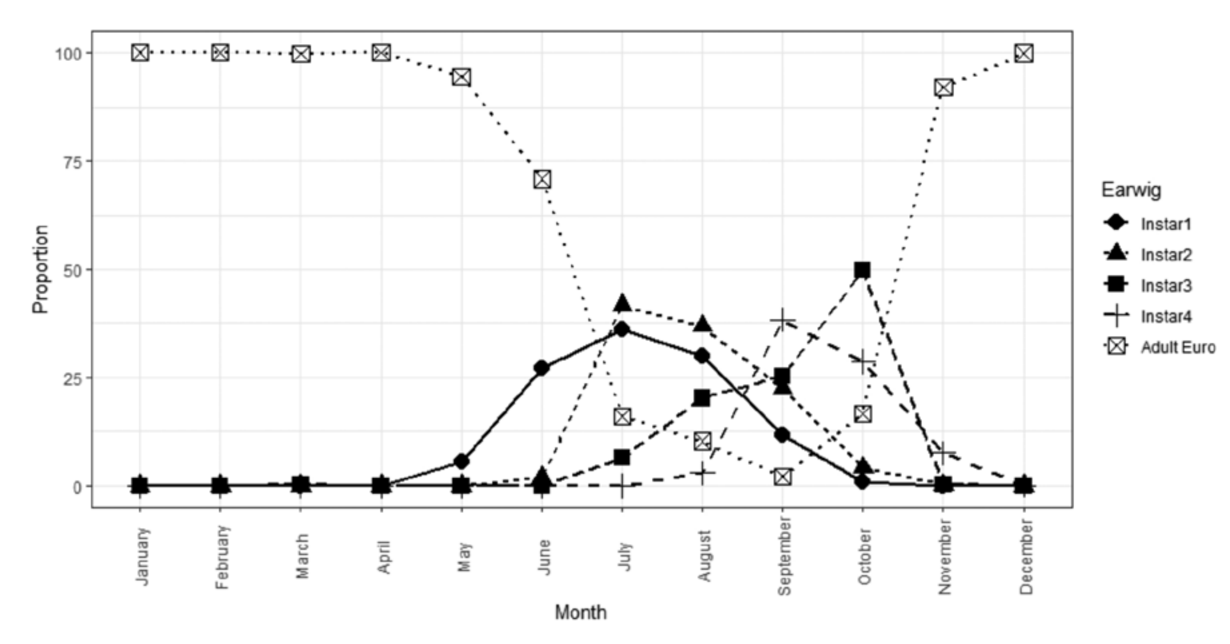

Figure 1. The lifecycle of the European earwig in grain crops. This figure shows the combined proportion (%) data of each *F. auricularia* lifestage from two years of sampling at five sites across Victoria and SA. Adults are present all year, but juveniles are only present from April to November.

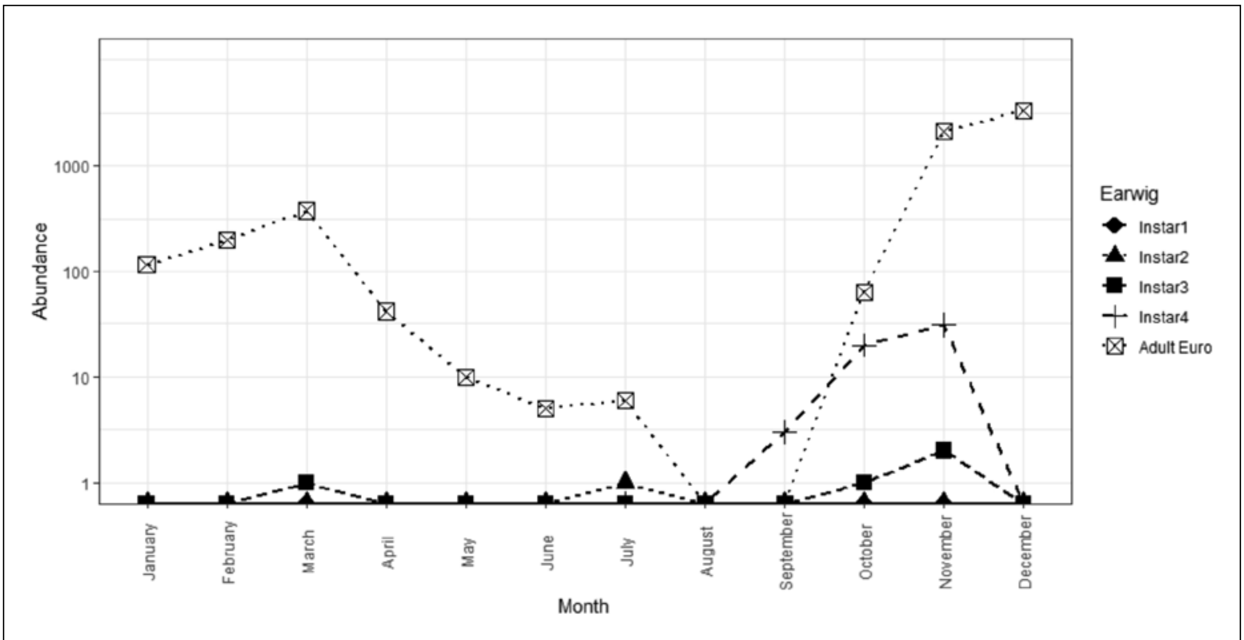

Figure 2. Mean abundance of European earwigs found in trees over time, note log scale axis. Adult numbers decline in the trees during the breeding phase from April to September where they burrow into the ground and care for developing juveniles. Fourth instar juveniles and freshly moulted adults generally move out of the paddock and into the trees over summer.

earwig attack, and if necessary, optimise timing of management tactics to reduce earwig numbers by targeting the appropriate lifestages.

Damage and management

The results for this section are part of an ongoing experiment. The results presented are based on incomplete preliminary data but suggest some initial patterns.

Seed coating

No significant difference was found in seedling establishment a month after sowing between seed treatments (p=0.25). Generally, canola is sown and starts growing several weeks before the European earwigs eggs hatch. As such, the severe damage caused by juveniles may be avoided during the plant's most vulnerable stage depending on when sowing occurs. However, adults will be present at this time and have the capacity to cause seedling damage (**cesar**, unpublished data), though there is a window of a few weeks where the adult female is underground caring for her eggs and not feeding. For this particular trial, the canola germinated as the females stopped feeding and started laying eggs. Thus, only very mild and occasional earwig damage was seen, not enough to significantly affect seedling establishment. Of course, there are many cases when earwigs can be damaging in autumn months. Although preliminary, these trials point to a complexity of factors at play that influence timing of events and thus impact the likely damage caused to emerging crop seedlings by European earwigs.

Once the earwig juveniles had hatched and reached second instar, significant damage started to occur to the canola (Figure 3). The damage caused by earwig nests at the 4 to 5 true leaf stage was significantly different (p<0.05) depending on the seed coating used (Figure 4). Fipronil provided significantly more protection over untreated and imidacloprid treated seed, while imidacloprid seemed to result in no significant improvement over untreated seed in terms of earwig damage. In laboratory studies, both imidacloprid and fipronil prevented earwig damage during the time in which the coating remained active (**cesar**, unpublished data). However, fipronil caused significant mortality in earwigs whereas imidacloprid did not (this chemical only acted as a feeding repellant). Potentially, fipronil is more effective in the long term due to the initial reduction in earwig numbers. Thus, as seen in this field trial, damage occurred after the imidacloprid seed coating had worn off and there were significantly fewer (p<0.05) earwig nests found in the fipronil treated areas.

In this experiment, the overall average biomass loss per plot was 0.17% for fipronil and about 1% for untreated/imidacloprid. This is with an average of eight 'nesting spots' for untreated/imidacloprid and 1.6 for fipronil; each 'nesting spot' represents either one earwig nesting location or several in very close

Figure 3. Damage to canola by second instar earwig juveniles. This is typical for canola that is in very close proximity to a European earwig nest, the white arrow (left) points to where the nest was found. The black arrow (right) points to an image of second instar earwigs feeding captured from about 11:00pm to 2:00am.

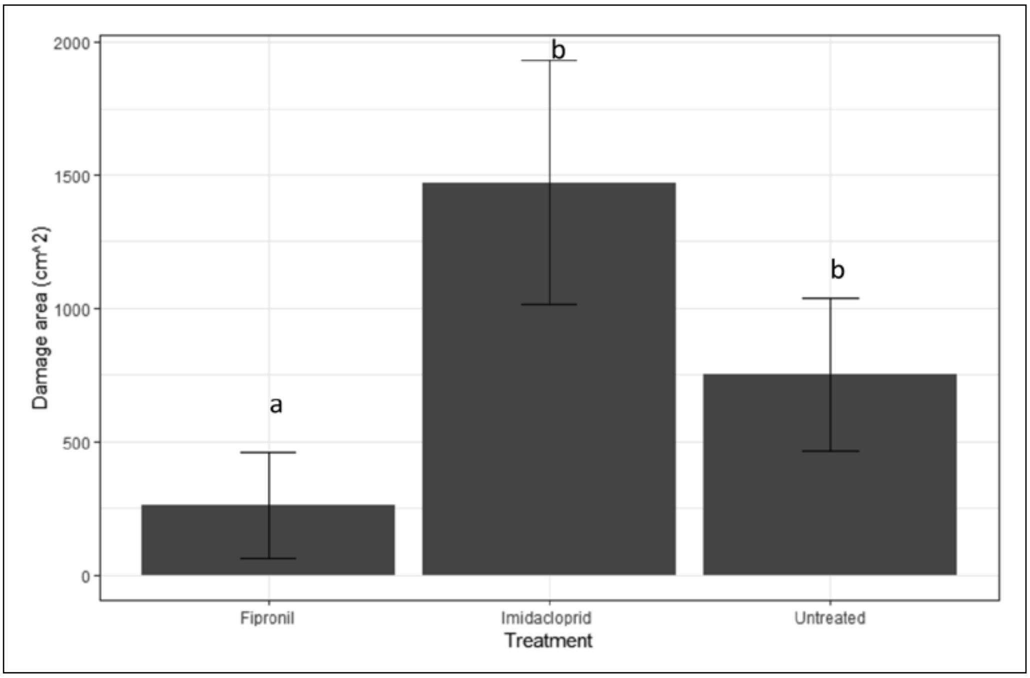

Figure 4. Total area of earwig damage measured in each 8m x 1.8m plot at the 4-5 true leaf canola growth stage. Bars represent the means with +- standard error. Letters represent similar means at $p<0.05$.

proximity. The damage does not seem to spread much further than 30cm from a single earwig nest during the pre-bolting growth stage of canola. This demonstrates that while the damage can look bad in isolation, it won't necessarily result in enough damage to significantly impact overall biomass or yield. This result is from one paddock only, and so additional data is required to assess how this changes with increased earwig nest densities, and how dense they need to be for losses to occur.

Native Earwigs

The common native species found in grain crops are *Labidura truncata* and *Nala lividipes*. Laboratory trials are underway at CSIRO, Black Mountain to determine the roles these species are likely to play in various crop environments. So far, pilot studies have indicated that neither *L. truncata* nor *N. lividipes* will feed on untreated canola seedlings under any of the conditions tested so far (including aphid/canola choice and canola only no-choice). *L. truncata* ate large numbers of green peach aphids when provided, hunting during both day and nighttime. *N. lividipes* ate smaller numbers of aphids than *L. truncata*, and also cannibalised each other (pers obs).

Conclusion

European earwigs are generally not regarded as a pest in grain crops internationally (other than occasional harvest contamination), and potentially play a beneficial role in pest management (Sunderland and Vickerman 1980). However, it is clear from damage reports that they can cause significant damage in Australian crops, particularly canola. European earwigs have the capacity to cause damage throughout the entire season. The nesting phase begins around April, which is often when canola is sown. Prior to nest establishment, adult earwigs are actively feeding, and can cause damage to emerging seedlings if the crop starts germinating at that time. However, there is a period of several weeks where the female earwig is confined underground caring for her eggs and crop feeding is less likely to happen. After the eggs have hatched and the juveniles start developing, significant damage to canola can occur which can be particularly harmful if the plant is still small and vulnerable. Hence, the timing of earwig feeding activity and crop vulnerability is likely to be an important predictor of crop damage.

European earwigs only have one generation per year (with potentially two broods per female), and they don't travel very far to feed as young juveniles. Once a nest is established, it is likely that the canola near the nest will be damaged, but the earwigs within that nest are likely to cause minimal damage to other parts of the crop. Extensive damage will be the result of many nests becoming established across large areas of the paddock. Monitoring for nests from April until June will allow for management before the earwigs reach the more destructive second instar stage from late June.

The accurate identification of what species of earwig is in the crop is the most important predictor of crop damage. Of the three dominant species found in canola, only European earwigs are confirmed as causing damage, while *N. lividipes* and *L. truncata* appear to have beneficial value. The pest activity of *N. lividipes* in winter cereals w ill be investigated although it may be season specific, as it is primarily reported as a pest of Queensland sorghum and maize during summer (Hargreaves 1970).

Our data so far suggests that the damage per earwig nest is spatially limited, but very high numbers distributed across a paddock will need to be controlled. So far, the data obtained around control methods is limited. The preliminary results of our trial suggest that fipronil might be useful as a seed coating in areas with a history of earwig problems. However, there is no registration for this pest. Due to the beneficial aspects of earwigs, reducing populations unnecessarily may have consequences for future crops. Therefore, it is important to properly identify which species of earwig is in the field before taking action.

Useful resources

www.grdc.com.au/GRDC-FS-Earwigs

http://cesaraustralia.com/sustainable-agriculture/pestnotes/insect/European-earwig

https://grdc.com.au/resources-and-publications/all-publications/publications/2019/insect-pests-of-establishing-canola-in-nsw

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‘Strip & disc’ farming – a grower’s experience

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THE 2017-2020 GRDC SOUTHERN REGIONAL PANEL

JANUARY 2019

CHAIR - JOHN BENNETT

Based at Lawloit, between Nhill and Kaniva in Victoria's West Wimmera, John, his wife Allison and family run a mixed farming operation across diverse soil types. The farming system is 70 to 80 percent cropping, with cereals, oilseeds, legumes and hay grown. John believes in the science-based research, new technologies and opportunities that the GRDC delivers to graingrowers. He wants to see RD&E investments promote resilient and sustainable farming systems that deliver more profit to growers and ultimately make agriculture an exciting career path for young people.

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DEPUTY CHAIR - MIKE MCLAUGHLIN

Mike is a researcher with the University of Adelaide, based at the Waite campus in South Australia. He specialises in soil fertility and crop nutrition, contaminants in fertilisers, wastes, soils and crops. Mike manages the Fertiliser Technology Research Centre at the University of Adelaide and has a wide network of contacts and collaborators nationally and internationally in the fertiliser industry and in soil fertility research.

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Peter is a farmer at Mudamuckla near Ceduna on South Australia's Western Eyre Peninsula. He uses liquid fertiliser, no-till and variable rate technology to assist in the challenge of dealing with low rainfall and subsoil constraints. Peter has been a board member of and chaired the Eyre Peninsula Agricultural Research Foundation and the South Australian Grain Industry Trust.

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JON MIDWOOD

Jon has worked in agriculture for the past three decades, both in the UK and in Australia. In 2004 he moved to Geelong, Victoria, and managed Grainsearch, a grower-funded company evaluating European wheat and barley varieties for the high rainfall zone.
In 2007, his consultancy managed the commercial contract trials for Southern Farming Systems (SFS). In 2010 he became Chief Executive of SFS, which has five branches covering southern Victoria and Tasmania. In 2012, Jon became a member of the GRDC's HRZ Regional Cropping Solutions Network.

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FIONA MARSHALL

Fiona has been farming with her husband Craig for 21 years at Mulwala in the Southern Riverina. They are broadacre, dryland grain producers and also operate a sheep enterprise. Fiona has a background in applied science and education and is currently serving as a committee member of Riverine Plains Inc, an independent farming systems group. She is passionate about improving the profile and profitability of Australian grain growers.

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A fourth generation grain grower at Turriff in the Victorian Mallee, Rohan has been farming for more than 25 years and is a director of Mott Ag. With significant on-farm storage investment, Mott Ag produces wheat, barley, lupins, field peas, lentils and vetch, including vetch hay. Rohan continually strives to improve productivity and profitability within Mott Ag through broadening his understanding and knowledge of agriculture. Rohan is passionate about agricultural sustainability, has a keen interest in new technology and is always seeking ways to improve on-farm practice.

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RICHARD MURDOCH

Richard along with wife Lee-Anne, son Will and staff, grow wheat, canola, lentils and faba beans on some challenging soil types at Warooka on South Australia's Yorke Peninsula. They also operate a self-replacing Murray Grey cattle herd and Merino sheep flock. Sharing knowledge and strategies with the next generation is important to Richard whose passion for agriculture has extended beyond the farm to include involvement in the Agricultural Bureau of SA, Advisory Board of Agriculture SA, Agribusiness Council of Australia SA, the YP Alkaline Soils Group and grain marketing groups.

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MICHAEL CHILVERS

Michael runs a collaborative family farming enterprise at Nile in the Northern Midlands of Tasmania (with property also in northern NSW) having transitioned the business from a dryland grazing enterprise to an intensive mixed farming enterprise. He has a broad range of experience from resource management, strategic planning and risk profiling to human resource management and operational logistics, and has served as a member of the the High Rainfall Zone Regional Cropping Solutions Network for the past six years.

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KATE WILSON

Kate is a partner in a large grain producing operation in Victoria's Southern Mallee region. Kate and husband Grant are fourth generation farmers producing wheat, canola, lentils, lupins and field peas. Kate has been an agronomic consultant for more than 20 years, servicing clients throughout the Mallee and northern Wimmera. Having witnessed and implemented much change in farming practices over the past two decades, Kate is passionate about RD&E to bring about positive practice change to growers.

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ANDREW RUSSELL

Andrew is a forth generation grain grower and is currently the Managing Director and Shareholder of Lilliput AG and a Director and Shareholder of the affiliated Baker Seed Co - a family owned farming and seed cleaning business. He manages the family farm in the Rutherglen area, a 2,500 ha mixed cropping enterprise and also runs 2000 cross bred ewes. Lilliput AG consists of wheat, canola, lupin, faba bean, triticale and oats and clover for seed, along with hay cropping operations. Andrew has been a member of GRDC's Medium Rainfall Zone Regional Cropping Solutions Network and has a passion for rural communities, sustainable and profitable agriculture and small business resilience.

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LUCY BROAD

Lucy Broad is the General Manager of the Grains Research and Development Corporation's (GRDC) Grower Communication and Extension business group. Lucy holds a Bachelor of Science in Agriculture, majoring in agronomy, and prior to working at the GRDC spent the last 13 years as Director and then Managing Director of Cox Inall Communications and Cox Inall Change, Australia's largest and leading public relations agency working in the Agribusiness and Natural Resource Management arena. Her entire career has been in communications, first with the Australian Broadcasting Corporation and then overseeing communications and behaviour change strategies for clients across the agriculture, natural resource management, government and not-for-profit sectors.

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2017–2019 SOUTHERN REGIONAL CROPPING SOLUTIONS NETWORK (RCSN)

JANUARY 2019

The RCSN initiative was established to identify priority grains industry issues and desired outcomes and assist the GRDC in the development, delivery and review of targeted RD&E activities, creating enduring profitability for Australian grain growers. The composition and leadership of the RCSNs ensures constraints and opportunities are promptly identified, captured and effectively addressed. The initiative provides a transparent process that will guide the development of targeted investments aimed at delivering the knowledge, tools or technology required by growers now and in the future. Membership of the RCSN network comprises growers, researchers, advisers and agribusiness professionals. The three networks are focused on farming systems within a particular zone – low rainfall, medium rainfall and high rainfall – and comprise 38 RCSN members in total across these zones.

REGIONAL CROPPING SOLUTIONS NETWORK SUPPORT TEAM

SOUTHERN RCSN CO-ORDINATOR: JEN LILLECRAPP

Jen is an experienced extension consultant and partner in a diversified farm business, which includes sheep, cattle, cropping and viticultural enterprises. Based at Struan in South Australia, Jen has a comprehensive knowledge of farming systems and issues affecting the profitability of grains production, especially in the high rainfall zone. In her previous roles as a district agronomist and operations manager, she provided extension services and delivered a range of training programs for local growers. Jen was instrumental in establishing and building the MacKillop Farm Management Group and through validation trials and demonstrations extended the findings to support growers and advisers in adopting best management practices. She has provided facilitation and coordination services for the high and medium rainfall zone RCSNs since the initiative's inception.

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LOW RAINFALL ZONE CO-LEAD: BARRY MUDGE

Barry has been involved in the agricultural sector for more than 30 years. For 12 years he was a rural officer/regional manager in the Commonwealth Development Bank. He then managed a family farming property in the Upper North of SA for 15 years before becoming a consultant with Rural Solutions SA in 2007. He is now a private consultant and continues to run his family property at Port Germein. Barry has expert and applied knowledge and experience in agricultural economics. He believes variability in agriculture provides opportunities as well as challenges and should be harnessed as a driver of profitability within farming systems. Barry was a previous member of the Low Rainfall RCSN and is current chair of the Upper North Farming Systems group.

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LOW RAINFALL ZONE AND MEDIUM RAINFALL ZONE LEAD: JOHN STUCHBERY

John is a highly experienced, business-minded consultant with a track record of converting evidence based research into practical, profitable solutions for grain growers. Based at Donald in Victoria, John is well regarded as an applied researcher, project reviewer, strategic thinker and experienced facilitator. He is the founder and former owner of JSA Independent (formerly John Stuchbery and Associates) and is a member of the SA and Victorian Independent Consultants group, a former FM500 facilitator, a GRDC Weeds Investment Review Committee member, and technical consultant to BCG-GRDC funded 'Flexible Farming Systems and Water Use Efficiency' projects. He is currently a senior consultant with AGRIvision Consultants.

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HIGH RAINFALL ZONE LEAD: CAM NICHOLSON

Cam is an agricultural consultant and livestock producer on Victoria's Bellarine Peninsula. A consultant for more than 30 years, he has managed several research, development and extension programs for organisations including the GRDC (leading the Grain and Graze Programs), Meat and Livestock Australia and Dairy Australia. Cam specialises in whole-farm analysis and risk management. He is passionate about up-skilling growers and advisers to develop strategies and make better-informed decisions to manage risk – critical to the success of a farm business. Cam is the program manager of the Woady Yaloak Catchment Group and was highly commended in the 2015 Bob Hawke Landcare Awards.

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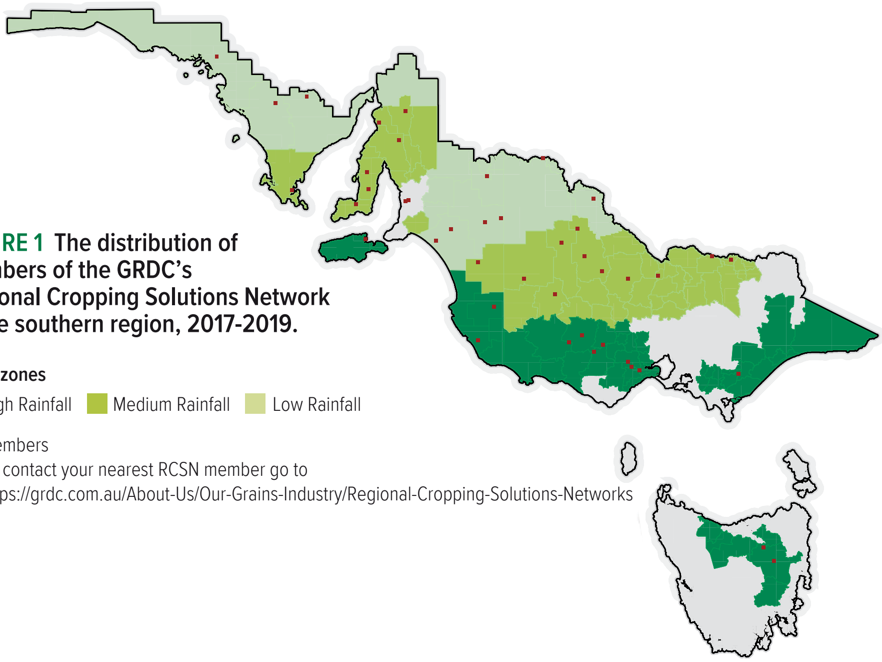

FIGURE 1 The distribution of members of the GRDC's Regional Cropping Solutions Network in the southern region, 2017-2019.

RCSN zones

High Rainfall · Medium Rainfall · Low Rainfall

Members

To contact your nearest RCSN member go to https://grdc.com.au/About-Us/Our-Grains-Industry/Regional-Cropping-Solutions-Networks

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- The local GRDC Grains Research Update planning committee that includes both government and private consultants and GRDC representatives.

- Partnering organisation: SFS

GRDC
GRAINS RESEARCH
& DEVELOPMENT
CORPORATION

Prefer to provide your feedback electronically or ‘as you go’? The electronic evaluation form can be accessed by typing the URL address below into your internet browsers:

www.surveymonkey.com/r/Derrinallum-GRU

To make the process as easy as possible, please follow these points:

- Complete the survey on one device
- One person per device
- You can start and stop the survey whenever you choose, **just click ‘Next’ to save responses before exiting the survey**. For example, after a session you can complete the relevant questions and then re-access the survey following other sessions.

2019 Derrinallum GRDC Grains Research Update Evaluation

1. Name

ORM has permisssion to follow me up in regards to post event outcomes.

2. How would you describe your main role? *(choose one only)*

- ❑ Grower
- ❑ Agronomic adviser
- ❑ Farm business adviser
- ❑ Financial adviser
- ❑ Communications/extension
- ❑ Grain marketing
- ❑ Farm input/service provider
- ❑ Banking
- ❑ Accountant
- ❑ Researcher
- ❑ Student
- ❑ Other* (please specify)

Your feedback on the presentations

For each presentation you attended, please rate the content relevance and presentation quality on a scale of 0 to 10 by placing a number in the box (**10 = totally satisfactory, 0 = totally unsatisfactory**).

3. Improving the establishment of canola – what factors matter most: *Col McMaster*

Content relevance /10 Presentation quality /10

Have you got any comments on the content or quality of the presentation?

4. Super high oleic oil safflower: *David Hudson*

Content relevance /10 Presentation quality /10

Have you got any comments on the content or quality of the presentation?

5. Harvest weed seed control: *James Manson*

Content relevance /10 Presentation quality /10

Have you got any comments on the content or quality of the presentation?

6. Focus on earwigs: *Matthew Binns*

Content relevance /10 Presentation quality /10

Have you got any comments on the content or quality of the presentation?

7. ‘Strip & disc’ farming – a grower’s experience: *Ted Langley*

Content relevance [ ] /10 Presentation quality [ ] /10

Have you got any comments on the content or quality of the presentation?

Your next steps

8. Please describe at least one new strategy you will undertake as a result of attending this Update event

9. What are the first steps you will take?

e.g. seek further information from a presenter, consider a new resource, talk to my network, start a trial in my business

Your feedback on the Update

10. This Update has increased my awareness and knowledge of the latest in grains research

Strongly agree	Agree	Neither agree nor Disagree	Disagree	Strongly disagree
❑	❑	❑	❑	❑

11. Overall, how did the Update event meet your expectations?

Very much exceeded	Exceeded	Met	Partially met	Did not meet
❑	❑	❑	❑	❑

Comments

12. Do you have any comments or suggestions to improve the GRDC Update events?

13. Are there any subjects you would like covered in the next Update?

Thank you for your feedback.