GRAINS RESEARCH UPDATE

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Griffith

Tuesday 13th August

9.00am to 1.00pm

Exies Bagtown Function Centre,

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Griffith GRDC Grains Research Update
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- 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***
9:10 am	**Super high oleic oil safflower – what is the fit for irrigation?**	***Rosemary Richards,*** *GO Resources Pty Ltd*
9:50 am	**Ameliorating sodic subsoil constraints under irrigation**	***Ehsan Tavakkoli,*** *NSW DPI*
10:30 am	***Morning tea***	
11.00 am	**Your seasonal climate update**	***Dale Grey,*** *Agriculture Victoria*
11:40 am	**Time of sowing impacts on lentil and chickpea performance**	***Tony Napier,*** *NSW DPI*
12.20 pm	**Managing those hard to kill weeds**	***Chris Preston,*** *University of Adelaide*
1.05 pm	***Close and evaluation***	***Brett Symes,*** *ORM*
1.10 pm	***Lunch***	

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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).

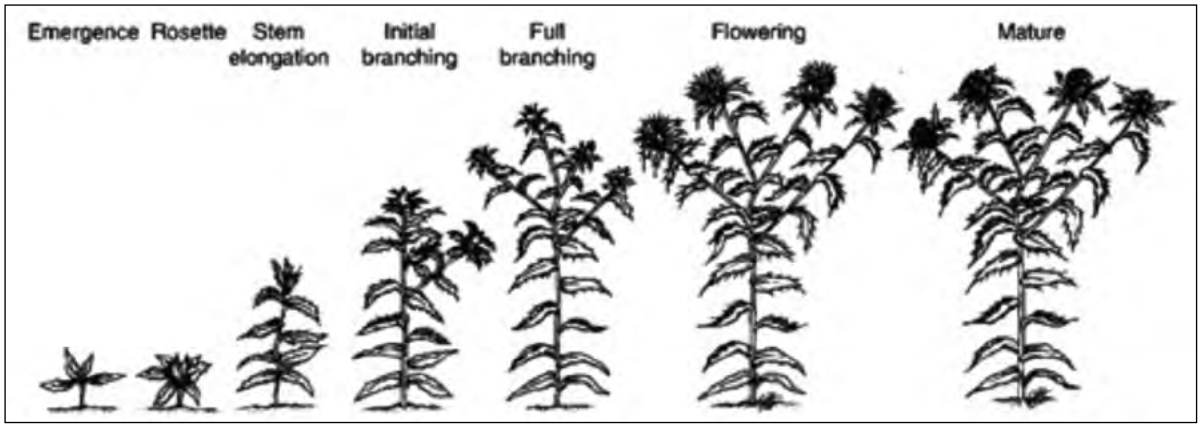

Figure 1. The development of a safflower plant (Source: Kaffka and Kearney, 1998).

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,

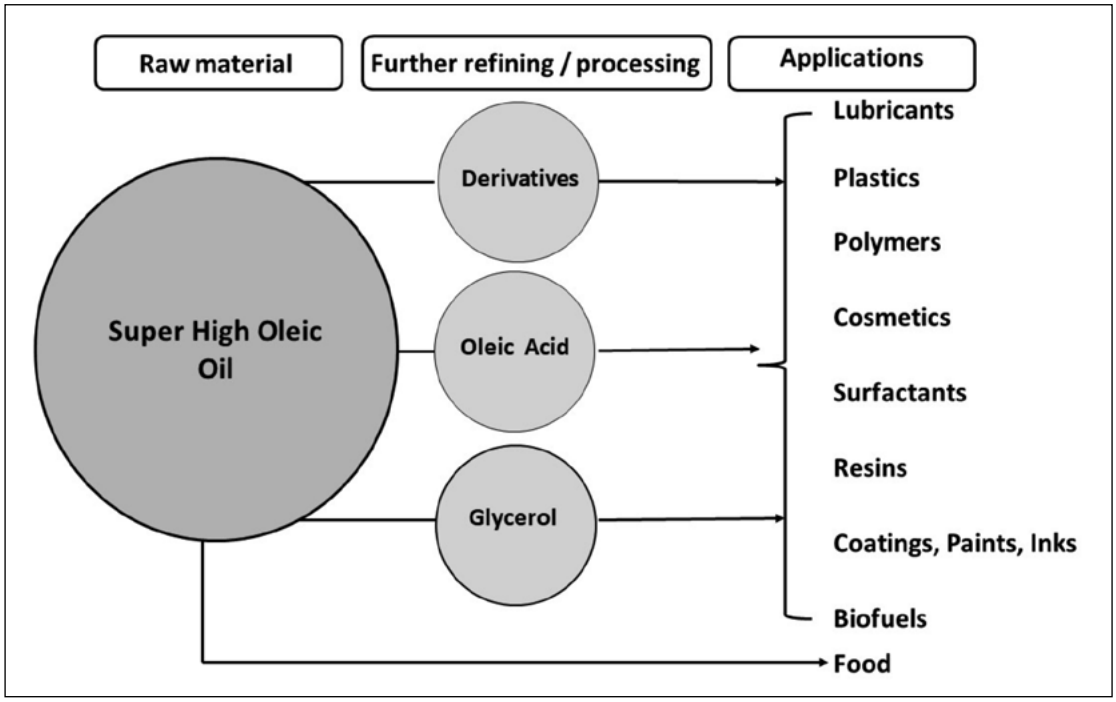

Figure 2. Market opportunities for super high oleic safflower oil.

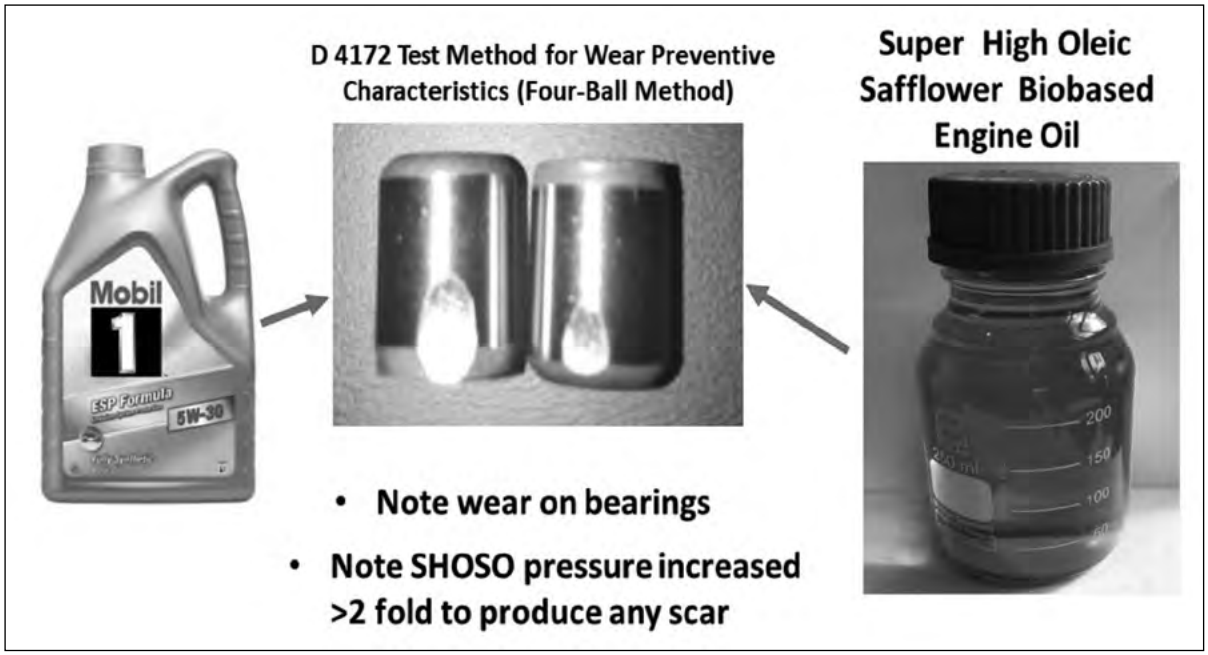

Figure 3. Reduced friction over conventional oils (Source: Montana State University Advanced Fuels Centre. June 2019).

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).

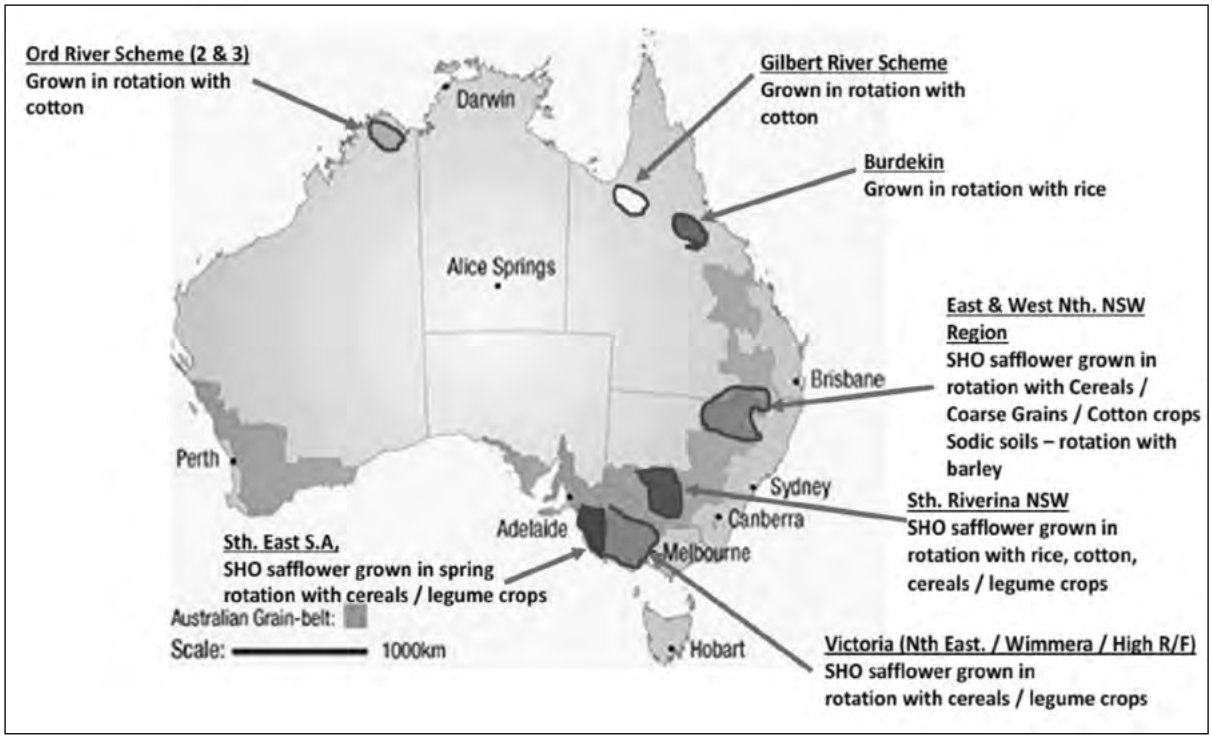

Figure 4. Safflower production locations in Australia.

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.

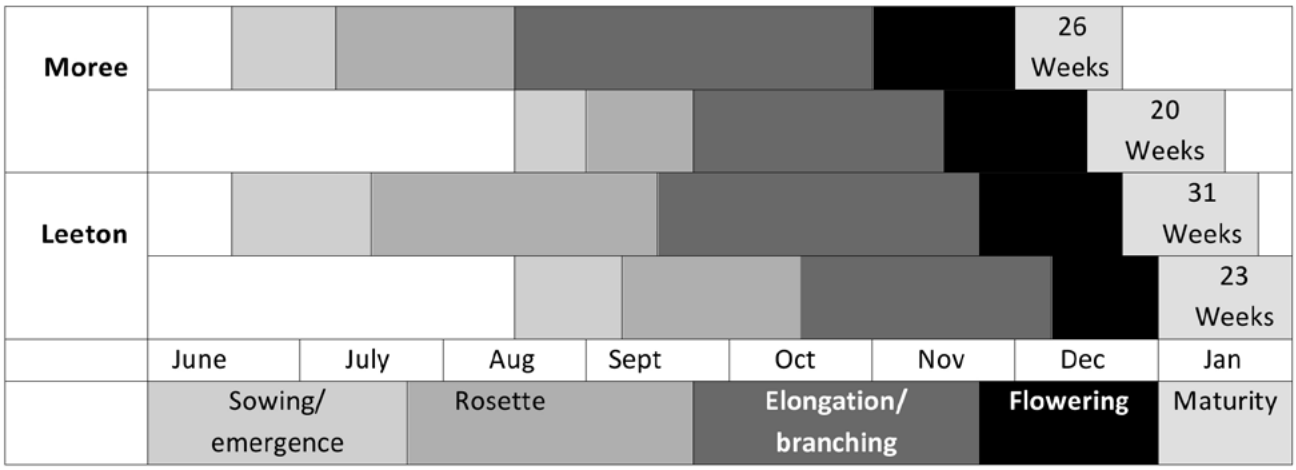

Figure 5. Effect of sowing in mid-June and mid-August on safflower development at Moree and Leeton in NSW (Source: Adapted from Colton, 1988).

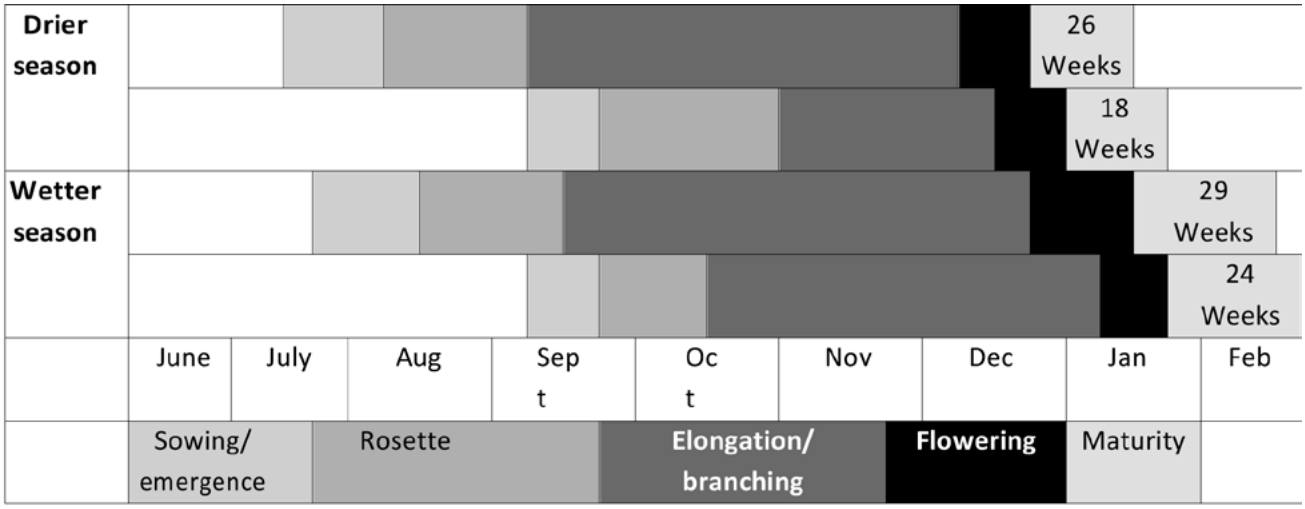

Figure 6. Effect of sowing in mid-July and mid-September on safflower development in a wetter and drier season at the same location in the Victorian Wimmera (Source: Adapted from Colton, 1988).

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 cartharmi*), 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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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.

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Understanding the amelioration processes of the subsoil application of amendments

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GRDC project code: DAV00149

Keywords

- soil constraints, sodic soils, amendments, amelioration.

Take home messages

- The early results of this project showed great potential in improving soil structure and crop productivity in sodic subsoils using deep placement of organic and inorganic amendments. The increases resulted from improvement in the physical and chemical properties of the clay soil volume around the rip line containing the organic and inorganic amendments, and from increased root growth through the subsurface soil layers adjacent to the rip lines. This improvement was possibly mediated by increased microbial activity that leads to improved soil aggregation.
- In both years of the field experiment, the greatest yield response was achieved in the pea hay + gypsum + nutrients treatment. Given multiple subsoil constraints including high pH, sodicity and poor soil structure that exist in south-east Australia, an amendment with multiple modes of action is required to improve hostile subsoils.
- It is proposed that a reduction in net dispersive charge and pH together with an enhanced microbial biomass carbon (C) resulted in improved soil aggregation. The changes in soil chemicophysical properties correlated with higher crop water uptake from the ameliorated layer.

Background

Approximately 75% of Australian soils have subsoil constraints that limit agricultural productivity. The major constraints to crop growth are poorly structured subsoils that result from high clay content and bulk density, as well as the presence of high subsoil exchangeable sodium (Na) concentrations (resulting in soils with poor subsoil structure, impeded drainage, waterlogging, and high soil strength). These constraints adversely affect soil water and plant available water content (PAWC) by impeding water entry into the soil, restricting water movement within the soil, reducing the soil's ability to store water and nutrients, and reducing the ability of plants to access and extract stored water and nutrients. Soil constraints may be multiple or singular, occurring either near the soil surface, or in the subsoil and they tend to be highly variable across any given paddock or property (McDonald et al. 2013).

A range of practices including deep ripping, subsoil manuring, clay incorporation, applying gypsum, installing underground drainage or use of 'primer-crops' have been tested to overcome

subsoil constraints, usually with unreliable results and often potential financial losses to growers (Gill et al. 2008). For example, despite the fact that gypsum is widely used as the main soil amendment in improving poor structure of sodic soils, it is a sparingly soluble salt and because of this attribute it is hardly possible to deliver adequate calcium (Ca) to correct sodicity issues in the subsoil. In regards to subsoil manuring, despite the demonstrated step change in crop yields that can be achieved by this management strategy, practice change in the grains industry to date has been limited. One constraint to widespread adoption includes the local availability and high cost of suitable organic ameliorants delivered in-paddock. This factor can be significant as research to date in the higher rainfall zones suggests rates of up to 20t/ha are required — transport costs quickly become prohibitive if this material needs to be sourced off-farm (Gill et al. 2008; Sale et al. 2019). Therefore, solutions integrating complementary sources of organic matter materials, such as crop residue and cover crop biomass produced in-situ, need to be investigated, with current project DAV00149 initiating this new area of research.

A series of field and glasshouse experiments was established to understand the amelioration process when various organic and inorganic amendments are placed at depth in dispersive subsoils. This paper will provide results of a GRDC project (DAV00149) aiming to ameliorate subsoil constraints and to understand the amelioration processes of the subsoil application of amendments. It will show how deep incorporation of organic amendments into the clay subsoil provided significant improvements in grain yield, which was associated with changes in subsoil properties and improved root growth.

Method

Field trial

The two-year field experiment was established on a farm in Rand, southern NSW, in February 2017. The site was located in a paddock that had been cropped with a cereal-canola rotation for more than 50 years. Selected soil properties collected from the untreated soil are presented in Table 1. The soil is a Sodosol (Isbell, 2002), with a texture-contrast profile increasing in clay content at depth. The physical and chemical properties indicate that the subsoil condition was unfavourable for root growth. The high clay content in this subsoil layer has a bulk density of 1.55g/cm3 that restricts water movement, and consequently the saturated hydraulic conductivity value is low at 0.03cm/hr (Table 1).

The experimental plots were 2.5m wide and 20m long. There were 14 treatments comprising 1) the control, 2) surface application of gypsum, 3) surface application of chicken manure, 4) surface application of pea hay, 5) deep ripping, 6) deep placement of gypsum, 7) deep placement of manure, 8) deep placement of wheat stubble, 9) deep placement of wheat stubble + nutrients, 10) deep placement of pea hay, 11) deep placement of biochar, 12) deep placement of pea hay + nutrients, 13) deep placement of liquid nutrients, and 14) deep placement of pea hay + gypsum + nutrients. The experiment was a randomised complete block design with four replicates. Ripping and subsoil incorporation treatments were carried out with a 3-D ripping machine (NSW DPI). The machine can deliver inorganic and/or organic amendments at two depths from 10cm to 30cm. The machine is also capable of delivering liquid nutrients/fertilisers at depth. The experiment at Rand was sown to barley (cv. La Trobe(ɬ)) on 18 May 2017 and wheat (cv. Lancer(ɬ)) on 15 May 2018.

A Geonics EM38® instrument in vertical dipole mode was used to measure the apparent electrical conductivity (EC_a) of the soil. Based on the map of EC_a, the most uniform area of each field was selected for the experiments. The experiment was direct sown using DBS tynes spaced at 250mm. At sowing, 80kg monoammonium phosphate (MAP) (18kgphosphorus (P)/ha and 8kg nitrogen (N)/ha) was added to all plots. Pre-crop weed control was undertaken by applying Roundup® at 1.5L/ha, as well as the pre-emergents Sakura® (pyroxasulfone 850g/L) at 118g/ha and Logran® (triasulfuron 750g/L) at 35g/ha, and was incorporated at sowing. Precautionary disease control was implemented, seed was treated with Hombre ®Ultra imidacloprid (360g/L) and tebuconazole (12.5g/L)] at 200mLs/100kg and Prosaro® (prothioconazole 210g/L and tebuconazole 210g/L) was applied at 300mL/ha at DC 31. The experiment was harvested on 1 December. Grain protein and seed quality were estimated using near infrared (NIR) (Foss Infratec 1241 Grain Analyzer) and seed imaging (SeedCount SC5000R), respectively. At anthesis, about 50 youngest fully mature leaves (YML) were obtained randomly from each replicate plot of each genotype and then dried at 70°C for 48 hours. Dried plant samples were digested in an acid mixture of nitric and perchloric acid and concentrations of ions were measured on inductively coupled plasma (ICP).

Incubation experiment

To provide further insights into the dynamics of C mineralisation and the interactive effects of organic

amendments and gypsum, a laboratory based incubation experiment was conducted. The soil (450g air-dried soil, equivalent to 430g oven-dried soil) was uniformly mixed with organic amendments (i.e. crop stubble) at an application rate of 6.2g C/kg soil with or without gypsum ($CaSO_4 \cdot 2H_2O$) of 7.2g/kg soil or nutrients. The soils were incubated for 90 days and the changes in soil pH, exchangeable Na%, microbial biomass C and aggregate stability were then measured.

Results and discussion

Soil constraints and weather

The depth-wise distribution of physicochemical soil constraints are shown in Figure 1. The profile is characterised by the soil pH ranges from 5.1-9.1 with increasing sodicity (ESP up to 30%) with depth. A dispersion test was performed on several aggregates and indicated significant dispersion in subsoil increasing with depth (Figure 1). A considerable amount of soil water below 60cm was found after harvest which suggests limitations to root growth reduced the ability of the crop to access subsoil water (Rengasamy et al. 2016).

The growing season rainfall in 2017 and 2018 was 329mm and 225mm, respectively. In 2017, rainfall during the April to November growing season was 62.5mm less than the long term average, whereas in 2018, it was 178mm less than the average rainfall. The average rainfall in 2018 was about 40% lower than 2017 (Figure 2).

Yield response to different amendments

This experiment established in 2017 showed consistent, significant ($P<0.05$) effects of amendment

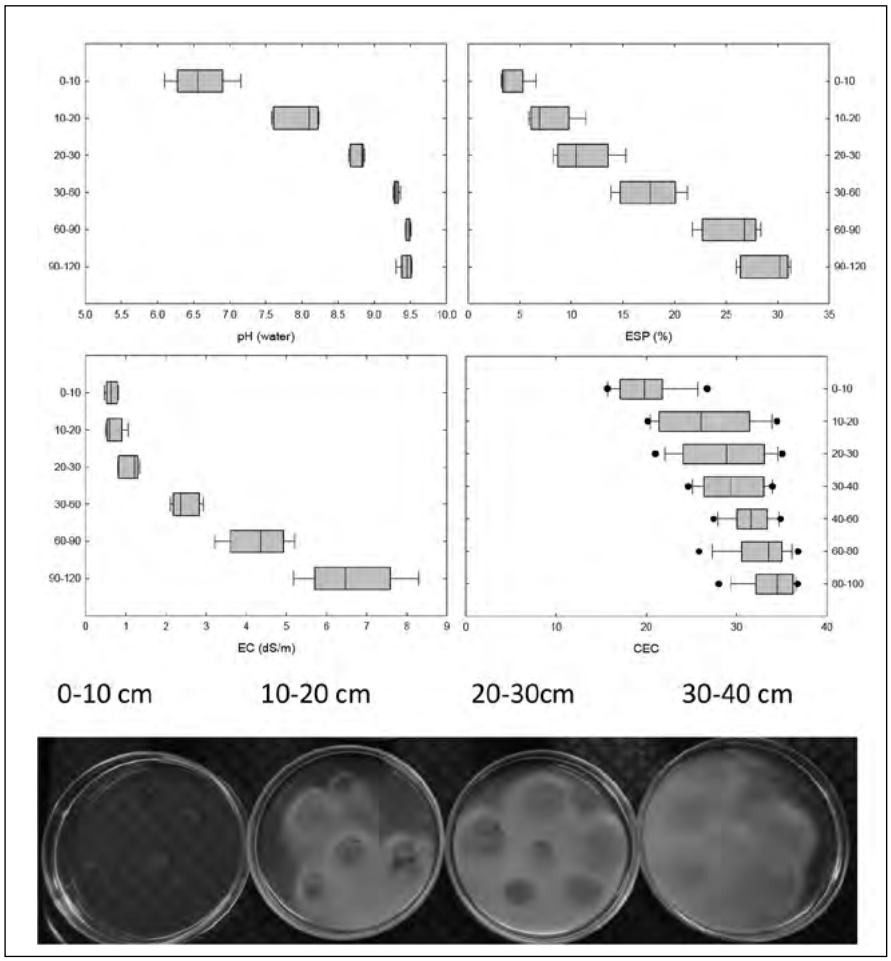

Figure 1. Soil characteristics of sodic site in Rand (southern NSW). Various lines indicate multiple locations across the trial. The picture shows the assessment of soil dispersion at four different depths. The increasing levels of exchangeable Na relative to calcium (Ca) and/or magnesium (Mg) in subsoil result in a decrease in soil structural stability and higher dispersion as shown above. When dispersion occurs, the dispersed clay particles fill up the pores between soil particles and aggregates, and when the soil dries out, the dispersed clay blocks soil pores. This can restrict seedling emergence, water and air movement, and root penetration. Dispersed soils are generally hard-setting and may form a surface crust or concrete-like lump which can also result in waterlogging.

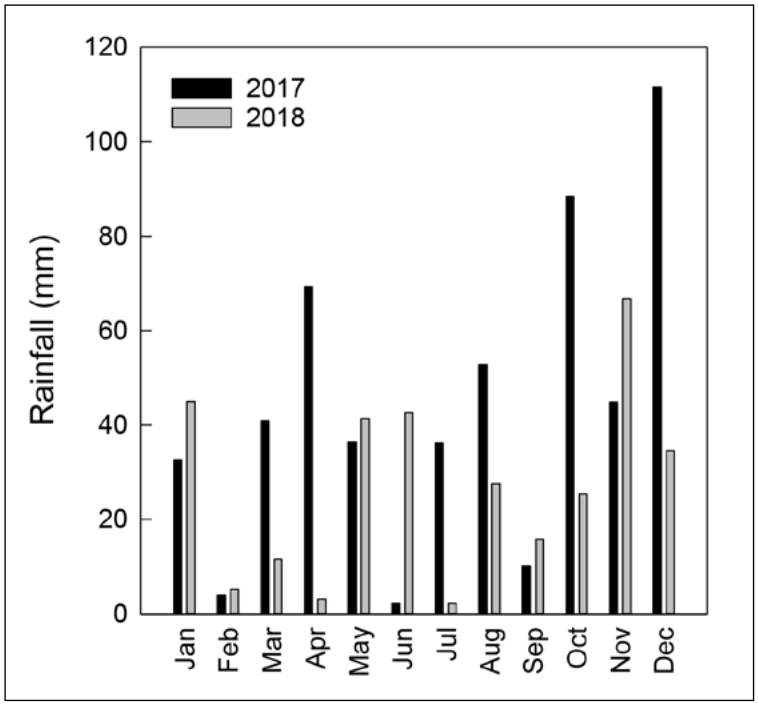

Figure 2. Mean monthly rainfall (histogram) and mean monthly air temperatures at the experimental site (Rand) in southern NSW in 2017 and 2018.

on grain yield in two consecutive years (Figures 3 and 4). In 2017, each plot with deep placement of amendments was harvested in two locations. These were on the amended rip line and off the amended rip line. This approach was undertaken based on the field observations of differential responses between crop rows on and off rip lines. While there was no significant difference (P>0.05) between the control and yield response off the amended rip line, a marked positive response was achieved for crop harvested on the amended rip line. Compared with the control treatment, the highest increase (P<0.05) in grain yield was observed for deep placement of pea hay + gypsum + nutrient (27%), followed by deep placement of manure (22%) and pea hay (20%). As a main effect, rip only, surface gypsum and surface pea hay treatments yielded 6%, 10% and 13% less than control treatments (Figure 3).

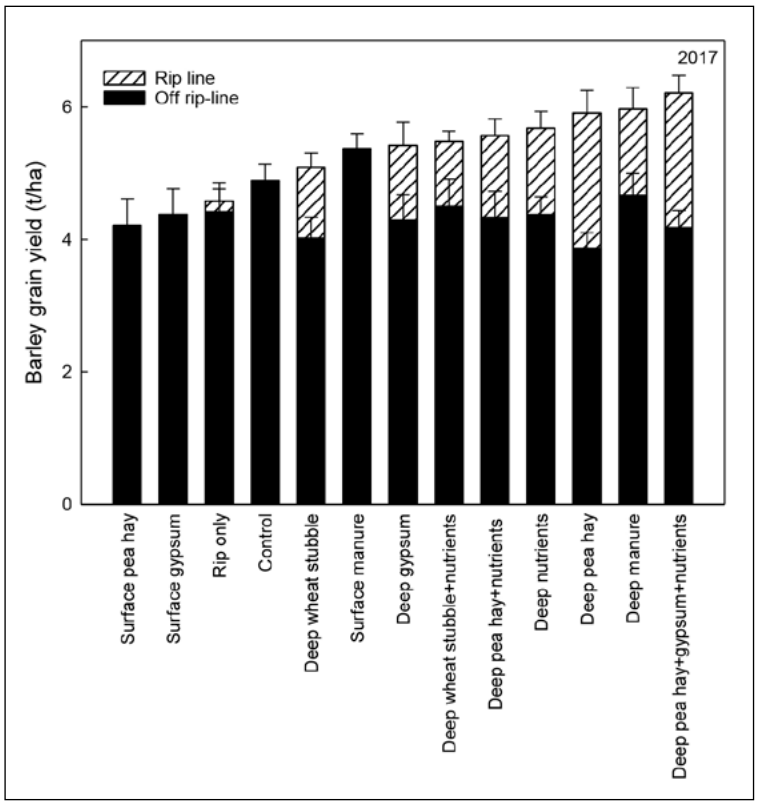

Figure 3. The effects of surface or deep placed amendments on grain yield of La Trobe(l) barley in 2017 at Rand, southern NSW. Plots with deep placement treatments were harvested on amended rip lines (dashed bars, on rip line) and off unamended rip lines (black bars, off-rip line). Values are averages (n = 4).

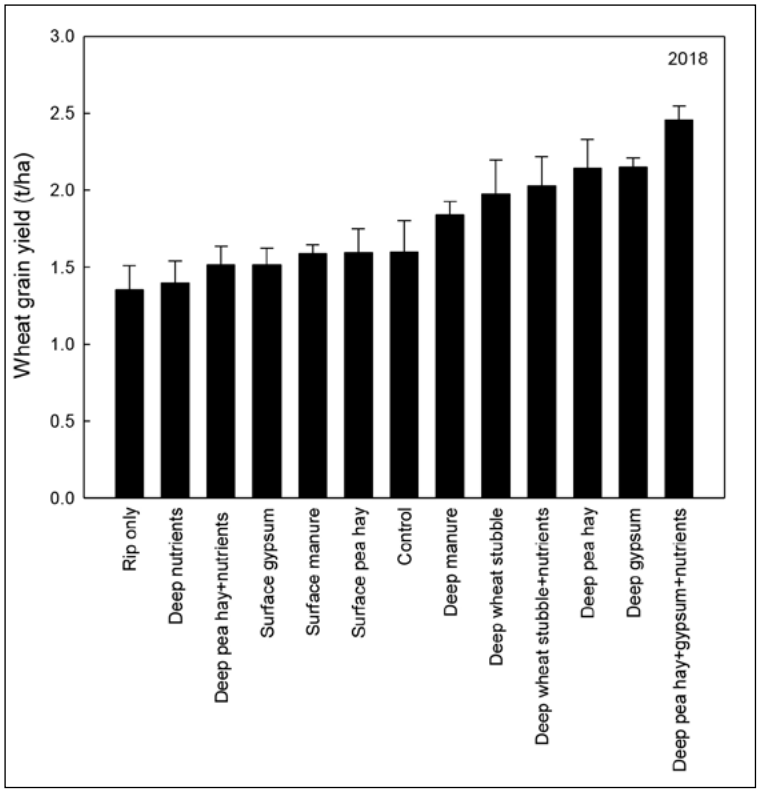

Figure 4. The effects of surface or deep placed amendments on grain yield (whole plot) of Lancer(l) wheat in 2018 at Rand, southern NSW. Values are averages (n = 4).

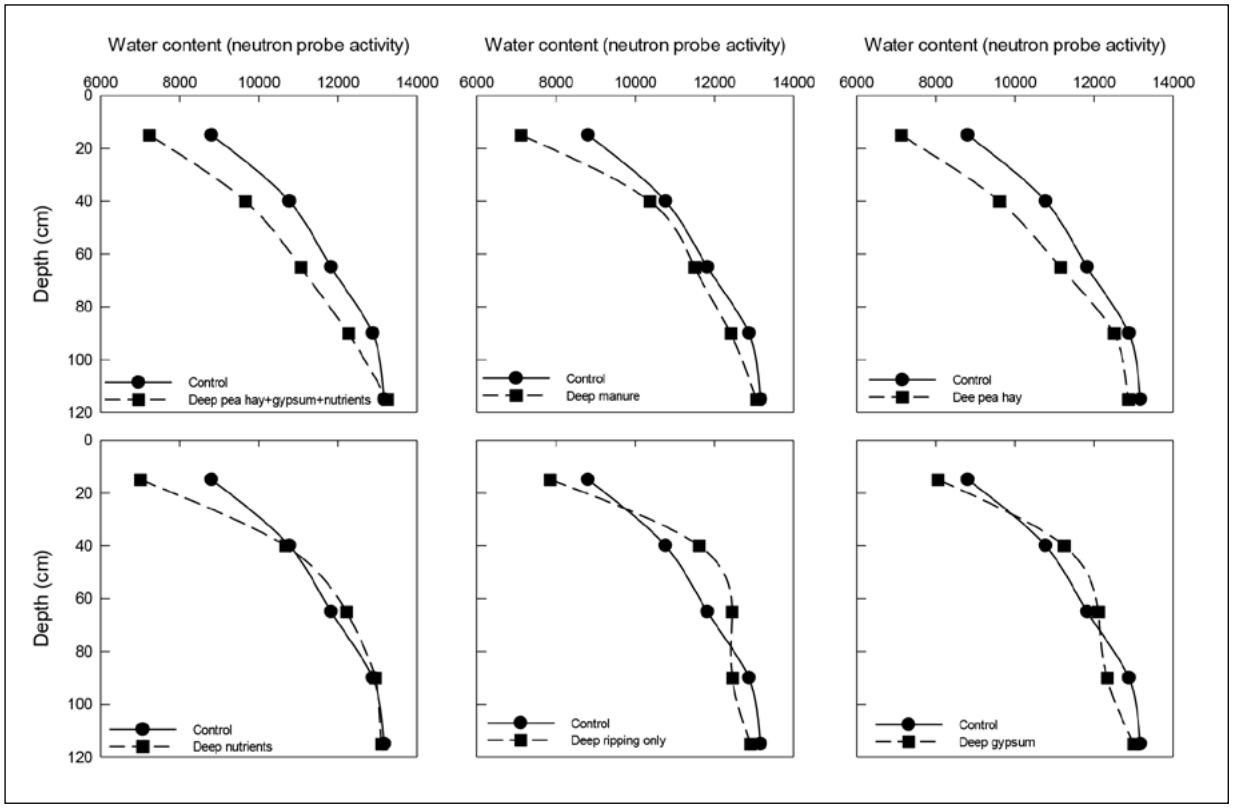

Figure 5. The changes in soil water content in various treatments compared with the control at the Rand site in 2018. Results are based on the neutron activity (raw data), where higher values represent higher water content in the soil profile. Values are averages (n = 4).

Table 1. The changes in soil exchangeable sodium percentage (ESP) and soil pH in selected treatments at the Rand site. Samples were collected in May 2018 pre-sowing. Values are means

	Control	Deep gypsum	Deep nutrients	Deep manure	Deep pea hay	Deep pea+ gyp+ nutrients	rip only
ESP (%)							
0-10	5.89	7.00	6.43	7.89	6.09	5.13	7.23
10-20	8.47	8.18	9.11	11.41	8.33	6.01	9.69
20-30	13.35	11.70	12.59	16.24	12.91	9.68	14.09
pH (1:5 water)							
0-10	6.61	6.96	7.04	6.37	6.87	6.89	6.86
10-20	7.98	7.77	7.99	7.66	7.76	7.69	7.91
20-30	8.99	8.13	8.96	8.60	8.87	8.38	8.94

In the 2018 season, wheat grain yield significantly (P<0.05) increased 27%-53% (compared with the control) following amendment application in 2017 (Figure 4). The highest increase was observed for deep placement of pea hay + gypsum + nutrient treatment (53%), followed by deep placement of gypsum (34%), pea hay (34%) and deep wheat stubble + nutrients (27%). As a main effect, surface pea hay, surface manure, surface gypsum, deep pea hay + nutrients, deep nutrients and rip only treatments yielded 0.1%-15% less than the control. These differences were not significant (P>0.05).

The volumetric water content in the soil declined in all layers of the profile as the wheat crop matured some 200 days after sowing (2018 growing season). A number of variations in the pattern of the decline in soil water were observed in different subsoil amelioration treatments. The most notable result occurred with the deep pea hay + gypsum + nutrients treatment followed by deep manure and deep pea hay, where there was a marked drying of the ameliorated layers as the crop matured (Figure 5). The effect was observed in the 40cm-60cm (amended layer). The neutron probe values in this layer were significantly lower (P<0.05) for the organic amendment treatments at crop maturity than for all other treatments including the control, the deep ripped, deep nutrients and the deep gypsum treatments (Figure 5).

Table 1 shows the effect of various amendments on soil ESP and pH at three depths. The deep placement of amendments at a depth of 15-40cm had a marked impact on the physicochemical properties in the subsoil layers. The 20-30cm deep subsoil layer in the control treatment had a pH of 9 and ESP of 13.4%. Deep placement of gypsum, pea hay + gypsum + nutrients and deep manure reduced the soil pH by 0.86, 0.61 and 0.39 unit, respectively (P<0.05). Compared with the control, the deep placement of gypsum and pea hay + gypsum + nutrients treatments also reduced the ESPby 12% and 27%.

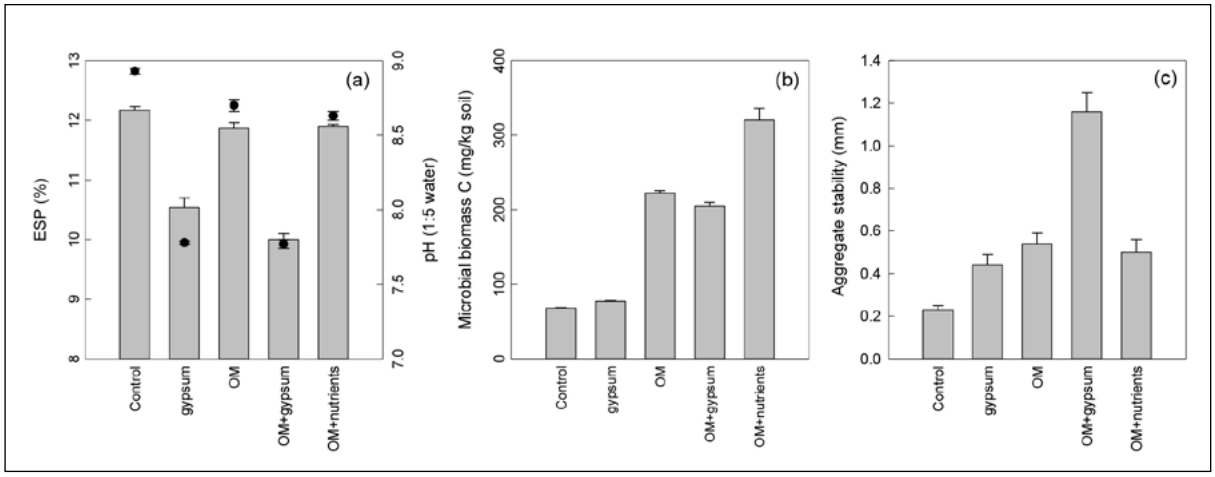

Figure 6. The effect of gypsum, OM, OM + gypsum and OM + nutrients on (a) soil ESP (bars) and pH (●), (b) microbial biomass C (mg/kg soil) and (c) aggregate stability (mm) over the 90-day incubation period. Error bars represent ± standard errors of the mean (n = 4).

To further explore the changes that organic amendments have on subsoil physical and chemical properties, primarily the effects on water-stable aggregates, an incubation experiment was conducted to investigate how the physical condition of the sodic clay soil may benefit from the addition of organic amendments that are able to benefit biological activity in the soil. Figure 6 shows the effects of gypsum, organic matter (crop stubble), organic matter + gypsum and organic matter + nutrients after an incubation of 90 days on the formation of water-stable aggregates. Similar to data from field trials, gypsum had a significant effect ($P<0.05$) on reducing soil pH (1.15 unit) and ESP (13%-17%) compared with the control. The addition of organic matter with or without nutrients had no influence on soil pH or ESP. However, the input of organic matter and organic matter + nutrient increased total microbial biomass C by 3-fold and 4.7-fold, respectively ($P<0.05$). Combined application of organic matter (OM) and gypsum had the greatest influence on the proportion of stable aggregates in the poorly structured sodic alkaline subsoil used in this study. While separate application of gypsum and OM increased the aggregate stability, the much greater improvement in soil aggregation in OM + gypsum treatment suggests that their co-application has an additive and/or interactive effect.

Discussion

This study provides early but significant indications that soil amelioration of alkaline-sodic subsoils with organic and inorganic amendments can provide significant grain yield increases that are associated with both improved soil chemicophysical properties and water use.

The extent of the changes in soil chemical and physical properties in the 15cm-40cm layers of this alkaline sodic soil, with the deep incorporation of organic and inorganic amendments, was remarkable. The changes occurred over the 14-month period between the incorporation of the amendments in late February 2017, and the taking of soil samples in May 2018. The key changes were a reduction in subsoil pH and ESP (Table 1) and an increase in soil porosity (data not shown) and higher water uptake by the crop (Figure 5). While the soil analysis is still in progress, it is suggested that this is resulted from improved soil aggregation, as incubation studies using this clay subsoil and similar organic amendments, led to a rapid improved aggregation in the clay matrix over three months (Figure 6).

The results demonstrated that amelioration of multiple soil constraints (high pH, sodicity and poorly structured aggregates) requires amendments and strategies with various modes of action and independent mechanisms. The suggested improvement in subsoil aggregation with OM + gypsum and the resulting significant increases in grain yield in this study can be attributed to several causes. The first was that application of gypsum resulted in a reduction in pH of 0.86-1.15 unit (Table 1, Figure 5). Tavakkoli et al. (2015) showed that carbonate salts of Na and potassium (K) dominate above pH 8.5 of many sodic subsoils in south-east Australia and a reduction in pH below 8.5 can decrease the net dispersive charge and ESP by changing the speciation of carbonate salts (Rengasamy et al. 2016). The second reason for the suggested improvement in subsoil aggregation was that the organic amendments provide a substrate for greatly enhanced microbial activity in and around the rip lines. The incubation study discussed above also found that the addition of OM to alkaline sodic, clay subsoil increased microbial biomass C over the 90 day of incubation period which in turn led to rapid improvement in aggregation (Clark et al. 2007; Gill et al. 2008; Fang et al. 2018).

Conclusions

The findings from this study demonstrate early results for amelioration of alkaline sodic subsoils in southern NSW. Deep application of organic and inorganic amendments resulted in significant yield increases in 2017 and 2018. The increases resulted from the improvement in the chemical and physical properties of the subsoil around the rip line containing the organic and inorganic amendments. This improvement was mediated by a reduction in soil pH and ESP and an increased microbial activity that leads to improved soil aggregation. This led to considerable water extraction from the deeper clay layers.

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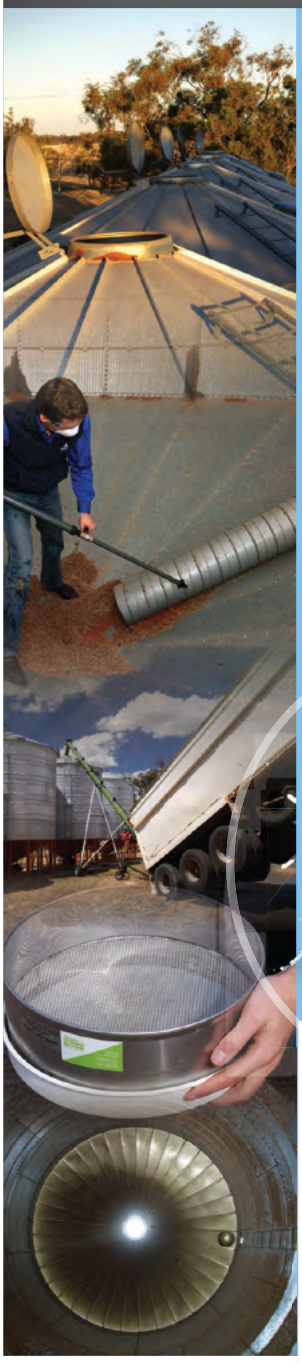

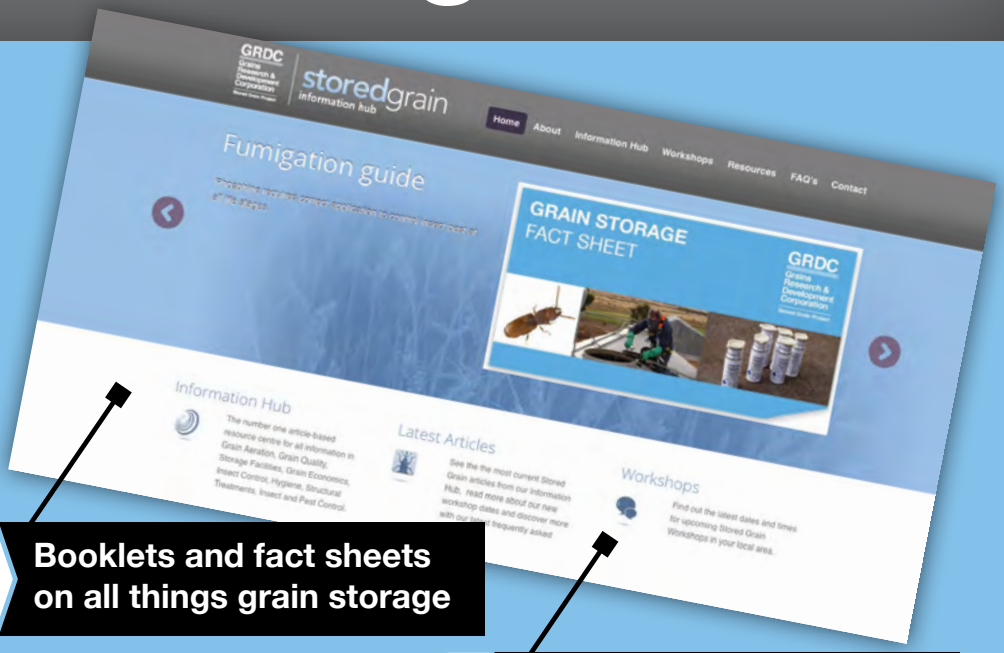

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The Indian Ocean Dipole revealed - Mitta Mitta, Goulburn and Murrumbidgee river areas

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Keywords

- climate forecasts, Indian Ocean Dipole, IOD..

Take home messages

- Like El Nino and La Nina, the Indian Ocean Dipole (IOD) is a major contributor to climate variability in south east (SE) Australia.
- The IOD is a coupled phenomenon where the ocean and the atmosphere feed off each other's behaviours.
- The IOD strongly effects the north west (NW) cloud band activity feeding in from over Broome.
- Positive IOD (+IOD) generally leads to drier winters and springs but there is the odd year that the opposite has happened.
- Negative IOD (-IOD) generally leads to wetter winters and springs but there is the odd year that the opposite has happened.

Introduction

The Indian Ocean Dipole (IOD) is a coupled ocean-atmosphere phenomenon that was first described in 1999 after Japanese and US researchers observed interesting things occurring in the Indian Ocean atmosphere and ocean during 1998. Research that ensued showed that the IOD is probably equally important as the El Nino Southern Oscillation (ENSO) as a climate driver for SE Australia.

Measurements of ocean temperatures go back with some reliability to 1877 to classify IOD events. Cores of large brain corals (used to characterise ocean behaviour), sampled off Indonesia give the ability to go back even further to about 400 years.

Like ENSO, small temperature changes in the order of +/- 1°C make large differences to the potential amount of evaporation off the oceans to Australia's north west. Fundamentally what the IOD does is cool these waters down in positive IOD (+IOD) events or warm the waters up in negative IOD (-IOD) events. Cooler water means less evaporation to our NW and consequently, not as much moisture to draw on down to Victoria. Warmer water means more evaporation and more moisture to draw on down to Victoria.

The IOD is measured in two 'boxes' of ocean marked out off the coast of Kenya and Somalia in Africa and off the coast of Sumatra in Indonesia. A +IOD is when the water is cooler than normal off the coast of Sumatra and warmer than normal off the coast of Africa. A -IOD is when the water is warmer than normal off the coast of Sumatra and cooler than normal off the coast of Africa. Often these changes in surface temperatures (like ENSO events) are linked with cooler or warmer water to depth in the ocean underneath these regions. Cooler water at depth if disturbed at the surface is likely to upwell cooler water at the surface and vice versa for warmer water to depth.

Like ENSO the trade winds play a major role in instigating IOD events. In the Indian Ocean the trade winds come from a westerly direction (the opposite direction as per what occurs in the Pacific Ocean). Accentuations to the trade winds can help incite -IOD events as they push warmer water towards Australia's NW and hold it there while they continue to blow stronger. Such bursts can occur with the Madden-Julian Oscillation. Disruptions to the trade

winds can occur via tropical disturbances such as cyclones in the Indonesian region, reversing the trade winds with easterlies and allowing cooler water to up-well. Large high-pressure systems over Australia can also reverse or weaken the trade winds in the Timor Sea and cause upwelling of cooler water.

Many +IOD events have been coupled with El Ninos and -IODs with La Ninas. This is because what occurs in the western Pacific Ocean with ENSO can affect the IOD eastern box, via water passing through the small gaps between the islands of Sumatra, Java and Bali. This is another way IOD events can be roused.

The other phenomena in the atmosphere is the cloud response to these changes in ocean temperatures (Figure 1). In a +IOD there is usually a large patch of less cloud above the cooler water at Sumatra and a corresponding increase in cloud off the coast of Africa. During a -IOD the warmer water to the NW of Australia causes an increase in cloud and a corresponding lack of cloud off Africa (Figure 2). The +IOD is a very good inhibitor of NW cloud band activity travelling from Broome to Victoria. The -IOD is a very good accentuator of NW cloud band activity (Figure 3).

The IOD phenomenon can be active within the months of May to October. Due to the relative shallowness of the Indian Ocean the northern wet season or monsoon prevents an IOD forming any earlier than April. The onset of the northern wet season usually in November disrupts any IOD pattern that has set up and it quickly decays.

Models have about a month's lead time where they can accurately predict the IOD. IODs can form in as little as one month due to the quick response of wind and ocean temperature in the Indian Ocean This is very different to ENSO in the Pacific, which happens over a much slower three-month period but has a much longer period of predictability.

In June 2019 we have seen the onset of a potential +IOD pattern. Large high-pressure systems over the Great Australian Bight stirred up easterly winds in the Timor Sea that resulted in cooler water upwelling and a move of these waters into the Java and Sumatran region. Much warmer water exists off the coast of Africa as well. The cloud patterns have quickly responded with less cloud off Sumatra and greater cloud off Africa. Large high-pressure systems, typical of +IOD are sitting over Victoria but at this stage have been far enough north to let some fronts through. Most models predict a +IOD

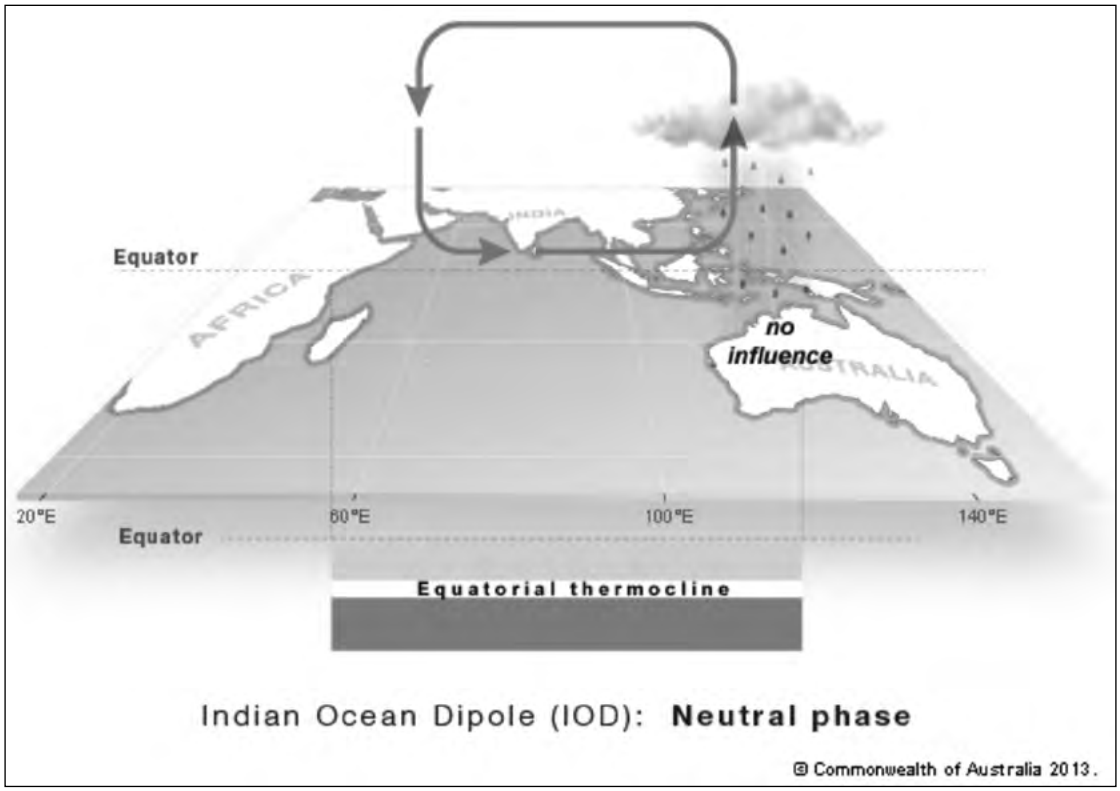

Figure 1. Normal wind and cloud patterns in the Indian Ocean.

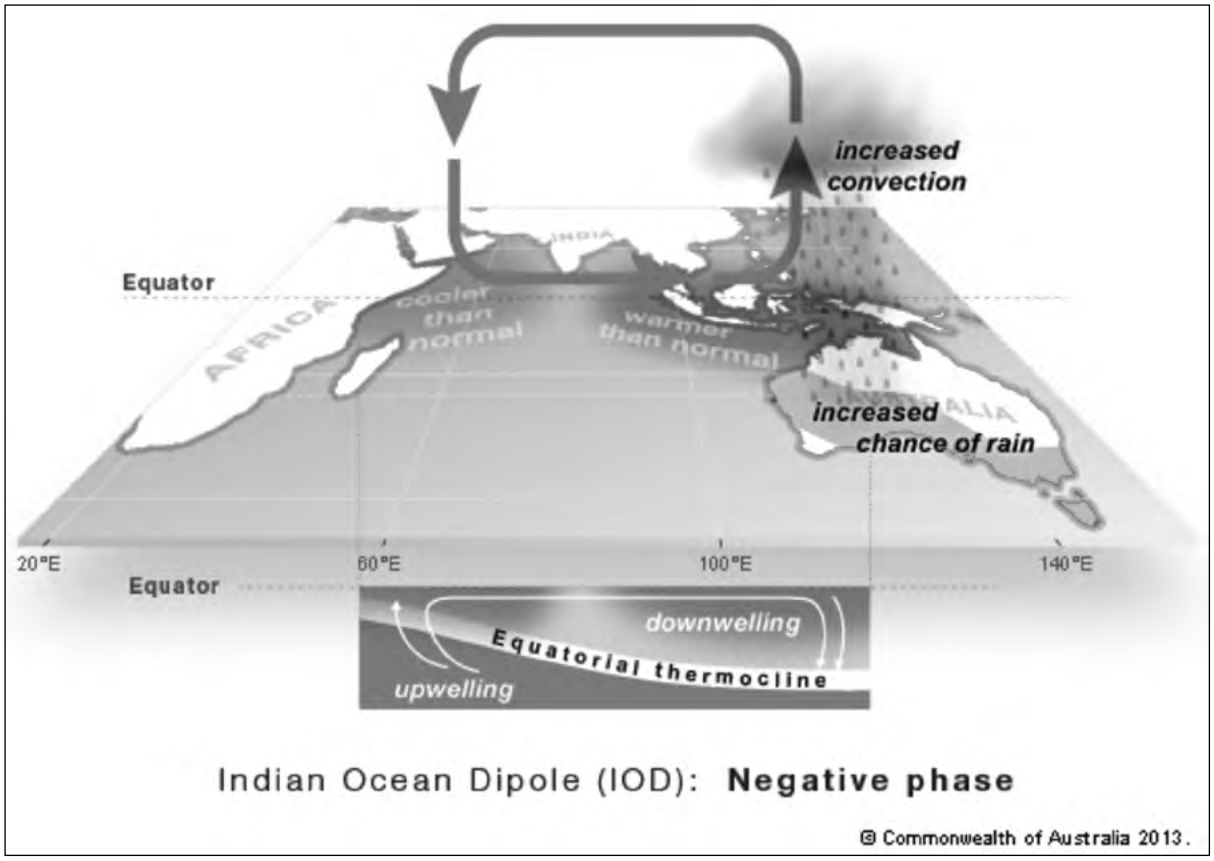

Figure 2. Wind, cloud and ocean temperatures in a negative IOD showing an enhanced Indian Ocean circulation.

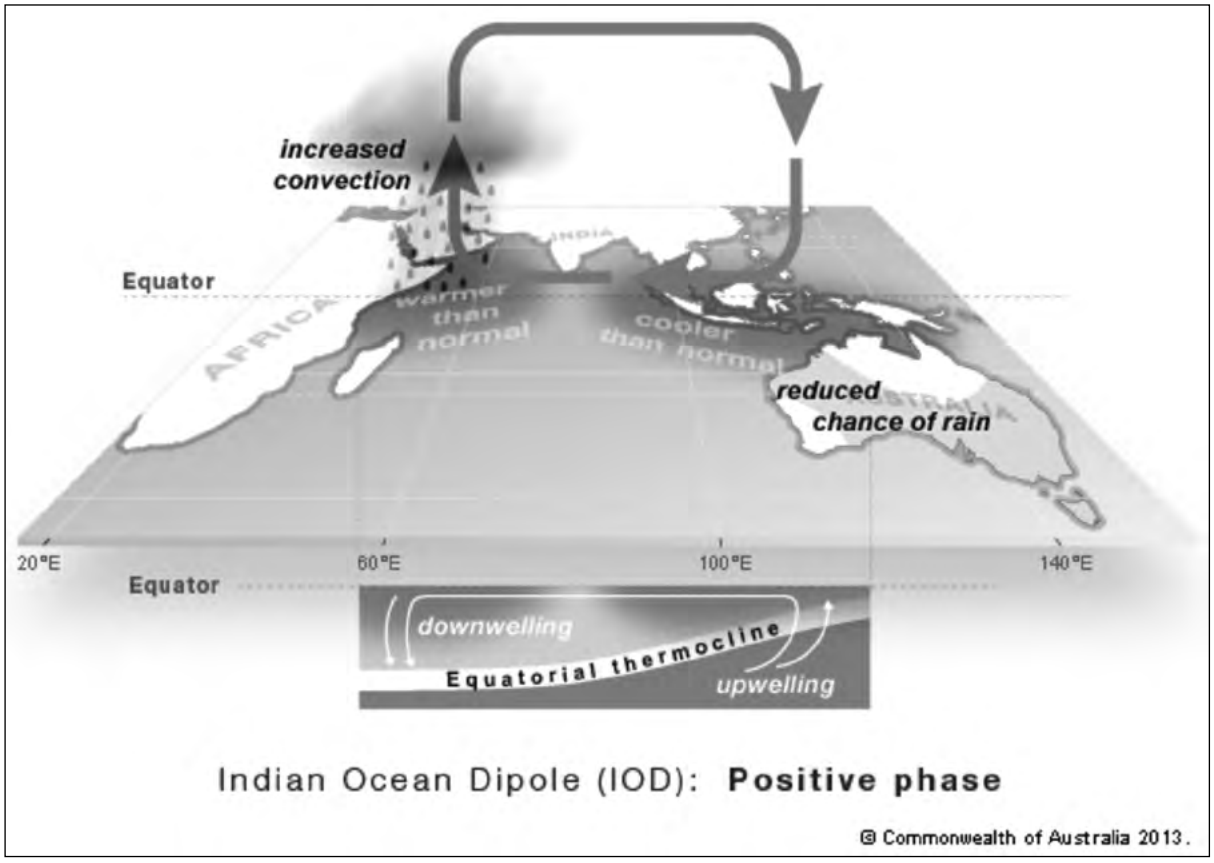

Figure 3. Wind, cloud and ocean temperatures in a positive IOD showing a reversed Indian Ocean circulation.

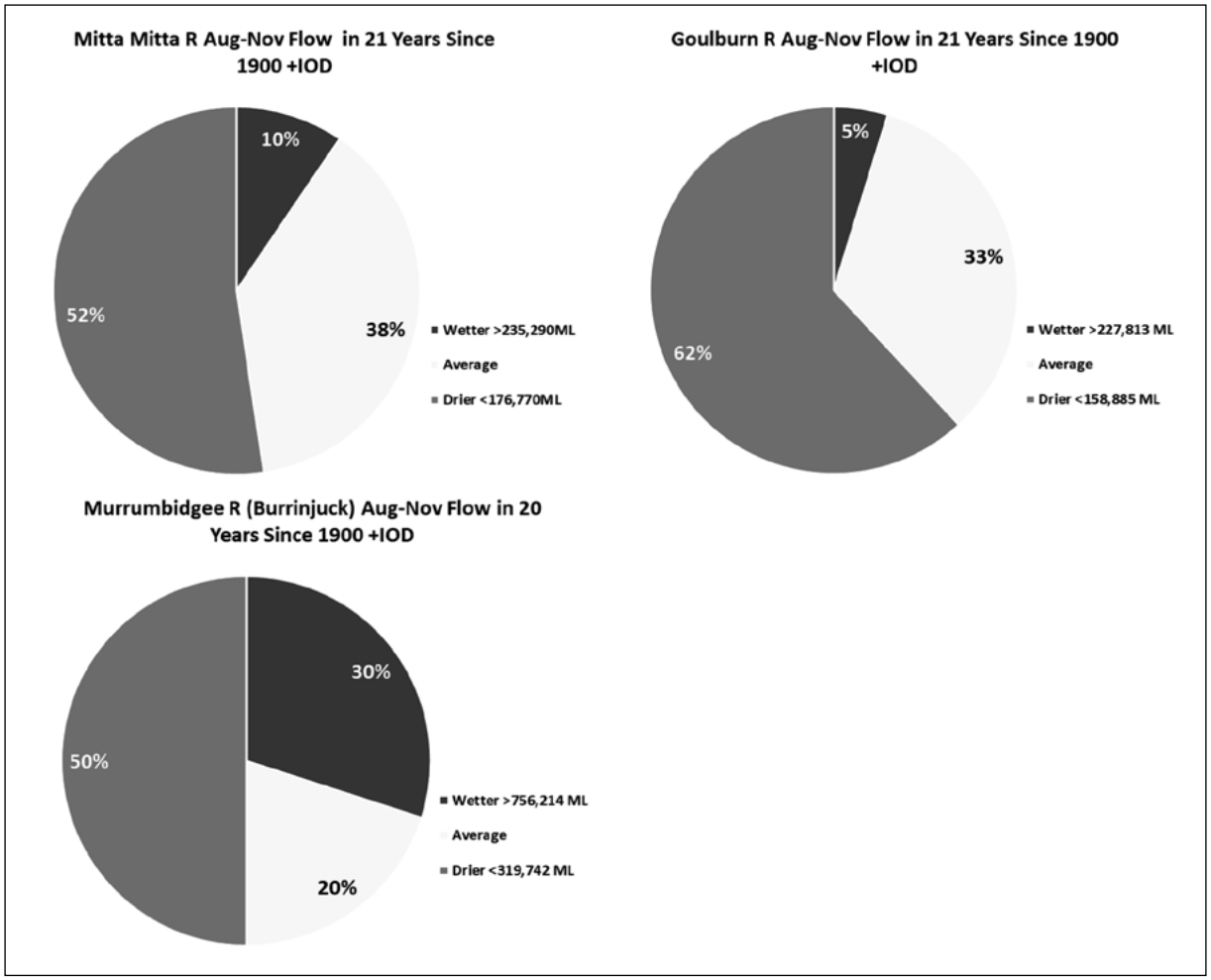

Figure 4. Chances of wetter, average and drier August – November river inflow in +IOD years.

to continue for the next three months and greater probability of lower rainfall. Things to take into consideration for planning in the coming months.

Historically on the Mitta Mitta, Goulburn and Murrumbidgee rivers, the past 21 +IOD events since 1900 have led to increased chances of lower rainfall in winter and spring (Figure 4). Greater than 50% of years have been drier inflow years, but only about 25% of all +IOD years have been terrible. Occasionally wetter or average years have occurred, however in recent times not many of these have occurred. We live in hope that 2019 may be one such year!

Useful resources

http://agriculture.vic.gov.au/agriculture/weather-and-climate/newsletters

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support.

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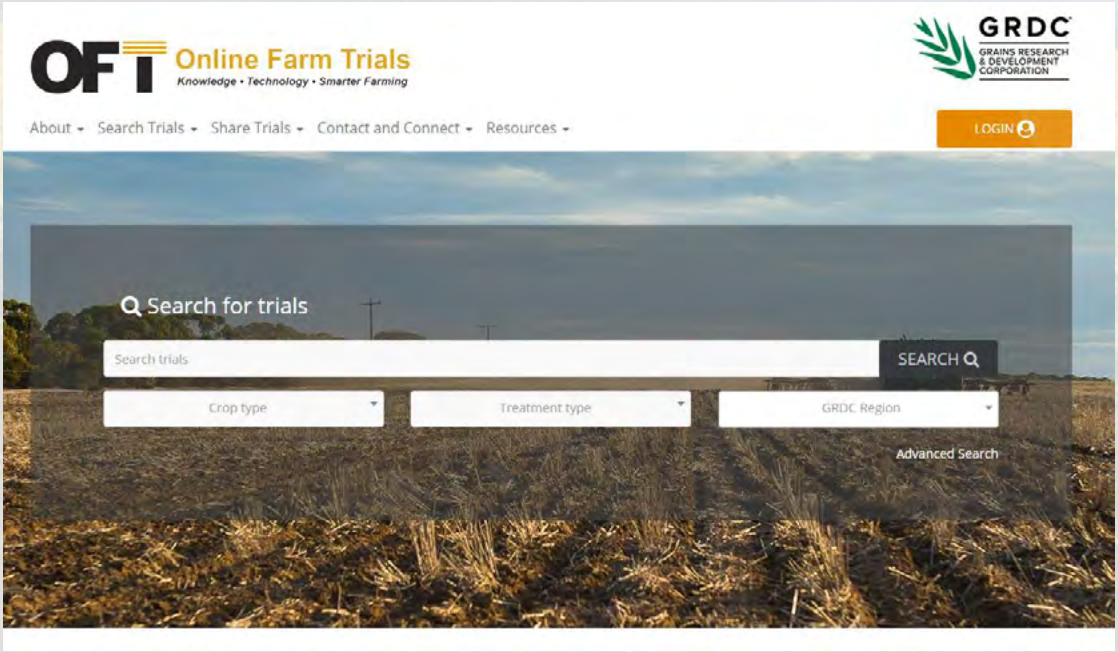

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Chickpea response to time of sowing – Riverina 2018

Tony Napier[1], Lance Maphosa[1], Mark Richards[2] and Daniel Johnston[1].

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GRDC project code: BLG 112

Keywords

- chickpea, phenology, sowing date, grain yield, total biomass, harvest index.

Take home messages

- The highest average grain yields were achieved with a late April to mid-May sowing date.
- There was an interaction between sowing date and variety for grain yield.
- PBA Slasher(ϕ), PBA Striker(ϕ) and CICA1521 were consistently amongst the highest yielding varieties across all three sites.
- The lower average yields at Yanco Agricultural Institute and Wagga Wagga Agricultural Institute (when compared to Leeton Field Station) were largely attributed to limited pre-sowing moisture and low in-crop rainfall.

Background

There were three chickpea experiments established in the Riverina during the 2018 growing season. The three sites included Leeton Field Station (LFS), Yanco Agricultural Institute (YAI) and Wagga Wagga Agricultural Institute (WWAI).

The object of these experiments was to identify the optimum sowing date that maximises yield potential by ensuring that critical growth phases such as flowering and podding do not coincide with abiotic stresses such as frost, drought and heat. The aim of these experiments was to determine the optimum sowing date for chickpeas by identifying the phenological drivers of crop development and grain yield.

Low temperatures during flowering and podding affected flower and pod abortion and ultimately yield. Chickpeas tend to abort pods at mean daily temperatures below 15°C. Variety selection and sowing date are management tools used to minimise the impact of low temperatures during the reproductive stage of chickpea production.

These experiments are part of a series of ongoing pulse experiments sown in central and southern NSW with the aims to:

- identify the phenological drivers of chickpeas and lentils in southern and central NSW,
- determine variety response to sowing date across varying climatic zones, and;
- determine optimal genotype and sowing date combinations.

Table 1. Details of the experimental sites at the Leeton Field Station (LFS), Yanco Agricultural Institute (YAI) and Wagga Wagga Agricultural Institute (WWAI).

Location	LFS	YAI	WWAI
Soil type	Brown Chromosol	Brown Chromosol	Red Chromosol
pHc_a	6.4 (10cm)	6.0 (10cm)	5.9 (10cm)
Previous crop	Barley	Bare fallow	Barley
Fertiliser	Zero	80kg/ha of Energiser Plus (N 13.5: P 13.5: K 0.0: S 9.5)	100kg/ha of Granulock® Z Soygran (N 5.5: P 15.3: K 0.0: S 7.5)
Pre-sowing watering	220mm (flood)	77mm (overhead)	Zero
In-crop watering	24mm (overhead)	64mm (overhead)	10mm (overhead)
Growing season rainfall	87mm	87mm	152mm

Trial design

There were 32 treatments with three reps at each location. The treatments included eight varieties sown at four different sowing dates.

Varieties

The eight chickpea varieties included five desi and three kabuli varieties at each site. The desi varieties included PBA Boundary(ф), PBA Striker(ф), PBA Slasher(ф), CICA1521 and Neelam(ф). The kabuli varieties included Genesis™ 079, Genesis™ 090 and Kalkee.

Sowing dates

There were four sowing dates (SD) at each location:

- SD1: 16 April 2018
- SD2: 30 April 2018
- SD3: 14 May 2018
- SD4: 28 May 2018

Results and discussion

Duration of growth phases

The average time to emergence across the three experiments ranged from 6 to 11 days in SD1 and increased to 24 to 26 days in SD4 (data not shown). The longer the delay in sowing, the longer it took for the plants to emerge. Chickpeas require a minimum threshold of approximately 115 growing degree days (GDD) to emerge, and this took longer to satisfy in the experiments of later sowing dates, as temperatures dropped in late autumn (Whish 2016; GRDC GrowNotes™ 2017).

Time taken to reach 'early flowering' varied between experiments with the average time for SD1 at YAI taking 106 days while the average time for SD1 at WWWAI taking 147 days (Figure1). The drier conditions at YAI resulted in that site reaching 'early flowering' 54 days earlier than at the WWAI site. Moisture stress at the YAI experiment also induced varietal response to flowering with PBA Striker(ф) and Genesis™ 079 both reaching 'early flowering' in under 73 days in SD1 (data not shown).

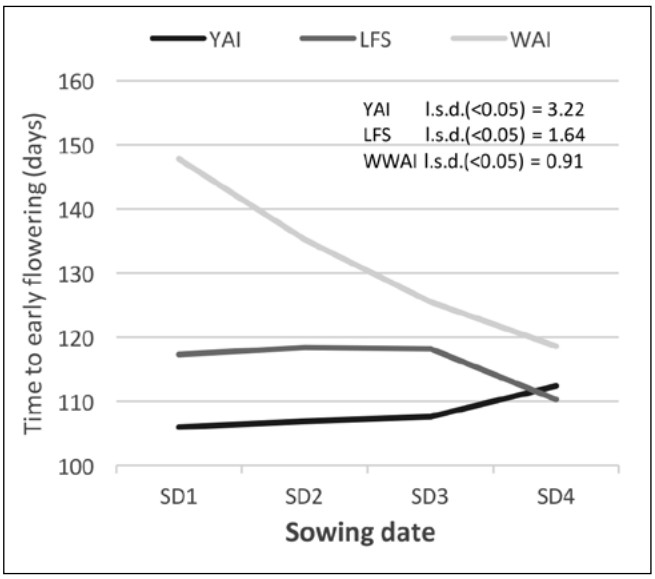

Figure 1. Length of time taken to reach the 'early flowering' stage for four sowing dates at YAI, LFS and WWAI in 2018.

Flowering duration was the longest in the early sown treatments and decreased as the sowing date was delayed (Figure2). The YAI and LFS sites flowered for 60 and 69 days, respectively in SD1 while the flowering duration at WWAI was only 35 days in SD1. Across all experiments the time to early flowering and the duration of flowering was the longest in the early sown treatments and decreased as the sowing date was delayed. The earlier and longer flowering phase meant that the early-sown treatments had a higher exposure to frost than those sown later.

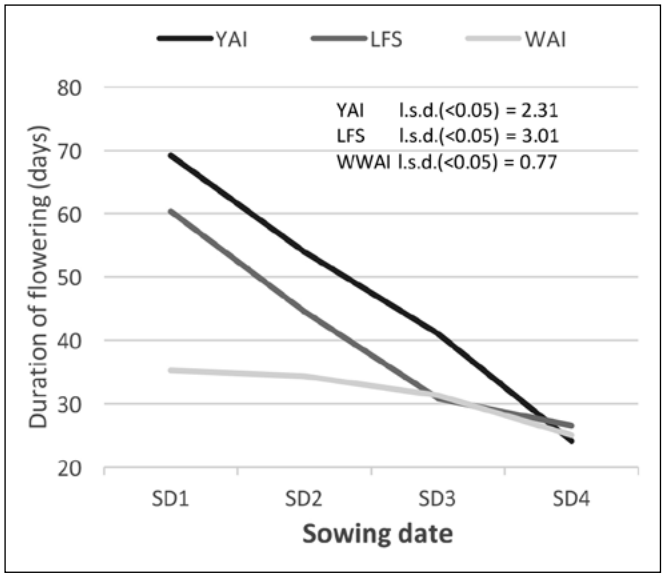

Figure 2. Duration of flowering for four sowing dates at YAI, LFS and WWAI in 2018.

Grain yield, biomass and harvest index

The average yield across the three sites varied considerably with the pre-watered site at LFS achieving the highest average yield of 2.29t/ha. The sites at YAI and WWAI had lower average yields with 1.23t/ha and 1.28t/ha, respectively (Figures 3 and 5).

At the LFS site, the yield ranged from 1.52t/ha for Genesis™ 090 (SD2) to 2.85t/ha for Genesis™ 079 (SD3) (Figure 4). At the YAI site, the yield ranged from 0.36t/ha for Genesis™ 090 (SD1) to 1.86t/ha for CICA1521 (SD3) (Figure 3). At the WWAI site, the yield ranged from 1.02t/ha for Genesis™ 090 (SD1) to 1.57t/ha for PBA Striker(ϕ) (SD3) (Figure 5).

At both the LFS and WWAI sites there was a significant interaction between varieties and sowing date. At the LFS site, Genesis™ 090 and Kalkee achieved a significantly higher yield at SD1 compared to SD2. Alternatively, CICA 1521, Genesis™ 079, Neelam(ϕ) and PBA Boundary(ϕ) all achieved a higher yield at SD3 and SD4 compared to SD1. Grain yields for PBA Slasher(ϕ) and PBA Striker(ϕ) were statistically similar across all four sowing dates at LFS.

At the WWAI site, Kalkee, Neelam(ϕ) and PBA Slasher(ϕ) achieved a significantly higher yield at SD1, SD2 and SD3 compared to SD4. Alternatively, CICA1521, Genesis™ 090 and PBA Boundary(ϕ) all achieved a higher yield at SD2, SD3 and SD4 compared to SD1. Grain yields for Genesis™ 079 was statistically similar across all four sowing dates at WWAI.

There was a significant response with grain yield to sowing date at both the YAI and WWAI sites. The late April (SD2) and mid-May (SD3) sowing dates produced the highest yields at these sites when averaged across varieties. At LFS there was no statistical effect on grain yield with sowing date but a substantial interaction between variety and sowing date was observed.

The highest average yields from all sites was from SD3 with a corresponding flowering time of around 108 days after sowing for YAI and 125 days after sowing for WWAI (Figure 1). There were different varietal yield responses and interactions with sowing date. High grain yield was mainly due to a larger number of seeds and pods per plant, and a larger seed size. High seed number was due to a high proportion of filled pods, or fewer unfilled pods per plant.

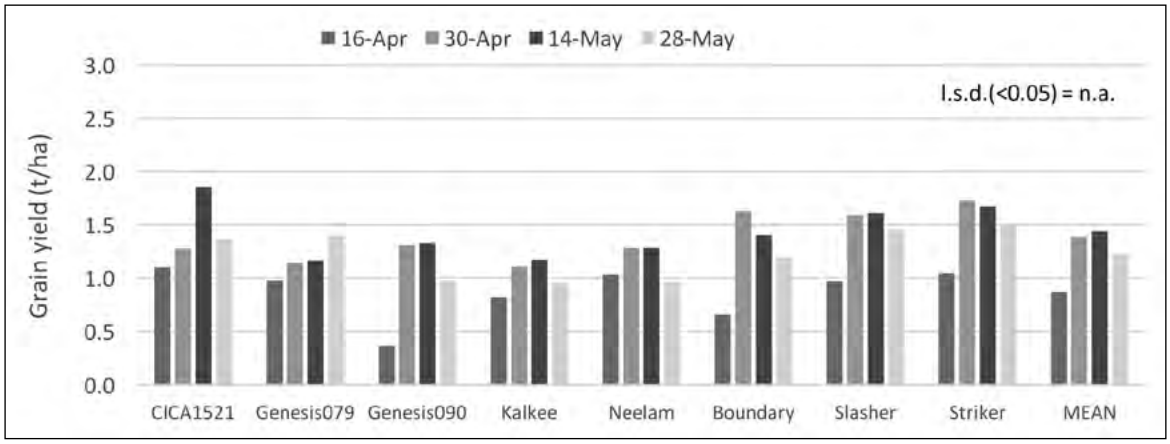

Figure 3. Grain yield of eight chickpea varieties across four sowing dates at YAI in 2018.

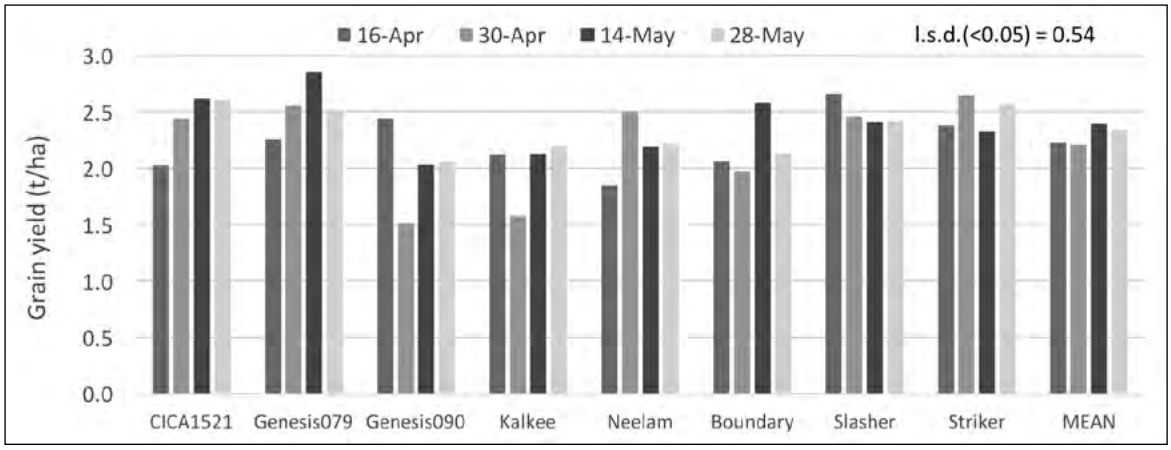

Figure 4. Grain yield of eight chickpea varieties across four sowing dates at LFS in 2018.

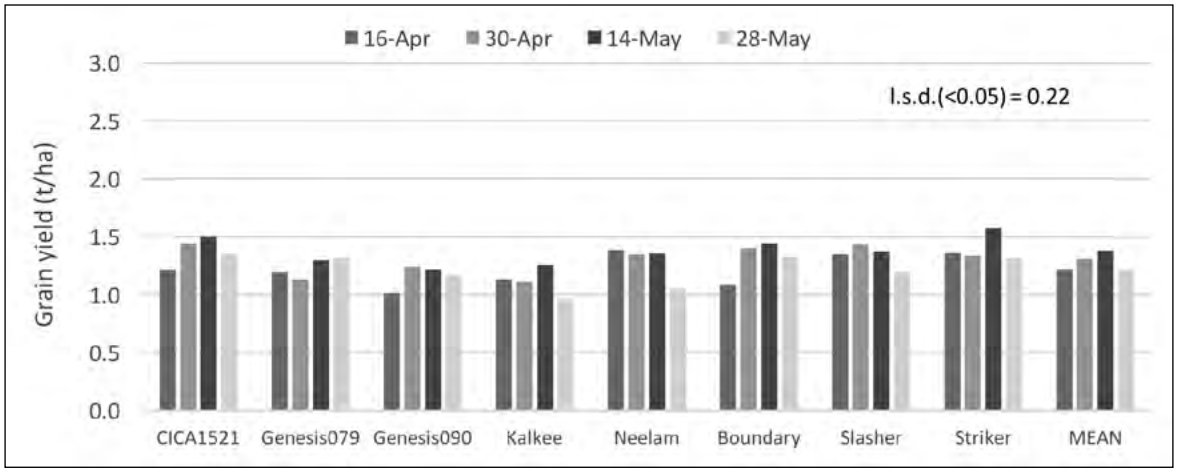

Figure 5. Grain yield of eight chickpea varieties across four sowing dates at WWAI in 2018.

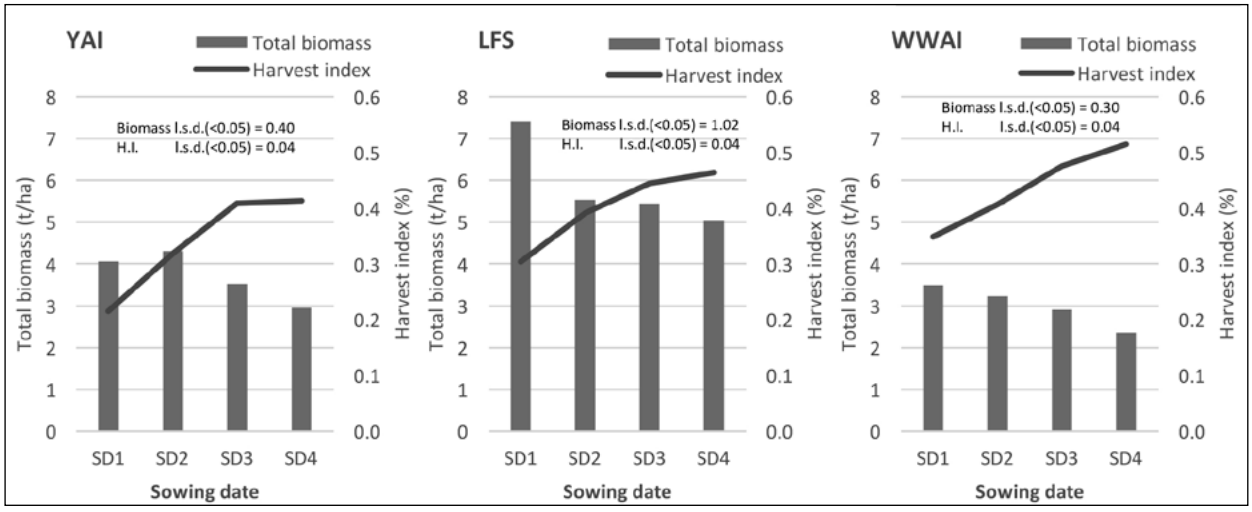

Figure 6. Total biomass and harvest index (HI) for four sowing dates at YAI, LFS and WWAI in 2018.

LFS achieved the highest average total biomass in SD1 with 7.41t/ha which was significantly higher than all other sowing dates at LFS (Figure 6). The WWAI site also achieved the highest average total biomass in SD1 with 3.49t/ha which was significantly higher than SD3 and SD4. The YAI site achieved the highest average total biomass in SD2 with 4.31t/ha which was significantly higher than SD3 and SD4.

The WWAI site achieved the highest harvest index (HI) with 0.51 in SD4 and was significantly higher than SD1 and SD2 at WWAI (Figure 6). The LFS site also achieved the highest HI in SD4 with 0.46 which was significantly higher than SD1 and SD2. The YAI site achieved the highest HI in SD3 and SD4 with 0.41 which was significantly higher than SD1 and SD2.

Across all sites a general trend was observed with total biomass decreasing and harvest index increasing as the sowing date was delayed.

Conclusion

Limited pre-sowing moisture affected plant growth, biomass accumulation and final grain yield at both the YAI and WWAI sites in 2018. The late April and mid-May sowing dates produced the highest yields at these sites when averaged across varieties. The YAI site achieved 1.38t/ha and 1.44t/ha, respectively while the WWAI site achieved 1.31t/ha and 1.38t/ha, respectively. At LFS, with a full moisture profile at sowing, a much higher biomass accumulation and final grain yield was achieved. Grain yields at LFS exceeded 2.20t/ha at all sowing dates but there was no effect on yield with sowing date.

The higher grain yields achieved in the late April and mid-May sowing dates at the YAI and WWAI sites was driven to a large extent by temperatures during flowering and podding, with lower temperatures resulting in flower and pod abortion at the mid-April sowing. Overall yield was influenced by a number of yield components such as the number of pods, filled and unfilled pods, seed number and seed weight per plant.

When averaged across sowing dates, a varietal response on grain yield was observed at all sites. The three desi varieties of PBA Slasher(ϕ), PBA Striker(ϕ) and CICA1521 were in the highest yielding group at all sites while the two kabuli varieties of Genesis™ 090 and Kalkee were in the lowest yielding group at all sites.

Yield was also affected by variety and sowing time interaction at the LFS and WWAI sites. While Genesis TM 090 had a low average yield when averaged across the four sowing dates at LFS, its yield in SD1 was 2.44t/ha putting it in the highest yielding group for SD1 at LFS. CICA1521, Genesis™ 090, Kalkee, Neelam(ϕ) and PBA Boundary(ϕ) all demonstrated some interaction between sowing time and variety on grain yield at LFS and WWAI.

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Thank you to Michael Hately and Gabby Napier for field assessments and data collection.

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Management of hard to control weeds

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GRDC project codes: UA00149, UA00158, UCS00020

Keywords

- fleabane, windmill grass, silverleaf nightshade, wild oats, glyphosate resistance.

Take home messages

- Management of hard to control weeds requires an understanding of when the weeds germinate.
- High efficacy is needed with the first herbicide mixture to achieve good double knock control of fleabane in summer.
- Windmill grass needs to be controlled as soon as it is noticed, as the old plants are much harder to control.
- Early autumn applications are better for getting glyphosate into the root system of silverleaf nightshade than summer applications.

Hard to control weeds

The main reason there are hard to control weeds in farming systems is that the current weed management practices that are used do not control them. This may be because there are no effective herbicides available for that weed, the germination pattern of the weed means it avoids current control methods or for a number of other reasons. Many of these weeds tend to be weeds that have come into prominence due to changes in farming systems, and therefore, we have limited experience with these weeds.

In order to develop better management strategies for these weeds it is necessary to understand the biology and ecology of the weeds, so that the management strategies can be better targeted. Understanding the time of emergence of the weeds can be particularly important, in order that control practices are implemented at the time of or shortly after emergence when weeds are small.

Fleabane

Fleabane has been present for a long time in Australia but it has only become a weed of cropping systems in recent years. Fleabane is a small seeded weed that requires several days of moist soil on the surface to germinate. Therefore, it is favoured by no-till, stubble-retention farming systems. It germinates primarily in spring, but if water is available, it can germinate through summer into early autumn provided temperatures are not too hot. Many fleabane populations in Australia are resistant to glyphosate, which makes them harder to control in the summer fallow period.

The best time to control fleabane is in late winter and early spring as it is germinating. Amicide® Advance and FallowBoss® Tordon® can be used in cereals. However, the latter has a 20-month plant back to pulse crops, cotton and pastures and a 12-month plant back to canola, so care needs to be taken when it is used in crop.

If control is left until after harvest, a double knock approach must be used. This is normally glyphosate plus a Group I herbicide, followed at least two weeks later by paraquat. However, the first application needs to provide at least 60% control of fleabane on its own to get effective fleabane control with the double knock (Figure 1).

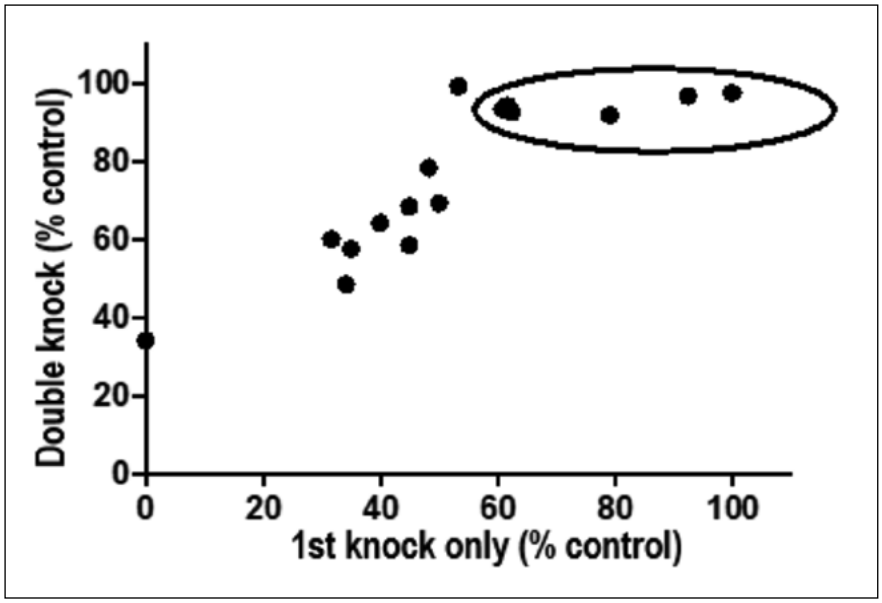

Figure 1. Fleabane control in fallow of standalone herbicide treatment (1st knock) compared with control from the double knock with paraquat for each treatment at two trial sites (Bute and Pinnaroo, SA). Data from Ben Fleet, University of Adelaide.

Crop competition can also be used to reduce establishment of fleabane. Fleabane occurs most commonly following poorly competitive cereals, pulse crops and pastures. Increasing the amount of competition in cereal crops will limit the number of fleabane plants that survive through to crop harvest.

Windmill grass

Windmill grass is another surface-germinating weed species like fleabane. Windmill grass is an Australian native and has been sown widely in areas with summer rainfall as a pasture grass. Unlike fleabane, windmill grass is a short-term perennial, with plants surviving for several years. Some windmill grass populations have evolved resistance to glyphosate, making them harder to control in the summer fallow period.

Windmill grass germinates in both spring and autumn. The optimum temperature for germination is 25°C but it has a broad range for germination from 15°C to 30°C (Figure 2). Light is required for germination, which is why windmill grass is increasing as a problem in no-till systems. Windmill grass seed fails to germinate from even as little as 0.5cm below the surface, so is unlikely to be a

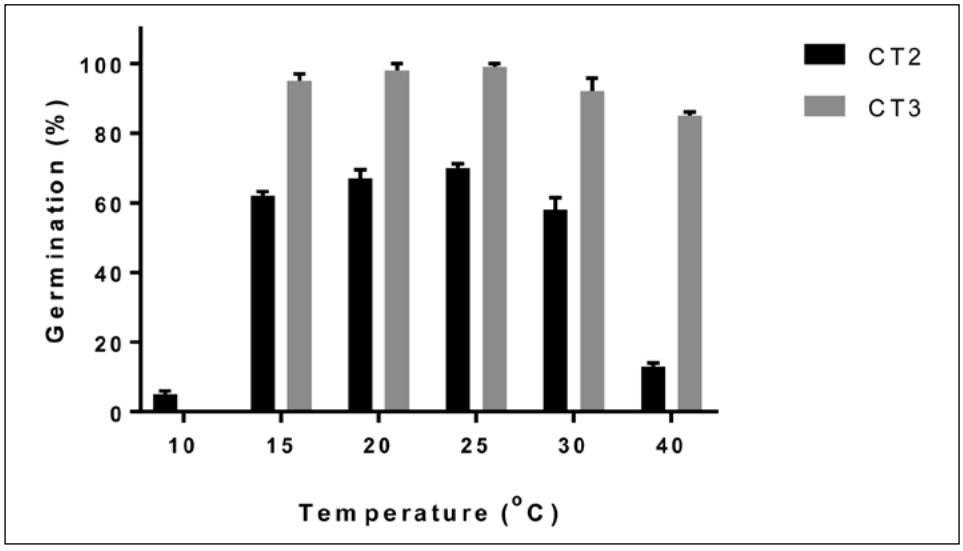

Figure 2. The effect of temperature in the light on germination of windmill grass seeds from two different populations (CT2 and CT3). Data from The Duc Ngo, University of Adelaide.

problem in cultivated cropping systems. Cultivation can also be used to control perennial plants, but a follow up treatment for new seedlings is required.

The challenge to managing windmill grass is that there are almost no herbicides registered for its control. Butroxydim in summer-growing broadleaf crops is the only registered in-crop herbicide. In summer fallows, some glyphosate products are registered for control. There is also a permit for the use of quizalofop-ethyl in fallows, provided it is double-knocked within seven days with paraquat. Particularly challenging to control are the older established plants from previous years, which often have dead leaves around the base. Getting good herbicide coverage on these older plants is challenging. Consequently it is important to control windmill grass as soon as it is noticed.

Silverleaf nightshade

Silverleaf nightshade is a summer growing perennial weed with a large root system. The root system may grow more than 3m deep and 10m or more across. Silverleaf nightshade has the ability to grow new stems from small root pieces. Controlling the shoots of silverleaf nightshade does not necessarily control the root system and control of the root system is necessary to achieve long-term control.

Silverleaf nightshade seedlings are rarely seen. Silverleaf nightshade seeds are covered by a mucilaginous coating that prevents germination. As this needs to be removed before germination can occur, germination typically only occurs after very wet conditions. Most often this will happen with wet spring and early summer conditions, such as in 2016. This is why silverleaf nightshade patches tend to appear out of nowhere. Control of seedlings is easy but finding them is difficult. This means control tends to focus on managing established plants.

Silverleaf nightshade seeds readily survive passage through stock. Sheep are the main cause of silverleaf nightshade spread in Australian agriculture. While initially stock may avoid eating the berries, sheep can get a taste for them and actively consume the berries. Birds, farm machinery and fodder are also likely vectors of spread of seed but are of much less importance than sheep. As silverleaf nightshade can grow new shoots from root fragments as small as 5cm in length, cultivation does not control silverleaf nightshade and can help to spread patches of the weed.

Work to introduce a biological control of silverleaf nightshade is underway; however, in the meantime herbicides are the only effective control practice. There are few herbicides with any efficacy against silverleaf nightshade. Some like 2,4-D simply kill the shoots without reducing root growth. With others, timing is everything in terms of getting the herbicide into the root system. Research work looking at glyphosate movement in silverleaf nightshade plants showed that application of glyphosate after flowering moved the most herbicide into the root system, whereas application at flowering tended to have little movement (Figure 3). This is because flowering plants are moving photosynthate (and glyphosate) into the developing flowers and fruits, rather than into the roots.

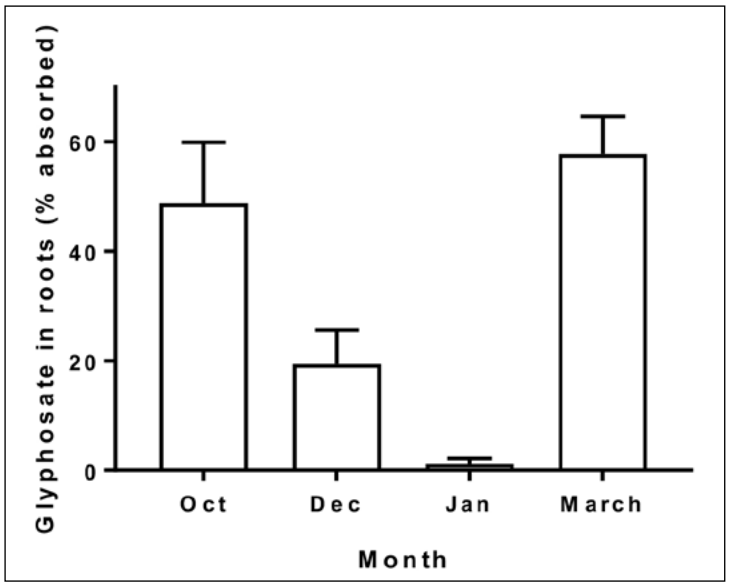

Figure 3. Translocation of glyphosate into roots of silverleaf nightshade plants at different times of the growing season. Silverleaf nightshade tends to flower in the period December to February and glyphosate translocation to the roots is reduced in this period. Data from Kerensa Greenfield, University of Adelaide.

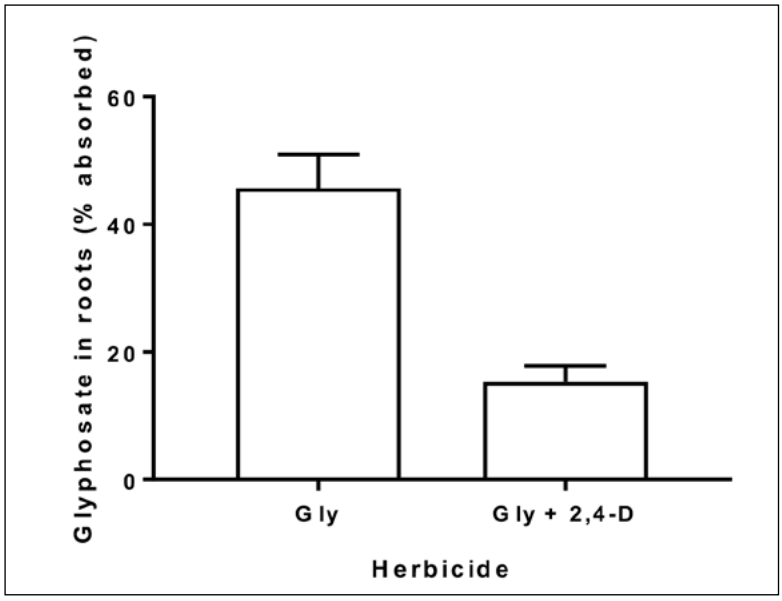

Figure 4. Effect of adding 2,4-D on translocation of glyphosate into roots of silverleaf nightshade plants. Data from Kerensa Greenfield, University of Adelaide.

Adding 2,4-D to glyphosate is counter-productive to getting glyphosate into the roots (Figure 4). This is because the addition of 2,4-D tends to kill the shoots quickly and limits the movement of glyphosate into the root system. The best approach for glyphosate application to silverleaf nightshade is to apply the herbicide immediately after harvest, but before flowering of the weed, and then to have a second application in early autumn. Due to the extensive root system, it will take five to ten years to see a noticeable decline in the density of silverleaf nightshade patches.

Wild oats

The main problem with wild oats is that it has resistance to both the Group A and Group B herbicides. What is more of a concern is the increasing resistance to Axial®, which is used for late season control of wild oat seed set. Our data suggests that resistance across the fop herbicides in wild oats can be variable, so getting a resistance test to determine whether any of the products still work can be useful.

Control of wild oats with pre-emergent herbicides has been challenging in the past, but new products and a move to no-till have offered new approaches to controlling wild oats. Data has shown that Trifluralin + Avadex®Xtra or Sakura® + Avadex® Xtra consistently provide control of wild oats in wheat. Due to the ability of seeds to bury themselves in soil and the more extended emergence of wild oats, crop competition in combination with pre-emergent herbicides is an essential component of reducing wild oat seed set of late emerging plants.

The challenge comes in the pulse phase of rotations where due to lower competition, later emerging wild oat seedlings can produce a lot of seed. Wild oat tends to mature earlier than ryegrass and seed can shed well before harvest. This makes crop topping and harvest weed seed control practices less effective on wild oats. Getting the rotation right and using all the practices that are available can keep wild oats under control.

Useful resources

https://grdc.com.au/__data/assets/pdf_file/0023/109049/grdc_fs_fleabane_low-res-pdf.pdf.pdf

http://sciences.adelaide.edu.au/agriculture-food-wine/system/files/docs/2017-wmg-biology.pdf

https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/839857/Silverleaf-nightshade-best-practice-management-manual-2018.pdf

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support.

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THE 2017-2020 GRDC NORTHERN REGIONAL PANEL

JANUARY 2019

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

CHAIR - JOHN MINOGUE

John Minogue runs a mixed broadacre farming business and an agricultural consultancy, Agriculture and General Consulting, at Barmedman in south-west NSW. John is chair of the district council of the NSW Farmers' Association, sits on the grains committee of NSW Farmers' Assn and is a winner of the Central West Conservation Farmer of the Year award. His vast agricultural experience in central west NSW has given him a valuable insight into the long-term grains industry challenges.

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DEPUTY CHAIR - ARTHUR GEARON

Arthur is a grain, cotton and beef producer near Chinchilla, Queensland. He has a business degree from the Queensland University of Technology in international business and management and has completed the Australian Institute of Company Directors course. He is a previous vice-president of AgForce Grains and has an extensive industry network throughout Queensland. Arthur believes technology and the ability to apply it across industry will be the key driver for economic growth in the grains industry.

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ROGER BOLTE

Roger Bolte is a fourth-generation farmer from the West Wyalong area in NSW, operating a 6500 ha winter cropping program with his wife and family focussing on cereals, legumes and hay. During his 35-years in the industry, Roger has been involved in R&D in various capacities and has had the opportunity to travel abroad and observe a variety of farming systems. He believes that R&D and education are the cornerstones of the industry and feels privileged to be afforded the opportunity to share his experiences.

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ROY HAMILTON

Roy Hamilton operates a 4400 ha mixed family farming enterprise near Rand in NSW's Riverina. He was an early adopter of minimum till practices and direct drill and press wheel technology and is currently migrating to CTF. The majority of the property is cropped while the remainder runs ewes and trade lambs. He has held roles on the south east NSW Regional Advisory Committee, the GRDC's southern region Regional Cropping Solutions Network and was a founding committee member of the Riverine Plains farming systems group.

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DR TONY HAMILTON

Tony is a grower from Forbes, NSW and managing director of an integrated cropping and livestock business. He is a director of the Rural Industries Research and Development Corporation. He has worked as an agricultural consultant in WA and southern NSW. With a Bachelor of Agricultural Science and a PhD in agronomy, Tony advocates agricultural RD&E and evidence based agriculture.

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ANDREW MCFADYEN

Andrew is a grower and private agricultural consultant near Lake Cargelligo NSW with more than 17 years agronomy and practical farm management experience. He is an active member of the grains industry with former roles on the Central East Research Advisory Committee, NSW Farmers Coolah branch and has served on the GRDC northern panel since 2015. He is also a board member and the chair of Grain Orana Alliance.

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PETER MCKENZIE

Peter operates a private agronomy consulting business based in Quirindi NSW. Prior to this he was facilitator/agronomist for AgVance Farming group, a communications conduit between industry and growers. He is a passionate supporter of research and has been active in extending weed management research information to industry, particularly in central west NSW, is a former director of Conservation Farmers Inc., a former member of the North East Regional Advisory Committee and a participant in Northern Growers Alliance local research group on the Liverpool Plains.

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GRAHAM SPACKMAN

Graham has been Managing Director of a private agricultural consultancy at Emerald, Queensland, for the past 28 years, providing advice on the agronomy and management of summer and winter, dryland and irrigated crops in grain and mixed farming systems. He has extensive involvement in RD&E having participated in two decades of GRDC and DPI-funded farming systems research, particularly in weed management, soil fertility and adaption of agronomic practices in CQ farming systems. Graham was a member of the CQ Research Advisory Committee for over 10 years and Chairman for five years.

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BRUCE WATSON

Bruce and his family operate a 3400 ha family grain growing business near Parkes NSW, which produces a mixture of dryland winter cereals, pulses and oilseeds as well as summer dryland cereals, pulses and cotton grown on a 12m zero till CTF platform with full stubble retention. Bruce holds a Bachelor of Agricultural Economics from the University of Sydney and previously worked with PricewaterhouseCoopers in its Transfer Pricing practice. He is an active member of the grains industry and was awarded a Nuffield Scholarship in 2009.

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DR JO WHITE

Dr Jo White is an experienced researcher with over 15 years' experience in agricultural research programs based at the Department of Agriculture and Fisheries in Queensland (DAFQ) and the University of Southern Queensland (USQ), including 10 years' experience in the field of plant pathology of broad acre summer crops. Jo has a keen interest in developing and delivering on-ground practical research solutions to growers which improve productivity and profitability of their farms and is now working as a private consultant based in Queensland.

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DR NICOLE JENSEN

Nicole Jensen is GRDC General Manager for the newly created Genetics and Enabling Technologies business group. Nicole brings a wealth of experience in plant breeding and related activities arising from several roles she has held in Australia and internationally in the seed industry including positions as Supply Innovation Lead with the Climate Corporation - Monsanto's digital agricultural flagship, Global Trait Integration Breeding Lead for Monsanto.

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NORTHERN REGION GROWER SOLUTIONS GROUP AND REGIONAL CROPPING SOLUTIONS NETWORK

JANUARY 2019

The Northern Region of the Grains Research and Development Corporation (GRDC) encompasses some of the most diverse cropping environments in Australia, ranging from temperate to tropical climates – it has the greatest diversity of crop and farming systems of the three GRDC regions.

Implemented, to provide structured grower engagement, the GRDC Grower Solutions Group projects and the RCSN project have become an important component of GRDC's investment process in the northern region. The Northern Region Grower Solutions Group and the RCSN have the function of identifying and, in the case of Grower Solutions Groups managing short-term projects that address ideas and opportunities raised at a local level which can be researched demonstrated and outcomes extended for immediate adoption by farmers in their own paddocks.

GROWER SOLUTIONS GROUP AND REGIONAL CROPPING SOLUTIONS NETWORK CONTACT DETAILS:

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Northern Grower Alliance (NGA) was established in 2005 to provide a regional capacity for industry-driven, applied agronomic grains research. NGA is currently working on a five year Grower Solutions project, fully funded by the GRDC, focussing on cropping areas from the Liverpool Plains to the Darling Downs and from Tamworth and Toowoomba in the east to Walgett, Mungindi and St George in the west. A network of six Local Research Groups, comprised of advisers and growers, raise and prioritise issues of local management concern to set the direction of research or extension activity. Areas of focus range from weed, disease and pest management through to nutrition and farming system issues.

GRAIN ORANA ALLIANCE (GOA)

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Grain Orana Alliance (GOA) is a not for profit organisation formed in 2009 to help meet growers research and extension needs in the Central West of NSW to support their enduring profitability. Currently operating under the GRDC Grower Solutions Group - Central NSW project, one of the key priorities is to identify and prioritise R,D and E needs within the region through engagement with local growers and advisers. This grower engagement helps direct both the GRDC investments in research projects and GOA's own successful research programs. GOA's research covers a wide range of relevant topics such as crop nutrition, disease management and weed control. The structure of the project allows for a rapid turnaround in research objectives to return solutions to growers in a timely and cost effective manner whilst applying scientific rigour in the trial work it undertakes. Trials are designed to seek readily adoptable solutions for growers which in turn are extended back through GOA's extensive grower and adviser network.

CENTRAL QUEENSLAND GROWER SOLUTIONS GROUP

ROD COLLINS

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The Central Queensland Grower Solutions project, is a GRDC and DAF Queensland investment in fast-tracking the adoption of relevant R,D & E outcomes to increase grower productivity and profitability across central Queensland. Covering approximately 550,000 ha and representing 450 grain producing businesses, the central Queensland region includes areas from Taroom and Theodore in the south to Mt McLaren and Kilcummin in the north, all of which are serviced by the project staff, located in Biloela and Emerald. Team leader Rod Collins is an experienced facilitator and extension officer with an extensive background in the central Queensland grains industry. He was part of the initial farming systems project team in the region throughout the late 90's and early 2000's which led the successful adoption of ley legumes to limit nutrient decline and wide row configurations in sorghum to improve yield reliability across central Queensland. He has more recently led the development and delivery of the Grains Best Management Practices program.

COASTAL HINTERLAND QUEENSLAND AND NORTH COAST NEW SOUTH WALES GROWER SOLUTIONS GROUP

The Coastal Hinterland Queensland and North Coast New South Wales Grower Solutions project was established to address the development and extension needs of grains in coastal and hinterland farming systems. This project has nodes in the Burdekin managed by Dr Steven Yeates from CSIRO; Grafton managed by Dr Natalie Moore from NSW DPI; Kingaroy managed by Nick Christodolou (QDAF) and Bundaberg managed by Neil Halpin.

BUNDABERG QUEENSLAND:

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Neil Halpin is a principal farming systems agronomist with the Queensland Department of Agriculture and Fisheries. He has over 30 year's field trail experience in conservation cropping systems, particularly in the sugar-based farming systems of the coastal Burnett. His passion is for the integration of grain legume break crops, reduced tillage, controlled traffic and organic matter retention in coastal farming systems. Maximising the productivity and profitability of grain legumes (peanuts, soybeans and mung beans) is a common theme throughout the various production areas and systems covered by this project.

KINGAROY QUEENSLAND:

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Nick Christodoulou is a principal agronomist with the Department of Agriculture & Fisheries (QDAF) on Qld's Darling Downs and brings over 25 years of field experience in grains, pastures & soil research, with skills in extension application specifically in supporting and implementing practice change. Nick has led the highly successful sustainable western farming systems project in Queensland. Nick was also project leader for Grain & Graze 1 Maranoa-Balonne and DAF leader for Grain & Graze 1 Border Rivers project, project leader for Grain and Graze 2 and was also Project leader for the Western QLD Grower Solutions project. Currently he is the coordinator for the Grower Solutions Southern Burnett program.

BURDEKIN QUEENSLAND:

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The Burdekin & tropical regional node of the Coastal and Hinterland Growers Solution Project is led by CSIRO research agronomist Dr Stephen Yeates and technical officer Paul McLennan, who are based at the Australian Tropical Science and Innovation Precinct at James Cook University, Townsville. The Burdekin & tropical Grower Solutions node has a committed and expanding advisory group of farmers and agribusiness professionals. Due to the rapid increase in farmers producing mungbean in the region an open door policy has been adopted to advisory group membership to ensure a balance in priorities between experienced and new growers. The node is focused on integrating grain crops into sugar farming systems in the lower Burdekin irrigation area in NQ and more recently contributing to other regions in the semi-arid tropics that are expanding or diversifying into grain cropping. Information and training requests for information and training from the Ord River WA, Gilbert River NQ, Mackay and Ingham areas necessitated this expansion. Recent work has focussed on the introduction of mungbeans in the northern Queensland farming systems in collaboration with the GRDC supported entomologists Liz Williams and Hugh Brier, Col Douglas from the mungbean breeding team, the Australian Mungbean Association and Pulse Australia. Both Stephen and Paul have many decades of experience with crop research and development in tropical Australia.

GRAFTON NEW SOUTH WALES:

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The NSW North Coast regional node of the Coastal and Hinterland Grower Solutions Project is led by NSW DPI research agronomist Dr Natalie Moore and technical officer Mr Nathan Ensbey, who are based at the Grafton Primary Industries Institute. The NSW North Coast Grower Solutions node prioritises and addresses issues constraining grain production via an enthusiastic advisory group comprised of leading grain growers, commercial agronomists from across the region and NSW DPI technical staff. In this high rainfall production zone (800-1400mm pa), winter and summer grain production is an important component of farming systems that also includes sugar cane, beef and dairy grazing pastures, and rice. The region extends east of the Great Dividing Range from Taree in the south to the Tweed in the north. Both Natalie and Nathan have many years experience with research and development for coastal farming systems and are also currently involved with the Australian Soybean Breeding Program (GRDC/CSIRO/NSW DPI) and the Summer Pulse Agronomy Initiative (GRDC/NSW DPI).

REGIONAL CROPPING SYSTEMS NETWORK (RCSN) SOUTHERN NSW

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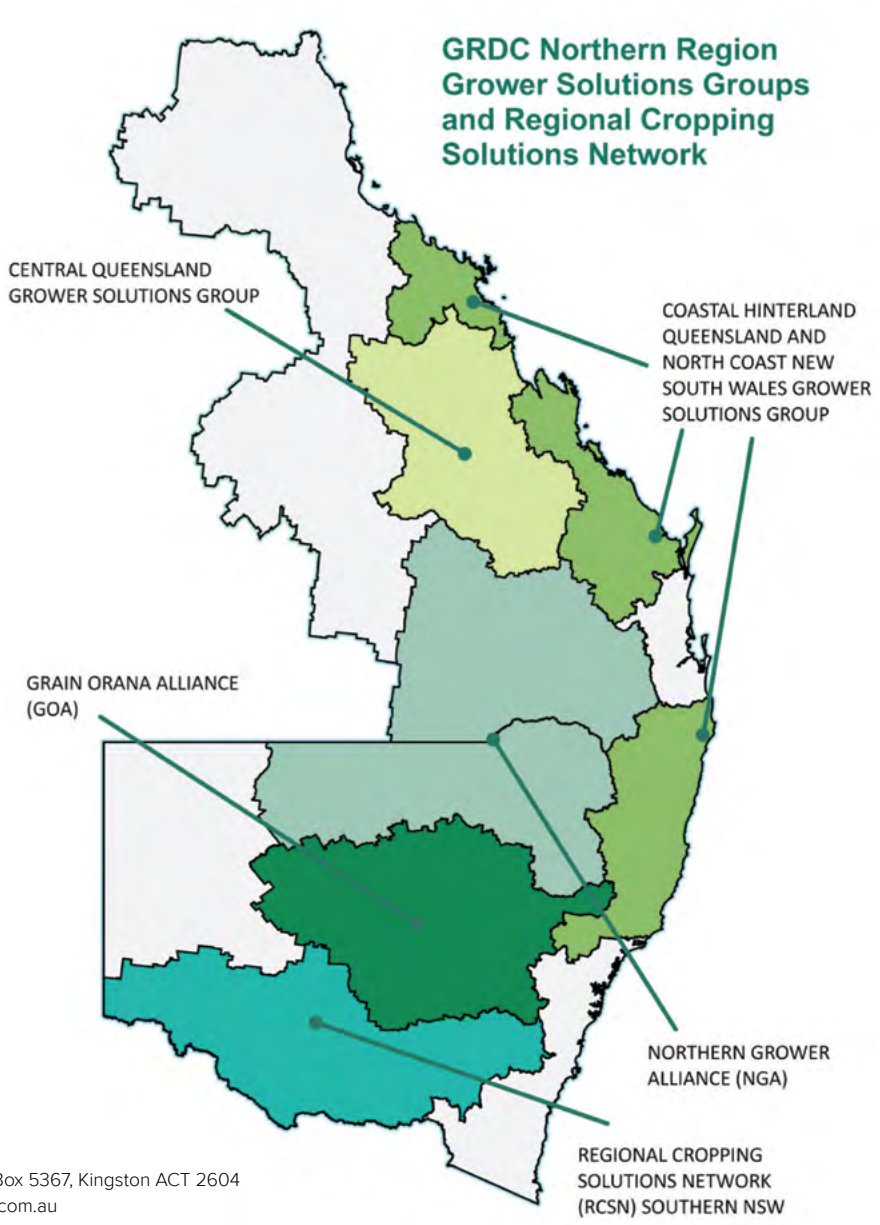
The Southern New South Wales Regional Cropping Solutions Network (RCSN) was established in 2017 to capture production ideas and opportunities identified by growers and advisers in the southern and western regions of New South Wales and ensure they translate into direct GRDC investments in local R, D & E priorities. The SNSW RCSN region covers a diverse area from the southern slopes and tablelands, through the Riverina and MIA, to the Mallee region of western NSW and the South Australian border. The region is diverse in terms of rainfall and climatic zones, encompassing rangelands, low, medium and high rainfall zones, plus irrigation. The SNSW RCSN is facilitated by Chris Minehan. Chris is an experienced farm business consultant and a director of Rural Management Strategies Pty Limited, based in Wagga Wagga, NSW. The process involves a series of Open Forum meetings which provide an opportunity for those involved in the grains industry to bring forward ideas, constraints and opportunities affecting grain grower profitability in their area. These ideas are reviewed by an RCSN committee comprises 12 members, including grain growers, advisers and researchers from across the region that meet twice per year to assist GRDC in understanding and prioritising issues relevant to southern NSW.



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The ORM team would like to thank those who have contributed to the successful staging of the Griffith GRDC Grains Research Update:

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

- Partnering organisation: IREC

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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/Griffith-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 Griffith 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 <u>main</u> 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. Super high oleic oil safflower – what is the fit for irrigation? *Rosemary Richards*

Content relevance ____ /10 Presentation quality ____ /10

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

4. Ameliorating sodic subsoil constraints under irrigation: *Ehsan Tavakkoli*

Content relevance ____ /10 Presentation quality ____ /10

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

5. Your seasonal climate update: *Dale Grey*

Content relevance ____ /10 Presentation quality ____ /10

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

6. Time of sowing impacts on lentil and chickpea performance: *Tony Napier*

Content relevance ____ /10 Presentation quality ____ /10

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

7. Managing those hard to kill weeds: *Chris Preston*

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.