Department of Primary Industries and Regional Development

Southern NSW research results 2024

RESEARCH & DEVELOPMENT – INDEPENDENT RESEARCH FOR INDUSTRY

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Department of Primary Industries
and Regional Development

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RESEARCH & DEVELOPMENT – INDEPENDENT RESEARCH FOR INDUSTRY

an initiative of Southern Cropping Systems

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Front cover image: A variety evaluation experiment conducted at Wagga Wagga Agricultural Institute in 2018, in collaboration with the Lentil Breeding Australia project (Agriculture Victoria). Photo by Mark Richards.

Back cover images: NSW DPIRD pulse research team activities (field trials, industry field days, trial operations and management). Photos NSW DPIRD.

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Foreword

NSW Department of Primary Industries and Regional Development (DPIRD) welcomes you to the *Southern NSW research results 2024*. This book has been produced to increase awareness of research and development (R&D) activities undertaken by NSW DPIRD in the southern mixed farming region of NSW. It delivers the outcomes of these activities to our stakeholders including agribusiness, consultants and growers.

This document is a comprehensive, annual report of NSW DPIRD Southern Cropping Systems R&D activities in southern NSW. This edition includes research covering agronomy and physiology, farming systems and crop protection.

NSW DPIRD, in collaboration with our major investment partner the Grains Research and Development Corporation (GRDC), is at the forefront of agricultural research in southern NSW and the largest research organisation in Australia. Our R&D teams conduct applied, scientifically sound, independent research to advance the profitability and sustainability of our farming systems.

The department's major research centres in the southern region of NSW are Wagga Wagga, Yanco and Condobolin where our team of highly reputable research and development officers and technical staff are based. The regional geographic spread of the research centres allows for experiments to be replicated across high, medium and low rainfall zones with Yanco providing the opportunity to conduct irrigated experiments.

NSW DPIRD's research program includes the areas of:

- plant germplasm improvement
- agronomy and crop management
- plant product quality and market access
- productive and sustainable use of soil
- productive and sustainable use of water
- integrated pest management within production systems
- livestock genetic improvement
- integrated weed management
- animal productivity and value chain efficiency and meat quality
- intensive livestock industries
- feedbase productivity
- drought preparedness, response and recovery
- climate adaptation
- climate mitigation
- agriculture landuse planning
- energy solutions.

The following papers provide an insight into selected R&D activities taking place in the southern region. We hope you will find them interesting and valuable to your farming system or the farming system clients you work with.

Special thanks to all the authors and editorial officers for their willingness to contribute to this publication and I acknowledge the effort in reviewing the diverse range of papers.

We acknowledge the many collaborators (growers, agribusiness and consultants) that make this research possible.

We also encourage feedback to help us improve future editions.

Andrew Carmichael
Acting Director Southern Cropping Systems
On behalf of the Southern Research and Development Teams
NSW Department of Primary Industries and Regional Development

Contents

Seasonal conditions 2023

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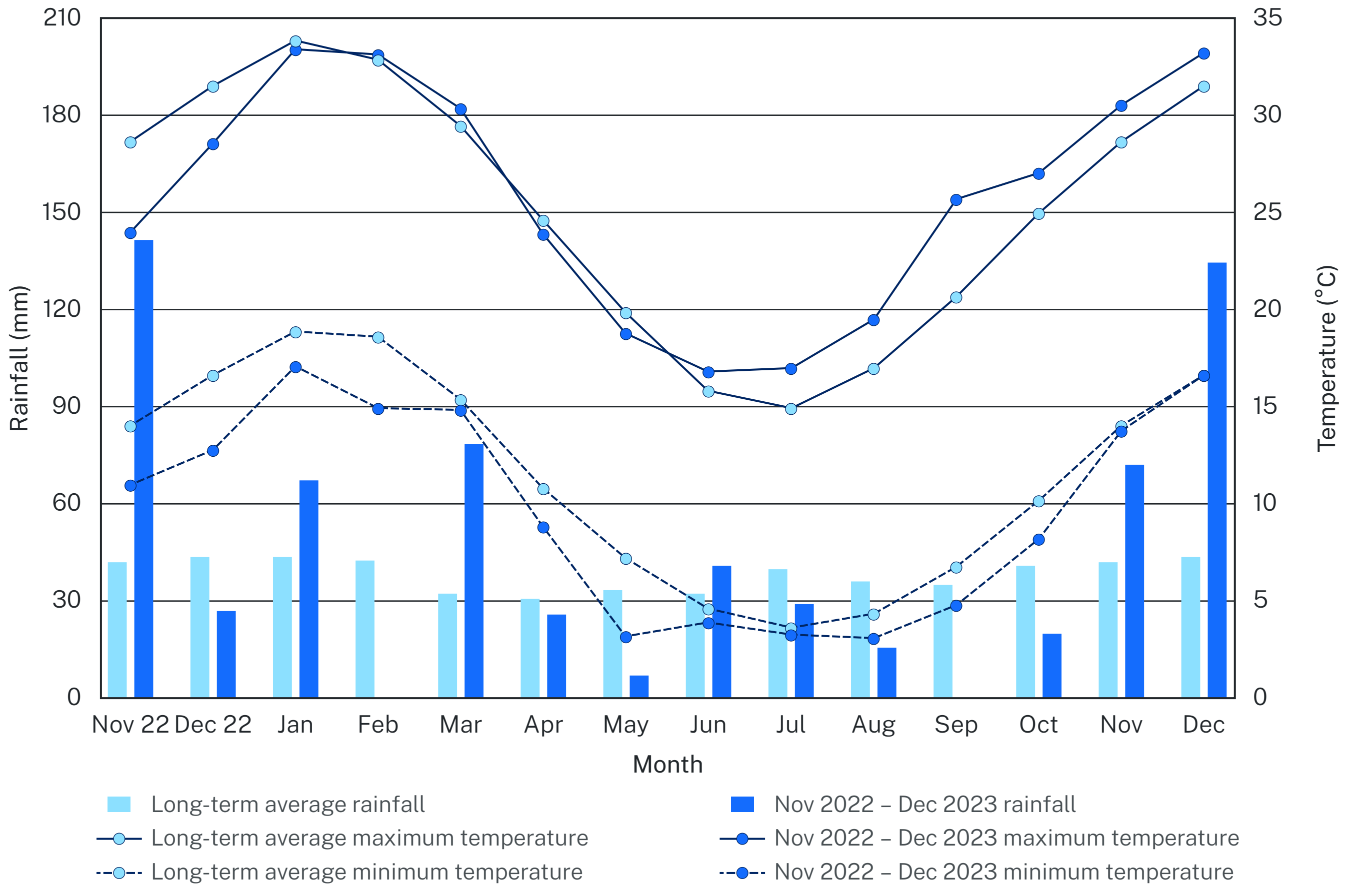
Climate summary

Condobolin Agricultural Research and Advisory Station

Minimum temperatures at Condobolin were near average to below the long-term monthly average (LTA) during 2023 (Figure 1). Maximum temperatures were below average during November and December 2022 and near average to above average during 2023. The maximum temperature for the growing season (May–October 2023) was 1.9 °C above average, while the minimum temperature for the growing season was 1.7 °C below average.

Rainfall was variable with very high totals in November 2022. Rainfall during the fallow period (November 2022–April 2023) was 111 mm above average, but during the growing season was 101 mm below average. Very high rainfall was recorded in December 2023.



Data source: ANUClimate, Australian National University.

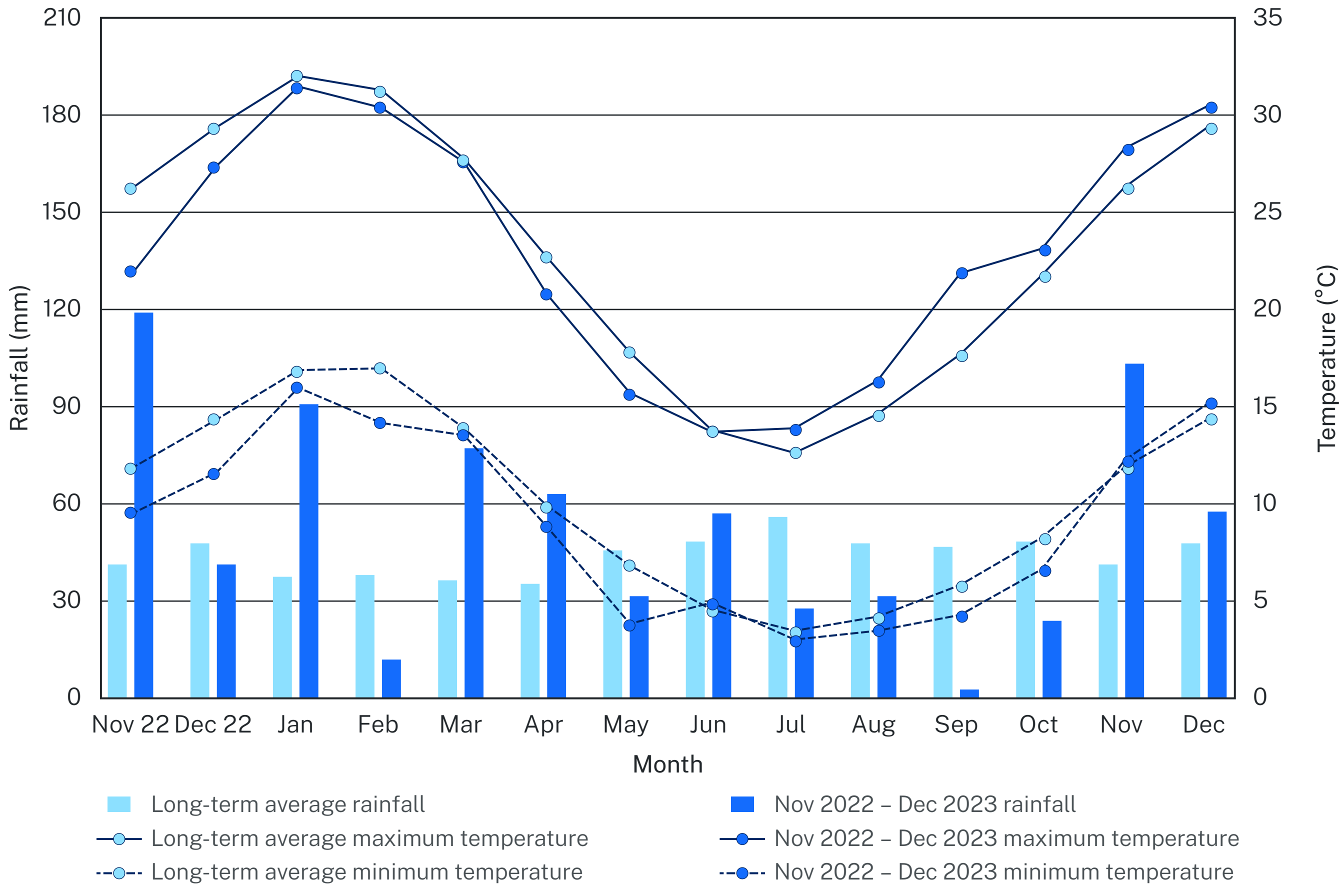
Figure 1 Average monthly minimum and maximum temperature, and total monthly rainfall from November 2022 to December 2023, and long-term averages (1981 to 2010 baseline period) at Condobolin.

Experiments established well at Condobolin in 2023, with all crops growing well early, due to timely sowing and adequate soil moisture. However, later in the season, drier conditions, coupled with frosts and hot days during the crops' reproductive stage, led to damage particularly in canola and chickpea. Drier spring conditions minimised pest and disease issues. Despite these challenges, the crops managed to finish the season with reasonable growth and grain production. All experiments were harvested by mid November.

Wagga Wagga Agricultural Institute

Minimum temperatures at Wagga Wagga were near average to below the LTA during 2023 (Figure 2). Maximum temperatures were below average during November and December 2022 and near average through the remainder of the fallow period (January–April 2023), and above average during the growing season (May–October 2023). The maximum temperature for the growing season was 1.1 °C above average, while the minimum temperature for the growing season was 1.2 °C below average.

Rainfall was variable with very high totals in November 2022. Rainfall during the fallow period was 166 mm above average, but during the growing season was 119 mm below average. Very high rainfall was also recorded in November 2023.



Data source: ANUClimate, Australian National University.

Figure 2 Average monthly minimum and maximum temperature, and total monthly rainfall from November 2022 to December 2023, and long-term averages (1981 to 2010 baseline period) at Wagga Wagga.

Autumn rains meant that experiments were established into excellent soil moisture conditions, resulting in even establishment across all crop species. However, below average rain throughout July, August and September resulted in moisture stress during the critical grain-fill period as crops were forced to access stored soil moisture from deep in the soil profile.

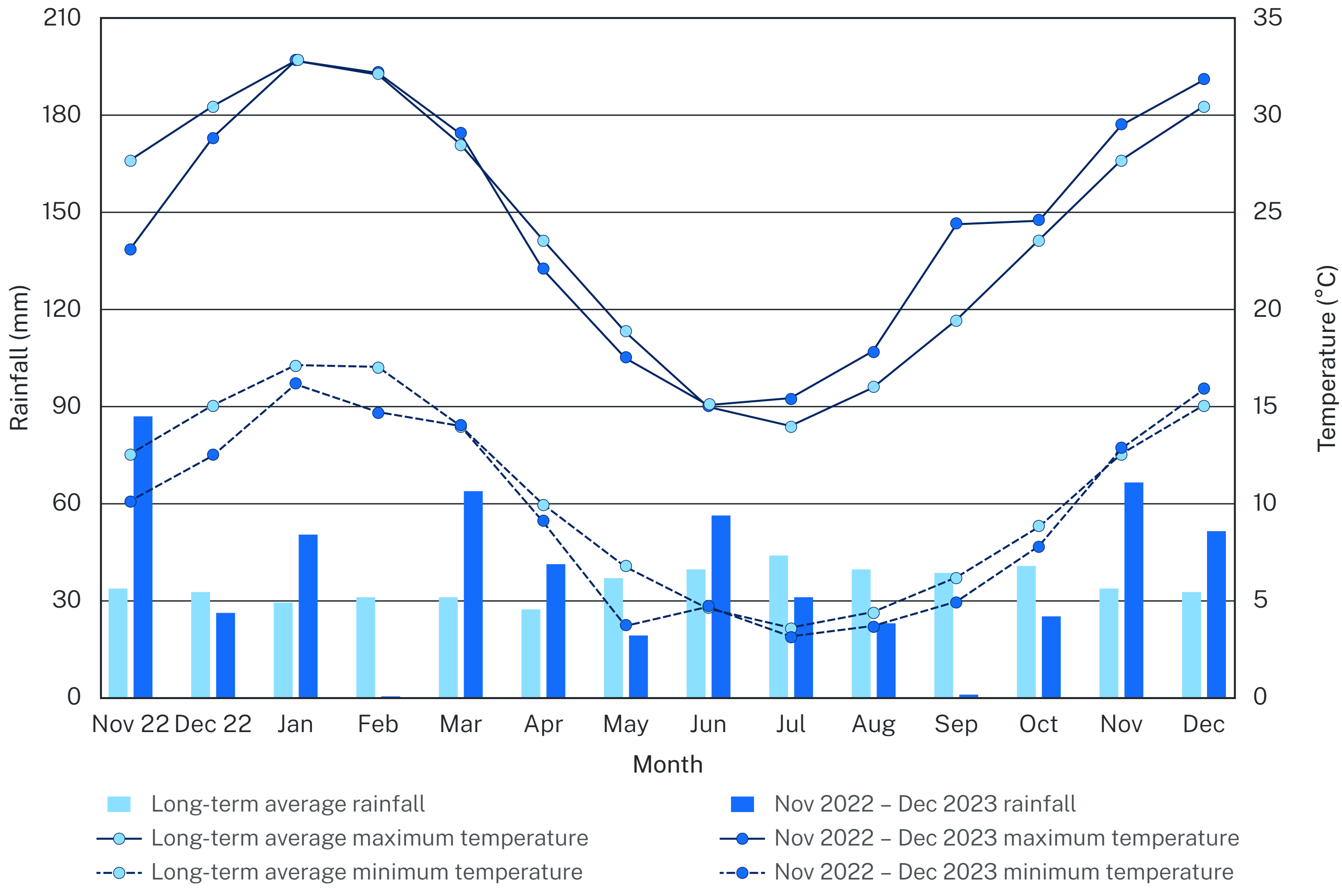
Yield and quality were maintained due to stored soil moisture from the above average autumn rain, which highlighted the importance of summer weed control and early crop establishment.

Temperatures at the institute were generally average with no 'heat shocks' adversely affecting crop yield or quality.

Yanco Agricultural Institute

Minimum temperatures at Yanco were generally near average to below the LTA during 2023 (Figure 3). Maximum temperatures were below average during November and December 2022 and near average to above average during 2023. The maximum temperature for the growing season was 1.3 °C above average, while the minimum temperature for the growing season was 1.1 °C below average.

Rainfall was variable with very high totals in November 2022. Rainfall during the fallow period was 83.1 mm above average, but during the growing season was 83.6 mm below average. High rainfall was also recorded in November 2023.



Data source: ANUClimate, Australian National University.

Figure 3 Average monthly minimum and maximum temperature, and total monthly rainfall from November 2022 to December 2023, and long-term averages (1981 to 2010 baseline period) at Yanco.

Winter crops at Yanco

Generally, Yanco Agricultural Institute had typical average minimum temperatures over the 2023 winter crop growing season, while the average maximum temperatures were slightly higher than the LTA. There was plenty of rainfall over the March–April period to sow the cereal and canola experiments at Leeton Field Station (LFS). With plentiful moisture, all winter cropping experiments were sown on time and established well. The 2023 season was a low frost season with no frost damage observed in any of the winter crop experiments.

Very little pest or disease was recorded in the winter cropping experiments at LFS. Aphid numbers were the lowest observed for many years with almost no aphids observed in any of the early or late sown canola. The cereal experiments were also generally free of insect pressure with only a late season infection of stem borers causing minor damage in one of the cereal experiments. Disease pressure was very low all season in all the cereal and canola experiments.

The dryland winter cropping experiments had a hard finish in the 2023 season due to limited rainfall over the grain fill period. At LFS, there was only 24 mm of rainfall from mid August to late November. There was a large rainfall event at the end of November but it was too late in the growing season to be useful. With low rainfall and higher than average maximum temperatures over the grain fill period, yields were very low where experiments were not irrigated. The November storms did not cause any significant grain quality or harvest issues at the end of the season.

Summer crops at Yanco

The 2023–24 summer cropping season started much like last season, with rain in early October delaying sowing across the region. The dry and warm September prompted some cotton and rice growers to sow earlier in late September, which was reflected in the early sowing date cotton treatments for the cotton experiments at LFS.

During early cotton crop growth and establishment there was high weed and insect pressure, a result of higher-than-average rainfall in back-to-back wet summer seasons and the favourable warm dry conditions early in the season. Leeton Field Station cotton experiments also had high weed pressure and early thrips damage in October. The wet October also led to weed issues in rice crops where pre-emergent herbicide applications could not be used due to the wet weather, so alternative herbicide programs were used to good effect.

Periods of cool, wet weather in October were quickly followed by warmer temperatures from November regularly in the 30s to 40s, resulting in the rapid accumulation of day degrees. The cotton experiments at LFS had relatively delayed growth early in the season, but rapidly developed from November allowing key growth stages such as first flower to occur within an optimal timeframe. The dry and warm conditions were optimal for rice growth after permanent water and for panicle initiation in late December to early January.

Harvest conditions were ideal for both rice and cotton with mostly dry weather, small periods of rain and multiple opportunities with good night conditions that allowed most growers to get their summer crops harvested in time.

The 2023–24 season was excellent in comparison with the previous year, with ideal conditions for summer cropping, which was reflected in high yields across the region.

Disease

Winter cereals

The start of the 2023 cropping season was marked by favourable conditions for disease, primarily due to average or above-average rainfall in autumn. This facilitated early sowing and disease development in crops.

Widespread, early septoria tritici blotch (STB) infection was evident in the lower canopy of susceptible wheat varieties across southern NSW (sNSW). However, unlike 2022, these infections did not progress to the upper canopy during grain filling, thereby averting significant yield losses. The contrasting infection levels between 2022 and 2023 can be attributed to notable climatic differences. Crucially, during August, September, and October in 2023 there were considerably fewer rain days and fewer consecutive rain days compared with 2022. The reduced rainfall, decreased leaf wetness duration, higher-than-average temperatures and proactive fungicide use at stem elongation, all contributed to STB staying in the lower to mid canopy of wheat crops. This pattern was not consistent for the entire cropping area of sNSW, particularly in the higher rainfall slopes regions, where STB continued to be a problem throughout the entire 2023 season.

Stripe rust developed early in the 2023 growing season. Similarly, to STB, this was halted by a combination of climatic conditions, sowing more resistant cultivars, and improved management – in particular, the increased use of flutriafol on fertiliser. The stripe rust population continued to be dominated by pathotypes 238 E191 A+ 17+ 33+ ('238') and 239 E237 A- 17+ 33+ ('239') making up 89% of the samples submitted to Australian Cereal Rust Survey at Sydney University. The pathotype 198 E16 A+ J+ T+ 17+ ('198'), which was the predominate pathotype during the 2020 season, continued to decline in the 2023 season.

The 2023 season NSW DPI/GRDC paddock surveys revealed the high levels of crown rot through the cropping region. Crown rot inoculum levels are being driven by growers repeatedly sowing cereals in succession, tight cereal broadleaf crop rotations and increasingly retaining cereal stubble.

Due to high residual wheat stubble loads from the high-yielding years of 2021 through to 2023, the risk of STB and crown rot inoculum is elevated for the 2024 season. However, the incidence of foliar diseases such as STB and stripe rust is highly dependent on climatic conditions, and the 2024 growing season conditions will determine the severity of any epidemic.

Winter pulse and oilseed

El Niño conditions in 2023 dominated the season across the region and kept crop yield potentials in check. Whilst autumn rains allowed crops to be sown on time and into high soil moisture levels across the region, warm and dry conditions in spring reduced crop yield potential in many districts across all broadleaf crops.

Late winter rainfall was below average in July and August, but crop growth remained steady with above average temperatures. Blackleg developed in canola crops at the end of May to early June, which is typical for the time of year. Crop surveys in 2023 started in August and detected blackleg in most of the canola crops assessed in southern and central NSW, and Sclerotinia in 40% of crops. However, warm dry conditions in September halted foliar disease development in pulse and oilseed crops across the region. The diseases that required judicious use of foliar fungicides in 2022 did not develop to significant levels in 2023, despite high background inoculum levels of sclerotinia stem rot, blackleg of canola, chocolate spot of faba bean and botrytis grey mould of lentil.

The positive yield responses to foliar fungicides in 2022 were much reduced in 2023, reinforcing the seasonal variability in the economics of fungicide use to manage disease.

The high levels of Sclerotinia infection in crops in 2022 still has the potential to affect crops for the next few seasons, despite dry conditions in 2023. Growers should continue to maintain vigilance for disease development in broadleaf crops in 2024.

Further information

Australian Cereal Rust Survey, The University of Sydney website, accessed 25 July 2024. https://www.sydney.edu.au/science/our-research/research-areas/life-and-environmental-sciences/cereal-rust-research/rust-reports.html

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Long coleoptile durum wheat experiment – Riverina 2023

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Key findings

- With adequate soil moisture, sowing durum wheat earlier in the season (22 May) at either 4 cm (0.48 t/ha benefit) or 12 cm deep (1.64 t/ha benefit) produced the highest yield compared with a later sowing (21 June).
- With earlier sowing, when there is not enough soil moisture at 4 cm, and the option to sow deeper at 12 cm into moisture is taken, equivalent yield can be achieved even though establishment was reduced.
- Deeper sowing at 12 cm must be done earlier in the season as delaying by 4 weeks resulted in reduced yield compared with shallower sowing at 4 cm.
- DBA Aurora⫯ was the best performing durum variety with the highest grain yield at both sowing depths and sowing dates. The long coleoptile durum lines did not demonstrate any advantage over the commercial durum varieties in this experiment.
- The effects of fusarium crown rot (FCR) on yield were reduced with earlier sowing with 8% (0.30 t/ha) yield loss when sown on 22 May and 16% (0.45 t/ha) yield loss when sowing was delayed until 21 June. Earlier sowing, even if it requires an increase in sowing depth to 12 cm appears to be a useful strategy to minimise yield loss from FCR in higher risk paddocks.

Keywords Durum, variety, grain yield, sowing depth, sowing date

Introduction

In seasons when the autumn break is delayed, growers might consider the option to sow cereals deeper than the normal 4–5 cm in search of adequate soil moisture to allow seed germination and emergence. When sowing depth is increased to 12 cm, there is the potential for wheat varieties with genetically longer coleoptiles to improve crop establishment and productivity. This experiment assessed yield and fusarium crown rot (FCR) outcomes associated with planting at 2 different depths for both early and later sowing within the sowing window.

We asked the questions: should growers adopt longer coleoptile durum varieties to improve establishment when sowing deeper, and what is the risk vs reward of these strategies for growers?

Site details

Location	Leeton Field Station (LFS)
Soil type	Self-mulching medium clay
Previous crop	Fallow (2022), wheat (2021)

Soil starting nitrogen (N)	95 kg N/ha (60 cm deep)
Fertiliser	• Pre-sowing: 100 kg/ha of mono-ammonium phosphate (MAP) (10 kg N/ha) • Top-dressing: 110 kg/ha of urea (50 kg N/ha)
Row spacing	350 mm
In-season rainfall	• Autumn: 9 mm • Winter: 102 mm • Spring: 25 mm
Fungicides	Veritas (200 g/L tebuconazole and 120 g/L azoxystrobin) at 600 mL/ha (× 3)
Herbicides	• Trilogy (480 g/L trifluralin) at 1.7 L/ha • Boxer Gold (800 g/L prosulfocarb and 120 g/L S-metolachlor) at 2.5 L/ha • Axial (100 g/L pinoxaden and 25 g/L cloquintocet-mexyl) at 600 mL/ha

Treatments

The experiment comprised 3 replicates of 6 varieties × 2 FCR treatments (minus and plus FCR) × 2 sowing depths × 2 sowing dates, with a total of 144 plots (Table 1). All plots were 1.4 m wide (4 rows at 35 cm apart) and 12 m long. The experiment was sown using a cone seeder for both seed placement and base fertiliser application. Nitrogen was topdressed as urea when the crop was at the GS31 growth stage and broadcast by hand.

Table 1 Treatments (sowing date, target sowing depth, FCR status and genotype) evaluated in the 2023 LFS long coleoptile durum wheat (LCDW) experiment.

Treatment	Comment
Sowing date (SD)	
SD1: 22 May	Early in the sowing window for the Riverina
SD2: 16 June	Late in the sowing window for the Riverina
Target depth	
4 cm	Actual depth ranged from 3.7 cm to 4 cm
12 cm	Actual depth ranged from 10 cm to 12 cm
FCR status	
Minus FCR	FCR inoculum NOT added to seed before sowing
Plus FCR	FCR inoculum added to seed before sowing
Genotype	
DBA Aurora⏀	Commercial durum variety
Scepter⏀	Commercial bread variety
DBA Vittaroi⏀	Commercial durum variety
V190245-6	Long coleoptile durum line
V189631-3	Long coleoptile durum line
V189586-4	Long coleoptile durum line

Measurements

Plant counts were conducted 3 times/week to determine emergence date and plant density. The date for emergence was determined when at least 50% of the final plant density had emerged. Final plant density was assessed 5 weeks after sowing. Early biomass accumulation was assessed using hand cuts at the GS31 growth stage. Early biomass samples were collected evenly across all 4 plant lines. Biomass samples were dried, weighed and expressed as g/m^2.

All plots were sown 12 m long and reduced to 10 m before harvest. The 10 m plots were harvested using a Kingaroy plot header with all 4 rows harvested to determine grain yield. Subsamples from the machine harvest were collected and used to determine grain quality with yield calculated at 12% grain moisture.

Results

Emergence, establishment and early growth

Average soil temperatures were relatively stable across sowing depths with a 0.1 °C increase between 4 cm and 12 cm depths in both SD1 and SD2 (Table 2).

Increasing sowing depth from 4 cm to 12 cm delayed emergence by 2.4 days for SD1. A longer delay of 4.3 days occurred for SD2 when the sowing depth was increased from 4 cm to 12 cm.

A large variation in early biomass accumulation by GS31 was observed between sowing date and sowing depth. Delaying sowing or increasing the sowing depth significantly decreased biomass accumulation. Biomass underpins yield; generally, the more biomass the better the yield. The average early biomass accumulation for SD1 at 4 cm was 100.8 g/m^2. The average early biomass accumulation for SD2 at 12 cm depth was 5.8 g/m^2, which is only 5.7% of SD1 at 4 cm (Table 2).

Table 2 Average measured soil temperature at 2 sowing depths and 2 sowing dates and the effect on days to emergence and early growth for the 2023 LCDW experiment at LFS.

Sowing depth	Soil temperature (°C)		Emergence (days)		Early biomass (g/m^2)	
	SD1	SD2	SD1	SD2	SD1	SD2
4 cm	12.4	9.2	13.0 [a]	21.1 [c]	100.8 [a]	61.8 [b]
12 cm	12.3	9.3	15.4 [b]	25.4 [d]	45.7 [c]	5.8 [d]

Values followed by the same letter are not significantly different at the 95% confidence level.

Scepter$^{\phi}$ sown at 4 cm deep had the highest density with 106.9 plants/m^2 and was statistically similar to the longer coleoptile variety V189586-4 at 4 cm, which had an average density of 99.1 plants/m^2 (Table 3). Scepter$^{\phi}$ sown at 12 cm had the lowest average density with 26.5 plants/m^2 and was statistically similar to DBA Aurora$^{\phi}$ at 12 cm with 34.1 plants/m^2.

Table 3 Effect of 2 sowing depths (averaged across both sowing dates) on density (plants/m^2) on one bread wheat and 5 durum wheat varieties for the 2023 LCDW experiment at LFS.

Variety	Sowing depth	
	4 cm	12 cm
DBA Aurora	88.7 [bcd]	34.1 [fg]
Scepter	106.9 [a]	26.5 [g]
Vittaroi	97.4 [abc]	38.2 [ef]
V190245-6	88.4 [cd]	39.6 [ef]
V189631-3	86.1 [d]	41.0 [ef]
V189586-4	99.1 [ab]	46.2 [e]
Average	94.1	46.2

Values followed by the same letter are not significantly different at the 95% confidence level.

SD2 at 4 cm achieved the highest average density with 97.6 plants/m^2 yet was statistically similar to SD1 at 4 cm with an average density of 91.6 plants/m^2 (Table 4). SD2 at 12 cm had the lowest density with 20.4 plants/m^2 and was significantly lower than all other combinations of sowing date and sowing depth.

Table 4 Effect of 2 sowing dates on density (plants/m^2) at 2 sowing depths for the 2023 LCDW experiment at LFS.

Sowing depth	Sowing date	
	SD1	SD2
4 cm	91.6 ^{a}	97.6 ^{a}
12 cm	54.9 ^{b}	20.4 ^{c}

Values followed by the same letter are not significantly different at the 95% confidence level.

Grain yield

Grain yield averaged 3.10 t/ha across all variety, sowing date, depth and fusarium treatments. DBA Aurora(D) was the highest yielding variety when averaged across all treatments at 3.68 t/ha and was statistically similar to Scepter(D) that had an average yield of 3.50 t/ha (Table 5). The 3 long coleoptile varieties (V189631-6, V189631-3 and V189586-4) all had a significantly lower average yield than DBA Aurora(D) or Scepter(D).

Table 5 Average grain yield (t/ha) for the one bread wheat and 5 durum wheat varieties in the 2023 LCDW experiment at LFS.

Variety	Grain yield
DBA Aurora	3.68 ^{a}
Scepter	3.50 ^{a}
Vittaroi	3.16 ^{b}
V190245-6	3.15 ^{b}
V189631-3	2.56 ^{c}
V189586-4	2.55 ^{c}
Average	3.10

Values followed by the same letter are not significantly different at the 95% confidence level.

SD1 sown at 4 cm achieved the highest average grain yield of 3.69 t/ha and was statistically similar to SD1 at 12 cm with an average yield of 3.57 t/ha (Table 6). SD2 sown at 12 cm had the lowest average grain yield with 1.93 t/ha and was significantly lower yielding than all other combinations of sowing date and sowing depth.

Table 6 Effect of 2 sowing dates on yield (t/ha) at 2 sowing depths for the 2023 LCDW experiment at LFS.

Sowing depth	Sowing date	
	SD1	SD2
4 cm	3.69 ^{a}	3.21 ^{b}
12 cm	3.57 ^{a}	1.93 ^{c}

Values followed by the same letter are not significantly different at the 95% confidence level.

DBA Aurora(D) at SD1 achieved the highest average grain yield with 4.23 t/ha and was statistically similar to Scepter(D) at SD1 with an average yield of 4.06 t/ha (Table 7). V189586-4 in SD2 and V189631-3 in SD2 had the lowest average grain yield with 2.02 t/ha and 2.12 t/ha respectively.

Scepter at 4 cm achieved the highest grain yield with 4.31 t/ha and was statistically similar to DBA Aurora at 4 cm with an average yield of 4.20 t/ha (Table 7). V189586-4 at 12 cm had the lowest average grain yield with 2.41 t/ha but was statistically similar to V189631-3 at 12 cm, V189586-4 at 4 cm, V189631-3 at 4 cm and Scepter at 12 cm.

Table 7 Average effect of 2 sowing dates and 2 sowing depths on yield (t/ha) on one bread wheat and 5 durum wheat varieties for the 2023 LCDW experiment at LFS.

Variety	Sowing date		Sowing depth	
	SD1	SD2	4 cm	12 cm
DBA Aurora	4.23 [a]	3.14 [c]	4.20 [a]	3.17 [cd]
Scepter	4.06 [a]	2.93 [c]	4.31 [a]	2.69 [efg]
Vittaroi	3.69 [b]	2.64 [d]	3.56 [b]	2.77 [ef]
V190245-6	3.73 [b]	2.57 [d]	3.39 [bc]	2.91 [de]
V189631-3	3.00 [c]	2.12 [e]	2.59 [fg]	2.53 [fg]
V189586-4	3.07 [c]	2.02 [e]	2.68 [efg]	2.41 [g]
Average	3.63	2.57	3.45	2.75

Values followed by the same letter are not significantly different at the 95% confidence level.

Fusarium

SD1 minus FCR achieved the highest average grain yield with 3.78 t/ha and was significantly higher yielding than SD1 plus FCR with 3.48 t/ha (Table 8). SD2 minus FCR achieved a grain yield of 2.80 t/ha which was significantly higher than SD2 plus FCR with 2.35 t/ha. Earlier sowing even in the presence of FCR infection was still 0.68 t/ha higher yielding than delayed sowing in the absence of FCR.

The sowing depth of 4 cm minus FCR achieved the highest average grain yield with 3.76 t/ha and was significantly higher yielding than the 4 cm sowing depth plus FCR with 3.15 t/ha (Table 8). The presence of FCR did not have a significant effect on yield at 12 cm. Sowing depth of 12 cm minus FCR achieved a grain yield with 2.82 t/ha which was statistically similar to the 12 cm plus FCR treatment with an average yield of 2.67 t/ha.

Table 8 Effect of 2 sowing dates and 2 sowing depths on yield (t/ha) with and without the presence of FCR for the 2023 LCDW experiment at LFS.

FCR	Sowing date		Sowing depth	
	SD1	SD2	4 cm	12 cm
Minus FCR	3.78 [a]	2.80 [c]	3.76 [a]	2.82 [c]
Plus FCR	3.48 [b]	2.35 [d]	3.15 [b]	2.67 [c]

Values followed by the same letter are not significantly different at the 95% confidence level.

Summary

There was a significant yield penalty associated with delayed sowing. At the shallower sowing depth (4 cm), delayed sowing delivered an average yield penalty of 0.48 t/ha (13%) and an average yield penalty of 1.64 t/ha (46%) at the deeper sowing depth (12 cm). The yield reduction from delayed sowing varied between varieties from 1.09 t/ha (25%) with DBA Aurora to 1.16 t/ha (31%) with V190245-6.

There was no yield difference between sowing depths for the early sowing date (SD1), but a significant yield reduction was seen in the later sowing date (SD2). An average yield reduction across all varieties of 1.28 t/ha (40%) was observed for SD2 when the sowing depth was increased from 4 cm to 12 cm. A significant interaction between varieties and sowing depth was observed. DBA Aurora, Scepter, DBA Vittaroi and V190245-6 all demonstrated a yield reduction from 4 cm to 12 cm when averaged across both sowing dates, while V189631-3 and V189586-4 demonstrated no yield penalty from 4 cm to 12 cm sowing depths.

Increasing sowing depth significantly reduced plant density for both sowing dates. Sowing depth and sowing date also had a significant effect on early biomass accumulation. Sowing deeper (12 cm) and delaying sowing (SD2) significantly reduced early biomass, which was probably associated with lower grain yield at harvest.

There was a significant yield penalty when FCR was present. At SD1 there was an average yield loss of 0.30 t/ha (8%) with FCR and at SD2 there was an average yield loss of 0.45 t/ha (16%) with FCR.

Earlier sowing, even if it requires an increase in sowing depth to 12 cm appears to be a useful strategy to minimise yield loss from FCR in higher risk paddocks. This highlights the strong interaction between FCR expression and yield loss with moisture and/or temperature stress during grain filling. Earlier sowing to reduce the extent of stress during grain filling provided significant yield benefit both in the presence and absence of FCR infection in this experiment.

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More information

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In-season agronomic manipulation of early sown spring wheat; to delay flowering and reduce frost effects – Wagga Wagga 2023

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Key findings

- This study showed it is possible to reset the flowering time for early sown quick–mid spring wheat varieties through in-crop mechanical defoliation, apical pruning, during early stem elongation (GS31–32).
- Depending on the intensity of the defoliation treatment, anthesis, was delayed by up to 25 days for Scepter⁽ᴰ⁾ from a 5 April sowing date (SD), which resulted in a significant increase in yield compared with the undefoliated control at 5.49 t/ha vs 4.31 t/ha.
- The heavy defoliation treatment enabled Scepter⁽ᴰ⁾ to reach anthesis on 25 September from the 5 April sowing, around the start of the optimum flowering period (OFP) for this environment, as opposed to the untreated control, which flowered on 31 August.
- Although apical pruning was shown to increase the yield potential of early sown quick–mid spring wheats, it was still not able to out-yield Illabo⁽ᴰ⁾, a locally well adapted mid winter wheat variety sown in its preferred sowing window, which achieved the highest yield of 7.40 t/ha.
- The best performing heavily defoliated Scepter⁽ᴰ⁾ was only able to achieve 89% (5.49 t/ha) of the yield from Scepter⁽ᴰ⁾ sown in its preferred sowing window (6.19 t/ha).
- Yield potential tends to be optimised when the correct phenology type is sown in its preferred window, so that it flowers within the OFP for a given environment.
- Apical pruning should only be considered as a possible management strategy when quick–mid spring wheats have been sown well outside their preferred window and/or are developing such that there is an increased risk of yield loss due to frost risk.

Keywords Apical pruning, mechanical defoliation, anthesis, grain yield, grain protein, optimal flowering period

Introduction

The aim of this experiment was to investigate the effect of mechanical defoliation and intensity, as a method of 'resetting flowering time' to stabilise the yield potential of early sown and/or quick maturing spring wheats. If successful, this would provide a strategy to reset flowering time and slow down the development of spring varieties sown either too early and/or developing too quickly.

Apical pruning by mechanical defoliation during early stem elongation (GS31–32) aims to remove and/or impede the emerging apical meristem/shoot apex, to impose a phenology reset on fast developing spring wheat crops (Porker et al. 2022). This is in contrast to what is generally the accepted practice when grazing dual-purpose winter wheats where defoliation/grazing is not recommended after the onset of stem elongation (i.e. GS30) so as to avoid damage to the emerging apical meristem.

The objective of this approach was to delay crop development so that flowering occurs within or close to the OFP for a given environment. This aims to:

- balance the risks of frost damage during flowering and moisture and heat stress during grain fill
- minimise production risk
- optimise grain yield potential.

Site details

Location	Wagga Wagga Agricultural Institute
Soil type	Red chromosol
Paddock history	Canola (2022), lupin (2021)
Sowing	Direct drilled with DBS tynes spaced at 250 mm using a GPS auto-steer system
Target plant density	120 plants/m^2
Soil pH_{Ca}	6.1 (0–5 cm); 5.4 (5–10 cm); 5.1 (10–15 cm); 5.2 (15–20 cm)
Mineral nitrogen (N)	142 kg N/ha at sowing (1.2 m depth)
Fertiliser	• 100 kg/ha mono-ammonium phosphate (MAP), treated with 200 mL/ha flutriafol at sowing. • In addition, a total of 110kg N/ha as urea (240 kg/ha urea) was applied after sowing. Of the 110kg N/ha, 46 kg N/ha (100 kg/ha of urea) was applied on 19 June with the remaining 64 kg N/ha (140 kg/ha of urea) applied to all treatments on 26 July.
Weed control	• Knockdown: 1.0 L/ha Crucial® (600 g/L glyphosate) at sowing. • Pre-emergent: 118 g/ha Sakura® + 1.6 L/ha Avadex® Xtra + 1 L/ha TriflurX® incorporated by sowing (pre-sowing – SD1: 5 April; SD2: 5 May; SD3: 15 May). • In-crop: 600 mL/ha MCPA 570 LVE + 25 g/ha Paradigm® Arylex® + 5% Uptake spray oil (27 June).
Disease and pest management	• Seed treatment: 2 L/t Hombre® Ultra + 2.6 L/t EverGol® Energy. • In-crop: 250 mL/ha Soprano® 500 + 0.25% SpreadWet 1000 (SD1 only on 1 June). All other sowing dates including SD1 received 400 mL/ha AmistarXtra® (27 June), 200 mL/ha Bumper® 625 (24 July) 400 mL/ha AmistarXtra®+600 mL/ha chlorpyrifos (17 August), 300 mL/ha Prosaro® 420SC (6 September).
Harvest date	27 November 2023

Rainfall	• In-crop
	  • 227 mm (April–October, Table 9)
	  • Long-term average: 352 mm	

Severe temperature events

- Three heat stress events (days >30 °C): 32.8 °C (18 September), 31.9 °C (19 September) and 35.3 °C (21 October).
- Eleven frosts (minimum temperature [T min] <0 °C ≥−2.0 °C) including: −2.0 °C (15 August), −1.0 °C (24 August) and 5 events (T min ≤−1.0°C) recorded in the first 2 weeks of September including −1.4 °C on 6 September (Figure 4). There was also 0 °C recorded on 17 October.

Table 9 In-crop monthly rainfall.

Month	April	May	June	July	August	September	October
Rainfall (mm)	72	13	58	27	32	5	20

Growing conditions The site had approximately 80 mm of plant available water (PAW) at sowing, after 320 mm of fallow rain (November 2022 – March 2023). This combined with April rain of 72 mm and follow-up rain of 58 mm in June (Table 9), meant that all sowing dates were successfully established under good soil moisture conditions. In contrast, the spring was characterised by a warm, dry September, with temperatures exceeding 30 °C on 2 consecutive days, 18 and 19 September with only 5.2 mm of rain recorded for the month (Figure 4). Consequently, there was the potential for yield penalty associated with later flowering, particular for the longer season varieties.

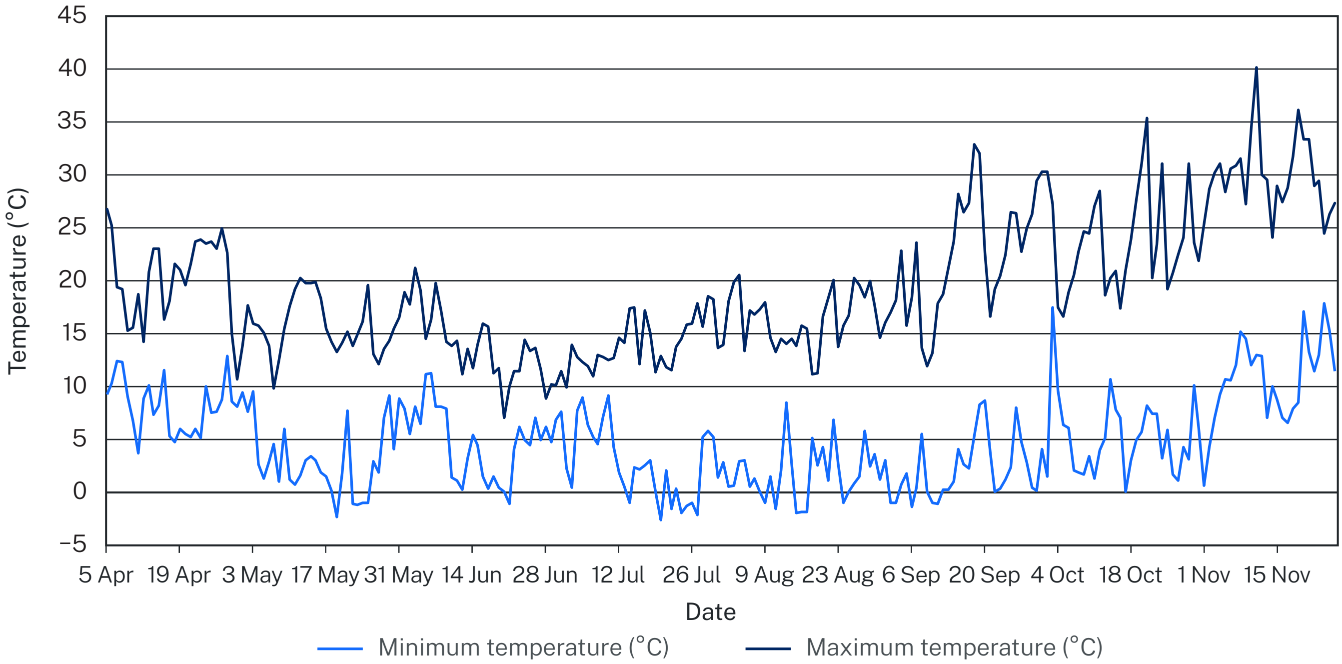

Figure 4 Minimum temperature (T Min) and maximum temperature (T Max) recorded at the Wagga Wagga site in 2023.

Frosts also affected the 2023 growing season, particularly in late August and early spring, with 5 frosts (T min ≤−1.0 °C) recorded in the first 2 weeks of September. These coincided with the critical development stage of early flowering, resulting in the potential for significant yield penalties.

Treatments

Variety

Six wheat genotypes (Table 10), varying in phenology type, were sown on 3 sowing dates.

Sowing date (SD)

- SD1: 5 April
- SD2: 5 May
- SD3: 15 May

Table 10 Phenology responses of genotypes according to the Australian Cereal Phenology Classification (Celestina et al. 2023).

Phenology types	Varieties
Slow winter (SW)	DS Bennett$^{\phi}$
Mid winter (MW)	Illabo$^{\phi}$
Slow–very slow spring	LRPB Nighthawk$^{\phi}$
Mid spring (MS)	Rockstar$^{\phi}$
Quick–mid spring (Q–MS)	Scepter$^{\phi}$
Quick spring (QS)	Vixen$^{\phi}$

Mechanical defoliation

Mechanical defoliation treatments were applied at differing intensities based on cutting height using a slasher. Vixen$^{\phi}$ for both SD1 and SD2 and Scepter$^{\phi}$ for SD1, had treatments applied when growth stages were ≥GS31 and ≤GS32 (Table 11). The defoliation intensity levels (Figure 5) were:

- heavy cut 2–4 cm from the plant base
- medium cut 4–8 cm from the plant base.

Table 11 Date defoliation treatments were applied and key growth stage timings.

Sowing date and variety	Defoliation date	GS31	GS32
SD1 Vixen	25 May	25 May	5 June
SD1 Scepter	15 June	5 June	19 June
SD2 Vixen	13 July	12 July	24 July

Crop measurements included flowering time, biomass at anthesis (GS65), harvest index, grain yield and yield components.

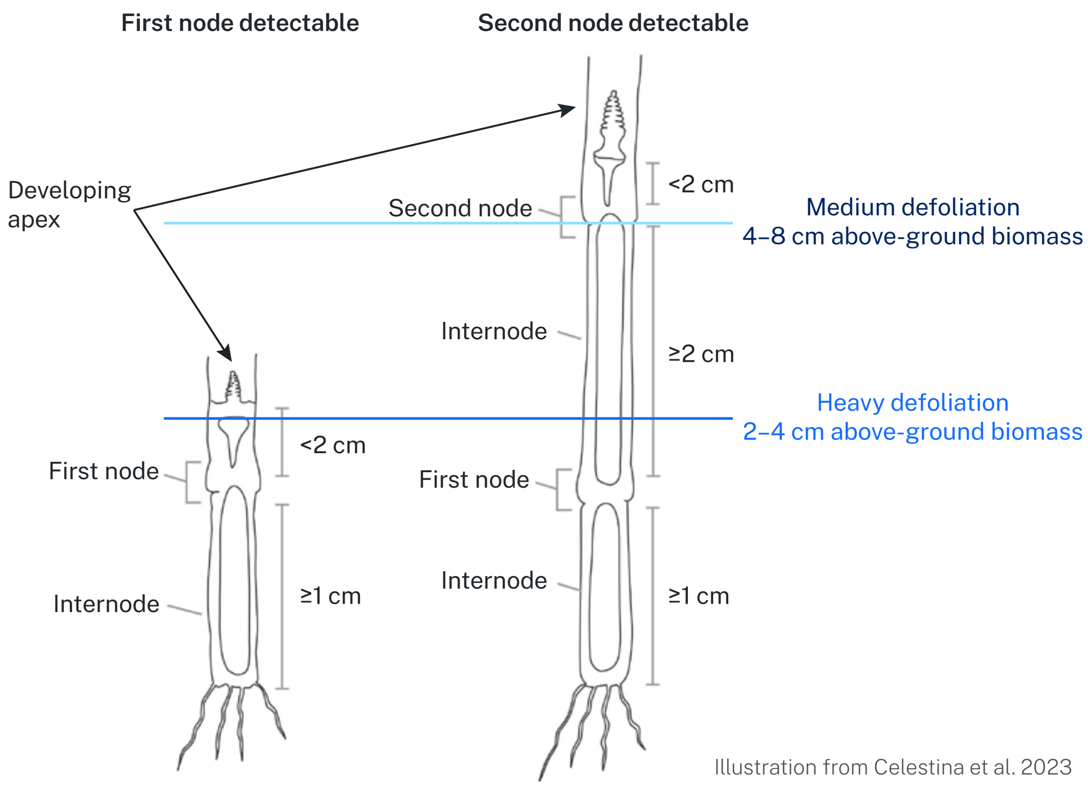

Figure 5 Schematic of defoliation intensities at GS31–32.

Results

This experiment demonstrated that apical pruning delayed or reset the flowering time of spring wheat varieties sown earlier than their ideal window. For Scepter⦶, sown on 5 April (SD1) approximately 4 weeks earlier than the start of its recommended sowing window for this environment (Matthews et al. 2023), the medium and heavy defoliations delayed anthesis (GS65) by 21 and 25 days respectively (Table 12). Likewise, the medium and heavy defoliation treatments, when applied to Vixen⦶ a quicker spring type than Scepter⦶ sown approximately 5 weeks earlier than its preferred window (SD1), were able to delay GS65 by 13 and 9 days respectively. The difference between the 2 varieties in terms of delay in anthesis, in response to defoliation treatments for SD1, might have been due to differences in the actual growth stage when the treatments were applied. Vixen⦶ in SD1 for example, had the defoliation treatments applied just as it reached GS31, whereas Scepter⦶ was closer to GS32 (Table 11). Vixen⦶ for SD2 was also closer to GS31 than GS32, resulting in only a 6 day delay in anthesis. These results are consistent with previous findings where anthesis delays in response to defoliation was shown to be influenced by intensity and the growth stage at which the defoliation treatment was applied (Graham et al. 2023). The more advanced the growth stage and defoliation intensity, the greater the delay in time to reach anthesis.

Table 12 Effect of defoliation treatment on flowering time and grain yield (t/ha).

Sowing date and variety	Treatment	Flowering date	Defoliation effect (days delayed)*	Grain yield (t/ha)
SD1: 5 April				
Vixen	Untreated control	25 August †	–	0.93
Vixen	Medium defoliation	3 September	9	2.07
Vixen	Heavy defoliation	7 September	13	2.44
Scepter	Untreated control	31 August	–	4.31
Scepter	Medium defoliation	21 September	21	4.74
Scepter	Heavy defoliation	25 September	25	5.49
Rockstar	Phenology control	6 September	–	6.53
LRPB Nighthawk	Phenology control	20 September	–	6.67
Illabo	Phenology control	22 September	–	7.40
DS Bennett	Phenology control	5 October	–	6.24
SD2: 5 May				
Vixen	Untreated control	19 September	–	6.61
Vixen	Medium defoliation	23 September	4	5.79
Vixen	Heavy defoliation	24 September	6	5.24
Scepter	Phenology control	22 September	–	6.19
Rockstar	Phenology control	25 September	–	6.01
LRPB Nighthawk	Phenology control	3 October	–	5.07
Illabo	Phenology control	2 October	–	4.97
DS Bennett	Phenology control	10 October	–	4.93
SD3: 15 May				
Vixen	Phenology control	25 September	–	5.77
Scepter	Phenology control	28 September	–	5.44
Rockstar	Phenology control	28 September	–	5.43
LRPB Nighthawk	Phenology control	7 October	–	4.34
Illabo	Phenology control	5 October	–	4.48
DS Bennett	Phenology control	10 October	–	4.25
P value				$P<0.0001$
l.s.d. ($P<0.05$)				0.52

* Defoliation effect on anthesis (days delayed) relative to untreated control.

† 50% anthesis date.

Grain yield

Grain yield results for this study showed that Illabo⊕, a mid winter phenology control sown in the early part of its preferred sowing window on 5 April (SD1), and flowering on 22 September around the start of the OFP for this environment, achieved the highest yield of 7.40 t/ha (Table 12). Illabo⊕ from SD1, was also the only variety × sowing date combination that was significantly higher yielding than the traditional on-time sown SD2 quick–mid spring Scepter⊕. When sowing was delayed, grain yield for Illabo⊕ declined in response to later flowering, due principally to a corresponding increase in heat and moisture stress, and exhibited a typical yield response curve for this phenology type in this environment: yield declining with delays in sowing date. The other slower phenology types, DS Bennett⊕ and LRPB Nighthawk⊕, displayed similar yield responses, with yield declining in response to delays in sowing date and hence anthesis.

In contrast, when Scepter⊕ was sown on 5 April (SD1) much earlier than it's preferred window, it suffered a 30% or 1.88 t/ha yield penalty (SD1: 4.31 t/ha vs SD2: 6.19 t/ha). This was due to frosts during the critical growing period, Scepter⊕ having reached anthesis on 31 August (Table 12). When Scepter⊕ was sown in a more favourable sowing window, on

5 May (SD2), it achieved its highest yield of 6.19 t/ha, reaching anthesis on 22 September. Importantly, when the heavy defoliation treatment was applied to Scepter⊕ for SD1, it was able to delay anthesis by 25 days, resulting in a 1.18 t/ha or 27% increase over the untreated control (5.49 t/ha vs 4.31 t/ha). The medium defoliation treatment, although able to delay anthesis for Scepter⊕ for SD1, resulting in a slight, but not significant, increase in yield. Although findings showed that targeted defoliation treatments for Scepter⊕ for SD1, were able to delay anthesis, to a similar period as the Scepter⊕ phenology control for SD2, there was still a yield penalty with the best performing heavy defoliated treatment Scepter⊕ SD1, achieving 89% of the Scepter⊕ yield for SD2.

Results for Vixen⊕, a quick spring type sown much earlier (i.e. SD1) than its preferred window, showed that there was a severe yield penalty associated with early flowering. This was related to a number of frosts during the critical developmental period in 2023, which included a −1.0 °C on 24 August and 5 further events (T min ≤−1.0° C) recorded in the first 2 weeks of September. Although these defoliation treatments were able delay flowering and resulted in significant increases in yield over the untreated control, they were still well below yields achieved for later sowing dates (SD2 and SD3). The best performing, the heavy defoliation Vixen⊕ treatment for SD1 only achieved 37% and 42% respectively of the Vixen⊕ controls for SD2 and SD3. Importantly, it should be noted that when sowing date was delayed and defoliation treatments were applied to Vixen⊕ in SD2, there was yield penalty associated with defoliation and intensity that was related to a decrease in biomass accumulation (Table 13).

These results further highlight the need to sow the correct phenology type in its preferred sowing window. Findings from this experiment did, however, show that defoliating quick wheats early did delay anthesis and was capable of alleviating some of the yield penalties associated with early flowering and frost risk. An understanding of frost risk and heat and moisture stress as it relates to phenology type and sowing options for a given environment is essential to optimise yield potential and manage season risk factors.

Grain quality

Results for Scepter⊕ in this study, showed that there was both a decrease in thousand seed weight (TSW) and grain protein (%) in response to the defoliation treatments for SD1 (Table 13). Although, in terms of grain yield, there was no significant difference between the untreated Scepter⊕ control and the medium defoliation, there were significant differences in both TSW and grain protein. The decrease in grain protein and TSW was further exacerbated under the heavy defoliation treatment, although it should be noted that grain yield was significantly greater than both the control and medium defoliation treatments. These results underline the need to consider adequate nitrogen to compensate for loss of biomass due to defoliation, in order to achieve both yield potential and to meet targeted grain protein classifications.

Table 13 Effect of defoliation treatments on grain yield, GS65 biomass, grain protein and seed weight.

Sowing date and variety	Treatment/timing	Grain yield (t/ha)	GS65 DM (kg/ha)	Grain protein (%)	Seed weight (g/1000)*
SD1: 5 April					
Scepter	Untreated control	4.31	15482	15.21	49.35
Scepter	Medium defoliation	4.74	10899	12.71	43.69
Scepter	Heavy defoliation	5.49	8829	10.71	40.03
Vixen	Untreated control	0.93	14297	15.34	45.70
Vixen	Medium defoliation	2.07	12550	15.76	48.15
Vixen	Heavy defoliation	2.44	11421	15.46	46.84
SD2: 5 May					
Scepter	Untreated control	6.19	14258	13.63	34.88
Vixen	Untreated control	6.61	14570	12.83	30.63
Vixen	Medium defoliation	5.79	10591	12.01	30.66
Vixen	Heavy defoliation	5.24	8182	12.96	32.94
SD3: 15 May					
Scepter	Untreated control	5.44	12600	12.42	32.56
Vixen	Untreated control	5.76	11801	13.61	28.64
P value		*P*<0.0001	*P*<0.0001	*P*<0.0001	*P*<0.0001
l.s.d. (*P*<0.05)		0.52	1348	2.36	2.43

* Thousand seed weight (TSW).

Summary

This study demonstrated that it is possible to reset the flowering time of early established spring wheat varieties through in-crop mechanical defoliation during early stem elongation (GS31–32). Depending on the intensity of the defoliation treatment, anthesis for example, was delayed by up to 25 days for Scepter$^{\phi}$ from SD1 and resulted in a significant increase in yield compared with the control. The heavy defoliation treatment enabled Scepter$^{\phi}$ to reach anthesis on 25 September for SD1, around the start of the OFP for this environment, as opposed to the untreated control that flowered on 31 August. Importantly, yield responses and corresponding delays in anthesis were observed to be greatest under heavy defoliation from an early establishment/sowing date: both Scepter$^{\phi}$ and Vixen$^{\phi}$ showing significant yield improvements compared with doing nothing. The grain quality results for the defoliated Scepter$^{\phi}$ also highlighted the need to consider adequate nitrogen to compensate for biomass loss from defoliation in order to achieve both yield potential and to meet targeted grain protein classifications.

It was also observed that with delays in establishment/sowing, for Vixen$^{\phi}$ for SD2 for example, increases in defoliation intensity resulted in decreased yield, even though anthesis was delayed. The decrease in yield potential was mostly likely associated with a decline in biomass accumulation due to defoliation and the decreased probability of frost events.

Although apical pruning was shown to increase the yield potential of early sown quick–mid spring wheats, it was still not able to out-yield Illabo$^{\phi}$, a locally well adapted mid winter wheat variety sown in its preferred sowing window. Furthermore, compared with Scepter$^{\phi}$ sown in its preferred sowing window (SD2), the best performing heavily defoliated Scepter$^{\phi}$ from SD1 was only able to achieve 89% of the Scepter$^{\phi}$ yield for SD2.

In conclusion, it is possible to reset/delay anthesis in early sown spring wheats using apical pruning as a management strategy to offset the risk of yield loss from the increased probability of frosts. The results from this study do, however, underline that yield potential tends to be optimised when the correct phenology type is planted in its preferred sowing window so that it flowers within the OFP for a given environment. On this basis, apical pruning should only be considered as a possible management strategy when quick–mid spring wheats have been planted well outside their preferred sowing window and/or development means that there is an increased risk of yield loss due to frost.

Agronomy–cereals

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Pulse variety experiments – faba bean, lentil, lupin, field pea, and chickpea – Methul 2023

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Key findings

- Average grain yield for all species was lower than the average over the last 5 years, due to severe moisture stress in the reproductive growth phase.
- The highest yielding faba bean varieties were FBA Ayla$^{\phi}$, PBA Nanu$^{\phi}$ and PBA Nasma$^{\phi}$. Flowering started in early August and continued until end September. Earlier flowering in faba beans was correlated with higher grain yields.
- The highest yielding lentil varieties were PBA Kelpie XT$^{\phi}$, PBA Ace$^{\phi}$, GIA Thunder$^{\phi}$, PBA Hallmark XT$^{\phi}$ and GIA Lightning$^{\phi}$. Most varieties started flowering in late August and finished in late September.
- PBA Bateman$^{\phi}$ and Coyote$^{\phi}$ were the highest yielding narrow-leaf lupin varieties. Coyote$^{\phi}$ had a significantly lighter seed weight than all other varieties.
- The highest yielding field pea varieties were PBA Pearl$^{\phi}$, PBA Taylor$^{\phi}$, PBA Noosa$^{\phi}$ and PBA Wharton$^{\phi}$. PBA Percy was the first to flower in late August and all varieties finished flowering by early October. Seed weight varied significantly across all varieties.
- There was no significant difference in yield or seed weight between the 2 chickpea varieties, CBA Captain$^{\phi}$ and PBA Slasher$^{\phi}$.

- **Important note:** while all seasons are unique, it is important to consider long-term phenology and yield data to determine varietal responses and adaptation to growing environment.

Keywords Methul, 2023, pulses, variety, phenology, faba bean, field pea, lupin, chickpea, lentil, grain yield, seed weight

Introduction

Pulse variety experiments were conducted at Methul in 2023 to support southern NSW pulse growers with additional local variety information at our key research sites. Experiments were conducted on a range of varieties to investigate crop phenology and grain yield responses for a range of commercially available faba bean, lentil, lupin, field pea and chickpea varieties.

Site details

Location	Anglia, Methul
Soil type	Red chromosol

Soil pH_{Ca}	5.6 (0–5 cm), 4.4 (5–10 cm), 4.5 (10–15 cm), 4.9 (15–20 cm), 5.4 (20–25 cm), 5.7 (25–30 cm)
Paddock history	Oats (2022), wheat (2021), barley (2020), wheat (2019), wheat (2018), canola (2017)
Fertiliser	100 kg/ha, SuPerfect® Grain Legume (N5:P15:S7:Ca11)
Rainfall	• Annual – 2023: 469 mm – Long-term average (LTA): 469 mm • In-crop (April–October) – 2023: 186 mm – LTA: 286 mm
Sowing and harvest	Table 14 shows the sowing and harvest dates for the experiments.

Table 14 Sowing and harvest dates for pulse variety experiments at Methul in 2023.

Species	Sowing date	Harvest date
Faba bean	12 May	13 November
Lentil	11 May	10 November
Narrow-leaf lupin	12 May	19 November
Field pea	15 May	6 November
Desi chickpea	15 May	19 November

Treatments

Variety

Table 15 lists the pulse species and varieties evaluated.

Table 15 Pulse species and varieties evaluated at Methul in 2023.

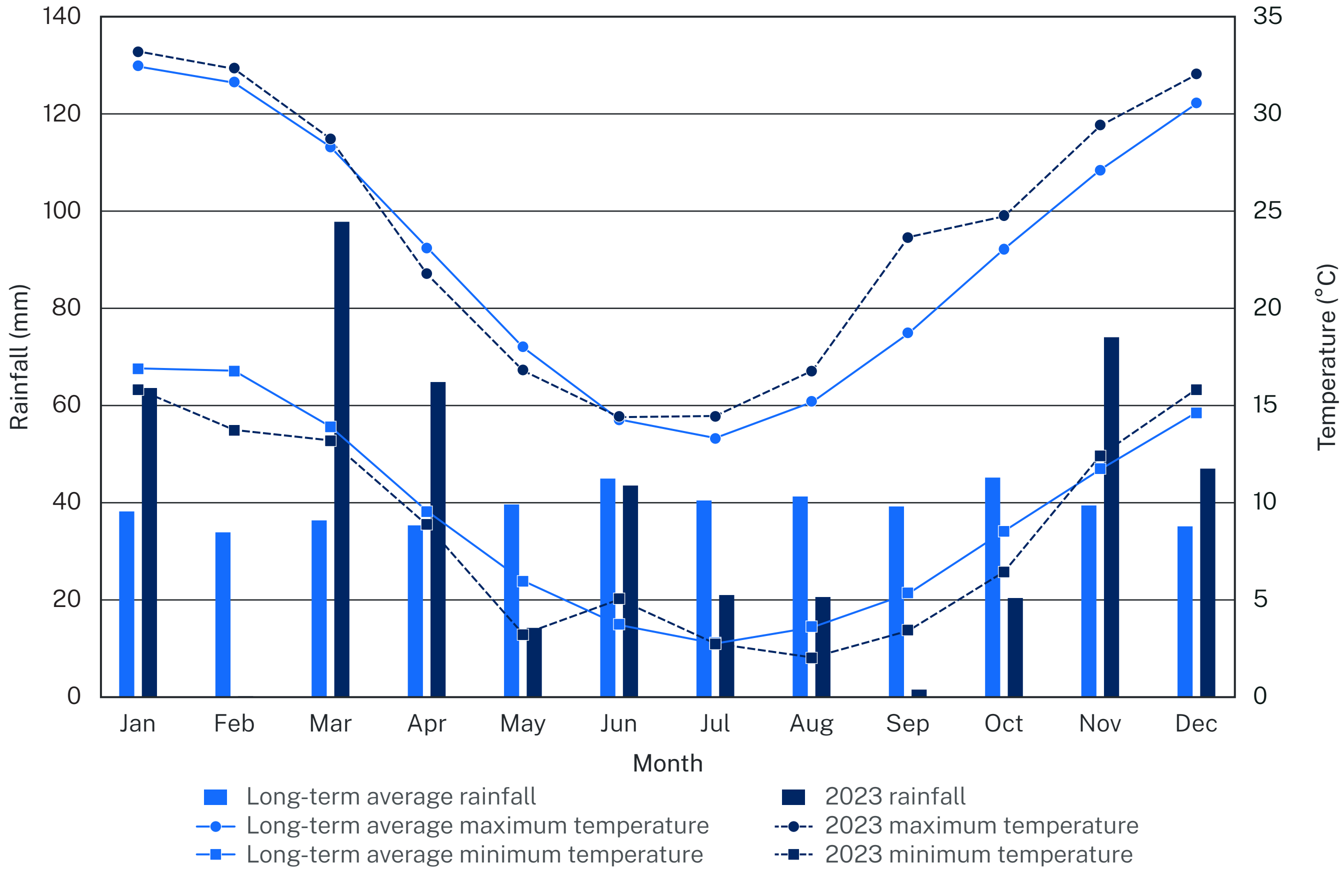
Species	Variety
Faba bean	FBA Ayla⌽, PBA Amberley⌽, PBA Marne⌽, PBA Nanu⌽, PBA Nasma⌽, PBA Samira⌽
Lentil	GIA Leader⌽, GIA Lightning⌽, GIA Thunder⌽, Nipper⌽, PBA Ace⌽, PBA Bolt⌽, PBA Hallmark XT⌽, PBA Highland XT⌽, PBA Jumbo2⌽, PBA Kelpie XT⌽
Narrow-leaf lupin	Coyote⌽, Lawler⌽, Mandelup⌽, PBA Bateman⌽, PBA Jurien⌽, Wonga
Field pea	APB Bondi⌽, PBA Butler⌽, PBA Noosa⌽, PBA Oura⌽, PBA Pearl, PBA Percy, PBA Taylor⌽, PBA Wharton⌽, Sturt
Desi chickpea	CBA Captain⌽, PBA Slasher⌽

Seasonal conditions

The 2023 winter growing season started with above average rainfall in January, March and April (Figure 6). This provided sufficient soil moisture for sowing in the recommended sowing windows. However, for July, August, September and October rainfall was lower than the LTA, resulting in moisture stress during spring, the yield formation window.

Twenty-nine frosts were recorded during the winter growing season, 15 of these were during flowering from early August to late September. There were 4 days with a maximum temperature above 33 °C in mid September and early October.

Low soil moisture levels in spring, coupled with frequent frost and high temperatures during the grain filling phase, decreased potential grain yield. There were no significant disease issues at this site in 2023.



Monthly temperature and rainfall data for 2023 taken from on-site weather station.
Long-term data extracted from SILO.

Figure 6 Monthly minimum and maximum temperature, and total monthly rainfall in 2023, and long-term averages at Methul.

Results

Faba bean

Yields ranged from 1.44 t/ha (PBA Ayla⍉) to 1.18 t/ha (PBA Amberley⍉ and PBA Samira⍉) (Table 16). The average site yield was 1.32 t/ha. The highest yielding varieties, PBA Ayla⍉, PBA Nanu⍉ and PBA Nasma⍉ displayed no significant difference in yield.

Table 16 Growing region, crop phenology and grain yield responses for faba bean varieties at Methul in 2023.

Variety	Proposed NSW growing region	50% flowering (date)*	End of flowering (date)†	Yield (t/ha)‡	100 seed weight (g)
FBA Ayla	Northern	3 Aug	19 Sep	1.44 [a]	51.3
PBA Nanu		5 Aug	19 Sep	1.39 [ab]	55.2
PBA Nasma		2 Aug	20 Sep	1.36 [ab]	54.1
PBA Marne	Southern	8 Aug	20 Sep	1.30 [bcd]	58.6
PBA Amberley		17 Aug	21 Sep	1.18 [de]	61.7
PBA Samira		16 Aug	20 Sep	1.18 [de]	59.3
Mean		7 Aug	20 Sep	1.32	58.4
l.s.d. (*P*<0.05)		1.70	2.46	0.13	2.53

* 50% flowering is the date when 50% of plants had one open flower.

† End of flowering is the date when only 5% of plants have an open flower.

‡ N.B. For grain yield interpretation, varieties with the same letter are statistically similar.

l.s.d. = least significant difference.

Agronomy–pulses

PBA Nasma⑪ reached 50% flowering (flowering) on 2 August, one day before FBA Ayla⑪ and 15 days before the last variety PBA Amberley⑪, on 17 August (Table 16). All varieties reached the end of flowering between 19 September and 21 September.

Hundred seed weight (HSW) ranged from 61.7 g for PBA Amberley⑪ to 51.3 g for FBA Ayla⑪ (Table 16). PBA Amberley⑪ was the only variety to record an HSW higher than 60 g.

Lentil

The average lentil yield was 0.81 t/ha (Table 17). There was no significant difference in yield between PBA Kelpie XT⑪, PBA Ace⑪, GIA Thunder⑪, PBA Hallmark XT⑪ and GIA Lightning⑪. GIA Leader⑪ was the lowest yielding variety at 0.57 t/ha, 44% lower than PBA Kelpie XT⑪.

Table 17 Crop phenology and grain yield responses for lentil varieties at Methul in 2023.

Variety	50% flowering (date)*	End of flowering (date)†	Yield (t/ha)‡	100 seed weight (g)	Classification (seed size)
PBA Kelpie XT	25 Aug	26 Sep	1.03 [a]	4.0	large
PBA Ace	31 Aug	30 Sep	1.02 [ab]	4.1	medium
GIA Thunder	29 Aug	27 Sep	0.92 [abcd]	3.2	small
PBA Hallmark XT	28 Aug	27 Sep	0.92 [abcd]	3.6	medium
GIA Lightning	3 Sep	26 Sep	0.89 [abcd]	3.0	small
PBA Jumbo2	27 Aug	27 Sep	0.79 [bcde]	4.3	large
Nipper	7 Sep	30 Sep	0.74 [def]	3.0	small
PBA Highland XT	25 Aug	27 Sep	0.60 [ef]	3.2	small
PBA Bolt	29 Aug	27 Sep	0.62 [ef]	3.9	medium
GIA Leader	30 Aug	28 Sep	0.57 [f]	4.1	medium
Mean	30 Aug	28 Sep	0.81	3.7	
l.s.d. (*P*<0.05)	0.85	1.31	0.23	0.14	

* 50% flowering is the date when 50% of plants had one open flower.

† End of flowering is the date when only 5% of plants have an open flower.

‡ N.B. For grain yield interpretation, varieties with the same letter are statistically similar.

l.s.d. = least significant difference.

Most varieties reached 50% flowering within a 4-day period, between 27 August and 31 August (Table 17). PBA Highland XT⑪ and PBA Kelpie XT⑪ were the quickest (25 August), Nipper⑪ was the slowest (7 September). All varieties finished flowering over a 5-day period between 26 September and 30 September.

HSW varied from 4.3 g for PBA Jumbo2⑪ to 3.0 g for GIA Lightning⑪ and Nipper⑪ (Table 17).

Narrow-leaf lupin

PBA Bateman⑪ and Coyote⑪ had statistically similar grain yields (Table 18). Their yields were significantly higher than all other varieties.

When sown on 12 May there was a 6-day difference in flowering date between the earliest flowering variety (Coyote⑪ on 19 August) and the latest (PBA Bateman⑪ and Lawler⑪ on 25 August) (Table 18). All varieties finished flowering over a 6-day period from 19 September to 24 September.

HSW ranged between 13.2 g (Lawler⑪) and 11.8 g (Coyote⑪). All varieties were significantly heavier than Coyote⑪ (Table 18).

Table 18 Crop phenology and grain yield responses for narrow-leaf lupin varieties at Methul in 2023.

Variety	50% flowering (date)*	End of flowering (date)†	Yield (t/ha)‡	100 seed weight (g)
PBA Bateman	25 Aug	24 Sep	1.25 ^{a}	13.0
Coyote	19 Aug	19 Sep	1.22 ^{a}	11.8
PBA Jurien	20 Aug	20 Sep	1.12 ^{b}	12.7
Wonga	22 Aug	20 Sep	1.08 ^{b}	13.0
Mandelup	20 Aug	21 Sep	1.07 ^{b}	13.0
Lawler	25 Aug	24 Sep	1.04 ^{b}	13.2
Mean	22 Aug	21 Sep	1.13	12.8
l.s.d. (P<0.05)	1.84	3.25	0.12	0.63

* 50% flowering is the date when 50% of plants had one open flower.

† End of flowering is the date when only 5% of plants have an open flower.

‡ N.B. For grain yield interpretation, varieties with the same letter are statistically similar.

l.s.d. = least significant difference.

Field pea

PBA Pearlᶲ, PBA Taylorᶲ, PBA Noosaᶲ and PBA Whartonᶲ displayed no significant difference in yield (Table 19). The average site yield was 1.40 t/ha.

PBA Percy was the earliest variety to reach flowering on 22 August (Table 19). The latest flowering variety was PBA Butlerᶲ on 5 September. All varieties finished flowering between 28 September and 1 October.

The average HSW was 17.1 g (Table 19). Seed weight varied between 20.4 g for PBA Percy and 15.1 g for Sturtᶲ.

Table 19 Crop phenology and grain yield responses for field pea varieties at Methul in 2023.

Variety	Type	50% flowering (date)*	End of flowering (date)†	Yield (t/ha)‡	100 seed weight (g)
PBA Pearl	white	28 Aug	30 Sep	1.47 ^{a}	16.8
PBA Taylor	kaspa	3 Sep	29 Sep	1.42 ^{ab}	17.7
PBA Noosa	blue	1 Sep	28 Sep	1.38 ^{abc}	17.0
PBA Wharton	kaspa	2 Sep	29 Sep	1.38 ^{abc}	17.7
PBA Oura	dun	31 Aug	28 Sep	1.37 ^{bc}	19.5
Sturt	white	29 Aug	1 Oct	1.32 ^{cd}	15.1
APB Bondi	kaspa	3 Sep	29 Sep	1.29 ^{cde}	17.8
PBA Percy	dun	22 Aug	30 Sep	1.26 ^{de}	20.4
PBA Butler	kaspa	5 Sep	29 Sep	1.26 ^{de}	16.6
Mean		1 Sep	29 Sep	1.40	17.1
l.s.d. (P<0.05)		1.84	1.13	0.10	1.62

* 50% flowering is the date when 50% of plants had one open flower.

† End of flowering is the date when only 5% of plants have an open flower.

‡ N.B. For grain yield interpretation, varieties with the same letter are statistically similar.

l.s.d. = least significant difference.

Chickpea

There was no significant difference in yield or HSW between CBA Captainᶲ and PBA Slasherᶲ (Table 20). The average yield and HSW was 1.0 t/ha and 26.8 g respectively.

CBA Captainᶲ reached flowering on 3 September, significantly earlier than PBA Slasherᶲ (6 September) (Table 20).

Table 20 Grain yield, date to 50% flower and 100 seed weight for desi chickpea varieties at Methul in 2023.

Variety	50% flowering (date)*	Yield (t/ha)	100 seed weight (g)
CBA Captain	3 Sep	1.06	26.2
PBA Slasher	6 Sep	0.94	27.4
Mean	4 Sep	1.00	26.8
l.s.d. (*P*<0.05)	0.75	n.s.	n.s.

* 50% flowering is the date when 50% of plants had one open flower.

l.s.d. = least significant difference.

n.s. = not significant.

Conclusion

The results of these experiments need to be considered in the context of unfavourable spring conditions, with severe moisture stress experienced by all experiments throughout the reproductive window. The site only received 121 mm of rain from May to October inclusive, less than 50% of the long-term average of 248 mm for the same period. Moisture stress, combined with some severe frosts in mid August and mid September, restricted yield potential for all species. Immediately following the 4 days of consecutive frosts in mid September was a week of hot weather averaging 30°C with the hottest day reaching 34 °C.

FBA Ayla$^{\phi}$ was the highest yielding faba bean variety, while PBA Nanu$^{\phi}$ and PBA Nasma$^{\phi}$ were statistically equivalent. These 3 varieties, developed for the northern growing region of NSW, performed better in this environment than the southern region bred lines due to their earlier flowering and faster maturity. They started to flower approximately 2 weeks earlier than the southern varieties. As a result, they were able to convert limited soil water more efficiently into grain yield before the slower maturing varieties, such as PBA Amberley$^{\phi}$ and PBA Samira$^{\phi}$.

Average yields for lentil varied significantly, ranging from 0.57 t/ha to 1.03 t/ha. Given the below optimum seasonal conditions, lentil did not reach its average plant height, which affected harvest efficiency for the shorter varieties. Flowering started in late August and continued through until late September. HSW ranged from 3.0 g to 4.3 g reflecting the normal seed classification of the respective varieties.

PBA Bateman$^{\phi}$ and Coyote$^{\phi}$ were the highest yielding narrow-leaf lupin varieties. HSW for Coyote$^{\phi}$ was significantly lower than all other varieties tested. Further information on the Coyote$^{\phi}$ variation in seed size across a range of seasons and environments is warranted, compared with other current varieties.

The average field pea yield across all varieties was higher than all the other pulse species at 1.4 t/ha. This is not surprising given the faster reproductive and maturity phases of field pea and hence it's capacity to take advantage of less favourable seasons where rainfall is particularly limiting.

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Find results from other pulse agronomy experiments in previous editions of Southern NSW research results (https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/southern-nsw-research-results).

Pulse variety experiments – faba bean, lentil, lupin, chickpea, field pea and vetch – Rankins Springs 2023

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Key findings

- Average grain yield for all species was lower than the average over the last 5 years, due to severe moisture stress in the reproductive growth phase.
- FBA Aylaᶲ, PBA Nanuᶲ and PBA Nasmaᶲ were the highest yielding faba bean varieties. Earlier flowering in faba beans was correlated with higher grain yields.
- PBA Kelpie XTᶲ was the highest yielding lentil variety, which was equal to to GIA Thunderᶲ, PBA Hallmark XTᶲ, PBA Jumbo2ᶲ and GIA Lightningᶲ.
- PBA Batemanᶲ and Jindalee out-yielded all other lupin varieties.
- In the NVT chickpea experiment, PBA Slasherᶲ, Neelamᶲ, Genesis™ 090, PBA Maidenᶲ and CBA Captainᶲ were the highest yielding varieties.
- In the NVT field pea experiment, PBA Taylorᶲ, APB Bondiᶲ, PBA Whartonᶲ, PBA Butlerᶲ and Sturt were the highest yielding varieties.
- In the vetch breeding experiment, Morava and Timokᶲ were the highest yielding varieties. Timokᶲ, Volgaᶲ and Studenciaᶲ had high biomass.

- **Important note:** while all seasons are unique, it is important to consider long-term phenology and yield data to determine varietal responses and adaptation to growing environment.

Keywords Rankins Springs, 2023, pulses, variety, phenology, faba bean, field pea, lupin, chickpea, lentil, vetch, grain yield, seed weight

Introduction

Pulse variety experiments were conducted at Rankins Springs in 2023 to support southern NSW pulse growers with additional local variety information at our key research sites. Experiments were conducted on a range of varieties to investigate crop phenology and grain yield responses for a range of commercially available faba bean, lentil, lupin, field pea, chickpea and vetch varieties.

Some of the experiments conducted were part of the National Variety Trials (NVT) program, the National Vetch Breeding program and the National Pulse Agronomy (NaPA) project.

Site details

Location	Hillview, Rankins Springs
Soil type	Kandosol

Soil pH_{Ca}	6.2 (0–5 cm), 4.8 (5–10 cm), 4.6 (10–15 cm), 5.6 (15–20 cm), 6.1 (20–25 cm), 6.3 (25–30 cm)
Paddock history	Wheat (2022), canola (2021), barley (2020), wheat (2019)
Fertiliser	100 kg/ha, SuPerfect® Grain Legume (N5:P15:S7:Ca11)
Rainfall	• Annual – 2023: 406 mm – Long-term average (LTA): 393 mm • In-crop (April–October) – 2023: 165 mm – LTA: 238 mm

Sowing and harvest dates

Table 21 shows the sowing and harvest dates for the experiments.

Table 21 Sowing and harvest dates for pulse variety experiments at Rankins Springs in 2023.

Species	Experiment	Sowing date	Harvest date
Faba bean	NaPA	24 April	13 November
Lentil	NSW DPI	10 May	23 November
Lupin	NaPA	24 April	4 December
Chickpea	NVT	9 May	4 December
Field pea	NVT	18 May	14 November
Vetch	National Vetch Breeding program	9 May	13 November

Treatments

Variety

Table 22 lists the pulse species and varieties evaluated.

Table 22 Pulse species and varieties evaluated at Rankins Springs in 2023.

Species	Variety
Faba bean	FBA Ayla⟑, PBA Amberley⟑, PBA Marne⟑, PBA Nanu⟑, PBA Nasma⟑, PBA Samira⟑
Lentil	GIA Leader⟑, GIA Lightning⟑, GIA Thunder⟑, Nipper⟑, PBA Ace⟑, PBA Bolt⟑, PBA Hallmark XT⟑, PBA Highland XT⟑, PBA Jumbo2⟑, PBA Kelpie XT⟑
Narrow-leaf lupin	Jindalee, Mandelup⟑, PBA Bateman⟑, PBA Gunyidi⟑, PBA Jurien⟑, Wonga
Chickpea	CBA Captain⟑, Genesis™ 090, Neelam⟑, PBA Boundary⟑, PBA Maiden⟑, PBA Seamer⟑, PBA Slasher⟑, PBA Striker⟑
Field pea	APB Bondi⟑, Kaspa, GIA Ourstar⟑, PBA Butler⟑, PBA Noosa⟑, PBA Oura⟑ PBA Pearl, PBA Percy, PBA Taylor⟑, PBA Wharton⟑, Sturt
Vetch	Morava, Studencia⟑, Timok⟑, Volga⟑

Seasonal conditions

The 2023 winter growing season began with above average rainfall in January and March (Figure 7). This led to sufficient soil moisture for sowing within recommended sowing windows. However, from May to October, there was only 140 mm of rain, which was much

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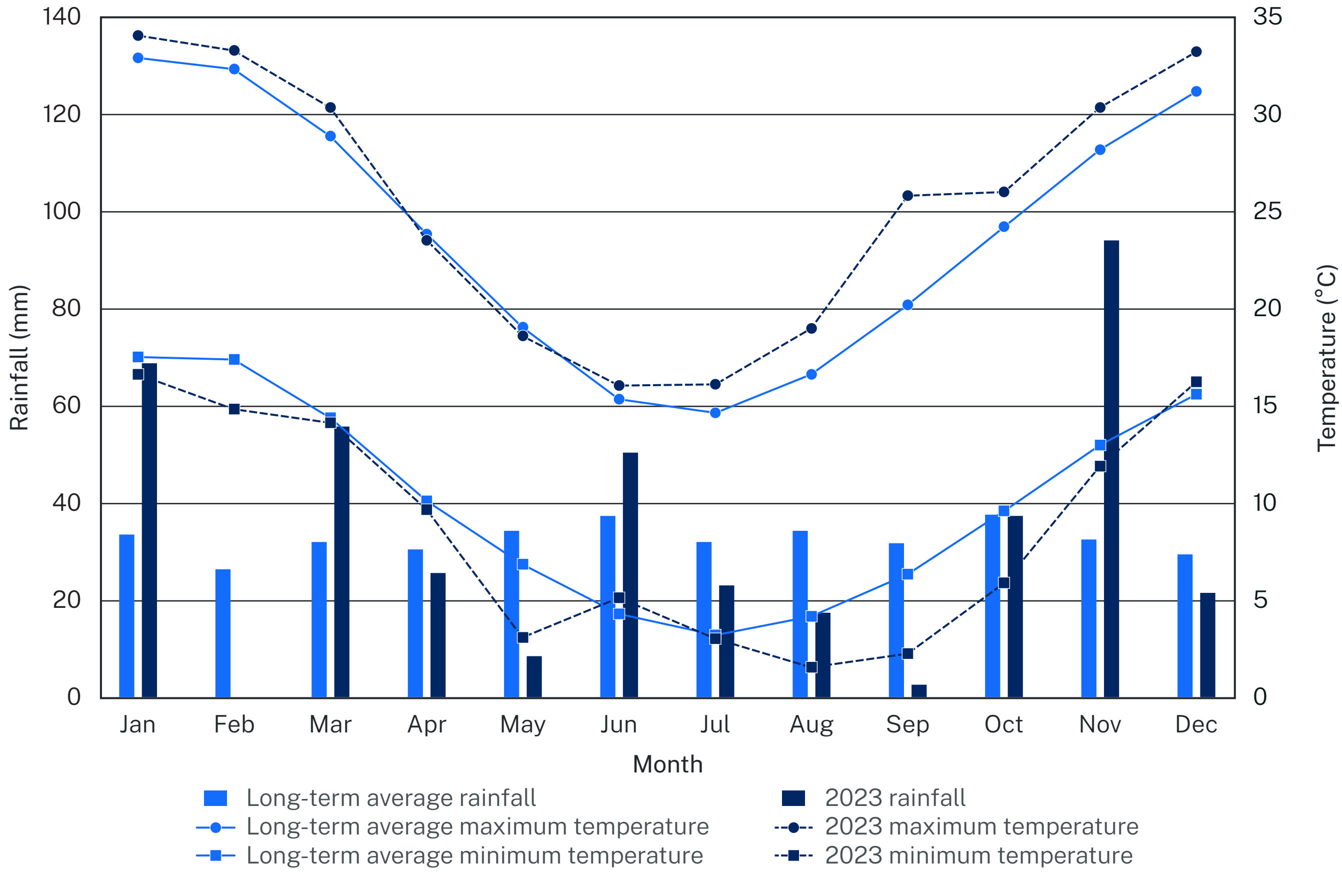
less than the LTA of 208 mm for that period. This caused severe moisture stress in the spring. There were also 27 frosts recorded between mid July and the end of September.

Following 4 consecutive days of frost from 9 to 12 September, the site had a week of hot weather, averaging 32 °C, with the hottest day reaching 36 °C on 18 September.

Low soil moisture levels in spring, coupled with frequent frost and high temperatures during the grain filling phase, significantly reduced the potential grain yield.

There were no significant disease issues at this site in 2023.



Monthly temperature and rainfall data for 2023 taken from on-site weather station.
Long-term data extracted from SILO.

Figure 7 Monthly minimum and maximum temperature, and total monthly rainfall in 2023, and long-term averages at Rankins Springs.

Results

Faba bean

FBA Ayla⟠ was the highest yielding variety, with PBA Nanu⟠ and PBA Nasma⟠ being statistically similar (Table 23). The average site yield was 1.43 t/ha.

Four varieties flowered in mid July when sown on 24 April, 3 northern (nNSW) bred varieties and the early flowering southern (sNSW) bred PBA Marne⟠ (Table 23). They flowered 2 weeks earlier than PBA Amberley⟠ and PBA Samira⟠. Generally, varieties that flowered earlier had higher grain yields due to faster grain development and less terminal drought affect.

Hundred seed weight (HSW) varied from 51.6 g for FBA Ayla⟠ to 63.4 g for PBA Nasma⟠ (Table 23).

Table 23 Growing region, crop phenology and grain yield responses for faba bean varieties at Rankins Springs in 2023.

Experiment conducted by NSW DPI as part of the CSIRO led National Pulse Agronomy Project (NaPA).

Variety	Proposed NSW growing region	50% flowering (date)*	Maturity biomass (t/ha)	Yield (t/ha)†	100 seed weight (g)
FBA Ayla	Northern	18 Jul	5.3	1.67 [a]	51.6
PBA Nanu		19 Jul	6.2	1.55 [a]	55.2
PBA Nasma		17 Jul	5.3	1.52 [ab]	63.4
PBA Marne	Southern	19 Jul	5.4	1.35 [bc]	57.7
PBA Amberley		8 Aug	5.8	1.26 [c]	61.0
PBA Samira		5 Aug	3.8	1.23 [c]	55.7
Mean		24 Jul	5.3	1.43	57.4
l.s.d. (*P*<0.05)		2.3	0.6	0.18	1.9

* 50% flowering is the date when 50% of plants had one open flower.

† N.B. For grain yield interpretation, varieties with the same letter are statistically similar.

l.s.d. = least significant difference.

Lentil

The average lentil yield was 0.5 t/ha (Table 24). There was no significant difference in yield between the varieties PBA Kelpie XT⊕, GIA Thunder⊕, PBA Hallmark XT⊕, PBA Jumbo2⊕ and GIA Lightning⊕.

The quickest variety to flower was PBA Highland XT⊕ on 24 August. Seven out of 10 varieties flowered before 27 August, with Nipper⊕ being the slowest, flowering on 31 August. Flowering continued until early October, with all varieties finishing flowering between 7 October and 11 October (Table 24).

Table 24 Crop phenology and grain yield responses for lentil varieties at Rankins Springs in 2023.

Experiment conducted by NSW DPI.

Variety	50% flowering (date)*	End of flowering (date)†	Yield (t/ha)‡	Classification (seed size)
PBA Kelpie XT	25 Aug	9 Oct	0.67 [a]	large
GIA Thunder	25 Aug	9 Oct	0.55 [abc]	small
PBA Hallmark XT	26 Aug	9 Oct	0.53 [abcd]	medium
PBA Jumbo2	28 Aug	9 Oct	0.52 [abcde]	large
GIA Lightning	25 Aug	11 Oct	0.50 [abcdef]	small
PBA Highland XT	24 Aug	9 Oct	0.48 [bcdef]	small
PBA Ace	26 Aug	7 Oct	0.44 [bcdef]	medium
GIA Leader	27 Aug	9 Oct	0.43 [cdef]	medium
PBA Bolt	26 Aug	8 Oct	0.39 [cdef]	medium
Nipper	31 Aug	9 Oct	0.35 [df]	small
Mean	27 Aug	9 Oct	0.50	
l.s.d. (*P*<0.05)	1.18	0.80	0.18	

* 50% flowering is the date when 50% of plants had one open flower.

† End of flowering is the date when only 5% of plants have an open flower.

‡ N.B. For grain yield interpretation, varieties with the same letter are statistically similar.

l.s.d. = least significant difference.

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Narrow-leaf lupin

The average narrow-leaf lupin yield was 0.90 t/ha (Table 25). PBA Bateman⍉ and Jindalee were the highest yielding varieties. Flowering times varied, with Mandelup⍉ the earliest to flower on 24 July and Jindalee the latest on 18 August. Biomass at maturity was similar across all varieties.

Table 25 Crop phenology and grain yield responses for narrow-leaf lupin varieties at Rankins Springs in 2023.

Experiment conducted by NSW DPI as part of the CSIRO led National Pulse Agronomy Project (NaPA).

Variety	50% flowering (date)*	Maturity biomass (t/ha)	Yield (t/ha)†	100 seed weight (g)
PBA Bateman	29 Jul	6.5	1.17 [a]	13.7
Jindalee	18 Aug	7.1	1.15 [a]	13.6
PBA Gunyidi	26 Jul	6.5	0.85 [b]	12.7
Wonga	2 Aug	6.6	0.83 [b]	12.3
PBA Jurien	28 Jul	6.1	0.72 [bc]	14.0
Mandelup	24 Jul	6.8	0.71 [bc]	14.1
Mean	31 Jul	6.6	0.90	13.4
l.s.d. (P<0.05)	11.2	n.s.	0.17	1.1

* 50% flowering is the date when 50% of plants had one open flower.

† N.B. For grain yield interpretation, varieties with the same letter are statistically similar.

l.s.d. = least significant difference.

n.s = not significant.

Chickpea

In the 2023 single site analysis there was no significant difference in yield between PBA Slasher⍉, Neelam⍉, Genesis™ 090, PBA Maiden⍉ and CBA Captain⍉ (Table 26). Yield rankings differed between the 2023 single-site analysis and the multi-environment trial (MET) analysis, which covers multiple years and locations, reflecting the unique seasonal conditions of 2023.

HSW results showed the genetic diversity of current varieties. Genesis™ 090, a small-seeded kabuli, was heaviest at 29.0 g, while the desi variety Neelam⍉ was the lightest at 20.8 g (Table 26).

Table 26 Grain yield, multi environment trial (MET) grain yield and hundred seed weight for chickpea varieties at Rankins Springs in 2023.

Experiment conducted by NSW DPI as part of the GRDC led NVT experiment. Data sourced from NVT website: Trial results | NVT (grdc.com.au) on 2 February 2024.

Variety	2023 single site yield (t/ha)*	Long-term MET yield (t/ha)	100 seed weight (g)
PBA Striker	1.21	1.34	23.1
Genesis™ 090	1.33	1.31	29.0
PBA Maiden	1.32	1.29	24.3
Neelam	1.33	1.26	20.8
PBA Slasher	1.35	1.24	24.2
CBA Captain	1.26	1.21	23.3
PBA Boundary	1.12	1.18	22.2
PBA Seamer	1.02	1.07	22.4
Mean	1.26	1.21	
l.s.d. (P<0.001)	0.11		

* Single site analysis F Value = 10.32 units, CV = 5.43%.

Single site analysis yield: Low reliability. Derived from 3 variety replicates, tested in one environment, in one year.

Long-term MET yield: High reliability. Derived from 3 variety replicates, tested in many environments across multiple years.

l.s.d. = least significant difference.

Field pea

In the 2023 single site analysis PBA Taylor⁽ᴾ⁾ was the highest yielding variety, closely followed by APB Bondi⁽ᴾ⁾, PBA Butler⁽ᴾ⁾, PBA Wharton⁽ᴾ⁾ and Sturt, all showing similar yields (Table 27). However, the longer term performance indicated by the MET analysis revealed that PBA Taylor⁽ᴾ⁾, APB Bondi⁽ᴾ⁾, PBA Butler⁽ᴾ⁾, PBA Wharton⁽ᴾ⁾ and Kaspa all statistically out-yielded other varieties.

HSW varied within the varieties tested. PBA Percy had the heaviest HSW at 19.4 g while Sturt had the lightest at 15.1 g (Table 27).

Table 27 Grain yield, multi environment trial (MET) yield and hundred seed weight for field pea varieties at Rankins Springs 2023.

Experiment conducted by NSW DPI as part of the GRDC led NVT experiment. Data sourced from NVT website: Trial results | NVT (grdc.com.au) on 2 February 2024.

Variety	2023 single site yield (t/ha)*	Long-term MET yield (t/ha)	100 seed weight (g)
PBA Taylor	1.15	1.15	18.0
APB Bondi	1.14	1.14	16.5
PBA Butler	1.07	1.11	16.1
PBA Wharton	1.09	1.08	17.4
Kaspa	0.89	1.01	16.2
PBA Oura	0.96	1.00	16.5
Sturt	1.07	0.99	15.1
PBA Pearl	0.86	0.99	18.2
PBA Noosa	0.84	0.95	16.1
PBA Percy	0.94	0.90	19.4
GIA Ourstar	0.73	0.74	17.4
Mean	1.00	0.99	
l.s.d. (*P*<0.001)	0.14		

* Single site analysis F Value = 10.35 units, CV = 8.72%.

Single site analysis yield: Low reliability. Derived from 3 variety replicates, tested in one environment, in one year.

Long-term MET yield: High reliability. Derived from 3 variety replicates, tested in many environments across multiple years.

l.s.d. = least significant difference.

Vetch

Morava and Timok[Φ] both recorded a yield of 0.60 t/ha, which was significantly higher than the other varieties (Table 28). Timok[Φ] had the highest biomass with 5.3 t/ha, closely followed by Volga[Φ] and Studencia[Φ], all showing similar maximum biomass.

Studencia[Φ] was first to flower on 17 September, while Morava was the last, flowering 20 days later, on 6 September (Table 28). All varieties finished flowering within a 5-day period, from 13 September to 18 September. The short flowering period, lasting only 12 to 29 days, combined with the unfavourable season, contributed to the low yield.

Table 28 Crop phenology and grain yield responses for vetch varieties at Wagga Wagga in 2023.

Experiment conducted by NSW DPI as part of the National Vetch Breeding program.

Variety	50% flowering (date)*	End of flowering (date)†	Biomass (t/ha) (26/9/2023)	Grain yield (t/ha)‡
Morava	6 Sep	18 Sep	4.1	0.60 [a]
Timok	29 Aug	17 Sep	5.3	0.60 [a]
Studencia	17 Aug	16 Sep	4.8	0.34 [b]
Volga	25 Aug	13 Sep	5.1	0.34 [b]
Mean	27 Aug	16 Sep	4.8	0.47
l.s.d. (*P*<0.05)	0.9	1.1	0.8	0.11

*50% flowering is the date when 50% of plants had one open flower.

† End of flowering is the date when only 5% of plants have an open flower.

‡ N.B. For grain yield interpretation, varieties with the same letter are statistically similar.

l.s.d. = least significant difference.

Conclusion

These experiment results should be interpreted in the context of very challenging spring conditions, marked by significant moisture stress affecting all experiments during the flowering and pod filling phase. The site received only 140 mm of rain from May to October, which is significantly less than long-term average of 208 mm for the same period. This moisture deficit, coupled with severe frosts in mid August and mid September, severely limited the yield potential for all crops. Following 4 consecutive days of frost from 9 to 12 September, the region had a week of hot weather, averaging 32 °C, with the hottest day reaching 36 °C on 18 September.

In faba bean, FBA Ayla⏀, PBA Nanu⏀ and PBA Nasma⏀ had the highest grain yield. Faba bean yields were lower than 2022 due to limited available soil moisture and high temperatures during spring. Varieties bred for nNSW typically flowered around 2 weeks earlier than lines bred for sNSW. This differing pattern of flowering windows of the northern varieties is associated with higher grain yields.

For lentil, PBA Kelpie XT⏀, GIA Thunder⏀, PBA Hallmark XT⏀, PBA Jumbo2⏀ and GIA Lightning⏀ grain yields were statistically similar and higher compared with the other varieties. However, overall grain yields were lower than previous years, primarily due to dry spring conditions.

The highest yielding narrow-leaf lupin variety was PBA Bateman⏀. Jindalee also yielded well. The average site yield was 0.9 t/ha. Flowering started with Mandelup⏀ on 24 July with Jindalee the last to start flowering on 18 August. Maturity biomass was similar across varieties.

In the 2023 single-site NVT chickpea analysis, PBA Slasher⏀ had the highest yield, followed closely by Neelam⏀, Genesis™ 090, PBA Maiden⏀, and CBA Captain⏀, all statistically similar in yield. Long-term MET analysis, however, highlighted PBA Striker⏀ as the top performer over several years and locations. Varietal performance differences between the single-site analysis and MET suggests varying adaptability to seasonal conditions, with consideration needed for short- and long-term yield predictions and disease resistance rankings when selecting varieties.

In the 2023 single-site NVT field pea analysis, the top 5 varieties by yield were PBA Taylor⏀, APB Bondi⏀, PBA Wharton⏀, PBA Butler⏀, and Sturt, all showing statistically similar yields. Long-term MET analysis confirmed that PBA Taylor⏀, APB Bondi⏀, PBA Wharton⏀, and PBA Butler⏀ consistently achieved high yields across multiple years and diverse environments, indicating their stability and reliability at this site.

Morava and Timok⏀ were the highest grain yielding vetch varieties. Timok⏀, Volga⏀ and Studencia⏀ produced the highest biomass. However overall, the short flowering period and dry spring conditions, limited the time for pod development and reduced yield potential.

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Chickpea and field pea data presented is part of GRDC and NVT analysed data from the chickpea (DMD23RANK2) and field pea (PMaA23RANK2) NVT experiments.

Vetch data presented is part of the National Vetch Breeding program (UOA2104-011RTX).

Faba bean and lupin data presented is part of the National Pulse Agronomy (NaPA) project 'Matching pulse crop designs to site and expected seasonal conditions to maximise yield and profit: a crop ecophysiology approach' (CSP2107-011RTX).

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Find results from other pulse agronomy experiments in previous editions of Southern NSW research results (https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/southern-nsw-research-results).

Pulse variety experiments – faba bean, lentil, lupin, field pea, chickpea and vetch – Wagga Wagga 2023

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Key findings

- Unfavourable seasonal conditions restricted yield potential at Wagga Wagga with terminal drought limiting yield potential of all pulse species. Despite these conditions, some species and varieties performed well, particularly those that flowered earlier.
- Despite unfavourable spring conditions, average grain yield across the 5 pulse species was 3.1 t/ha.
- The highest yielding faba bean varieties were the early flowering PBA Nasma⦹, FBA Ayla⦹ and PBA Warda⦹. Flowering started in early August and continued until the end of September. In 2023, higher grain yield was associated with an earlier and longer flowering period.
- The highest yielding lentil varieties were PBA Jumbo2⦹, PBA Kelpie XT⦹, GIA Thunder⦹, PBA Ace⦹, GIA Lightning⦹, PBA Hallmark XT⦹ and ALB Terrier⦹. Most varieties started flowering in early September and finished in mid October.
- Grain yields for the 6 narrow-leaf lupin varieties ranged from 2.83 t/ha to 2.54 t/ha and were all statistically equal.
- The highest yielding field pea varieties were PBA Taylor⦹, PBA Percy, PBA Wharton⦹, PBA Noosa⦹ and APB Bondi⦹. PBA Percy was the first to flower in late August and all varieties finished flowering in October.
- Volga⦹ was the highest yielding vetch variety at 1.91 t/ha, significantly higher than all other varieties. Studencia⦹ was first to flower in early September, 6 days before the next.

- **Important note:** while all seasons are unique, it is important to consider long-term phenology and yield data to determine varietal responses and adaptation to the growing environment.

Keywords Wagga Wagga, 2023, pulses, variety, phenology, faba bean, field pea, lupin, chickpea, lentil, vetch, grain yield, seed weight

Introduction

Pulse variety experiments were conducted at Wagga Wagga in 2023 to support southern NSW pulse growers with additional local variety information at our key research sites. Experiments were conducted on a range of varieties to investigate crop phenology and grain yield responses for a range of commercially available faba bean, lentil, lupin, field pea, chickpea and vetch varieties.

Some of the commercial variety results presented in this paper have been extracted from experiments conducted by the National Faba Bean Breeding program, Chickpea Breeding Australia program and National Vetch Breeding program.

Site details

Location	Wagga Wagga Agricultural Institute, Wagga Wagga
Soil type	Red kandosol
Soil pH_{Ca}	6.5 (0–5 cm), 5.5 (5–10 cm), 4.9 (10–15 cm), 5.2 (15–20 cm), 5.6 (20–25 cm), 5.8 (25–30 cm)
Paddock history	Wheat (2022), oats (2021), wheat (2020)
Fertiliser	100 kg/ha, SuPerfect® Grain Legume (N5:P15:S7:Ca11)
Rainfall	• Annual – 2023: 454 mm – Long-term average (LTA): 536 mm • In-crop (April–October) – 2023: 205 mm – LTA: 331 mm

Sowing and harvest dates

Table 29 shows the sowing and harvest dates for the experiments.

Table 29 Sowing and harvest dates for pulse variety experiments at Wagga Wagga in 2023.

Species	Sowing date	Harvest date
Faba bean	8 May	27 November
Lentil	17 May	19 November
Narrow leaf lupin	17 May	23 November
Field pea	17 May	14 November
Chickpea	17 May	6 December
Vetch	22 May	13 December

Treatments

Variety

Table 30 lists the pulse species and varieties evaluated.

Table 30 Pulse species and varieties evaluated at Wagga Wagga in 2023.

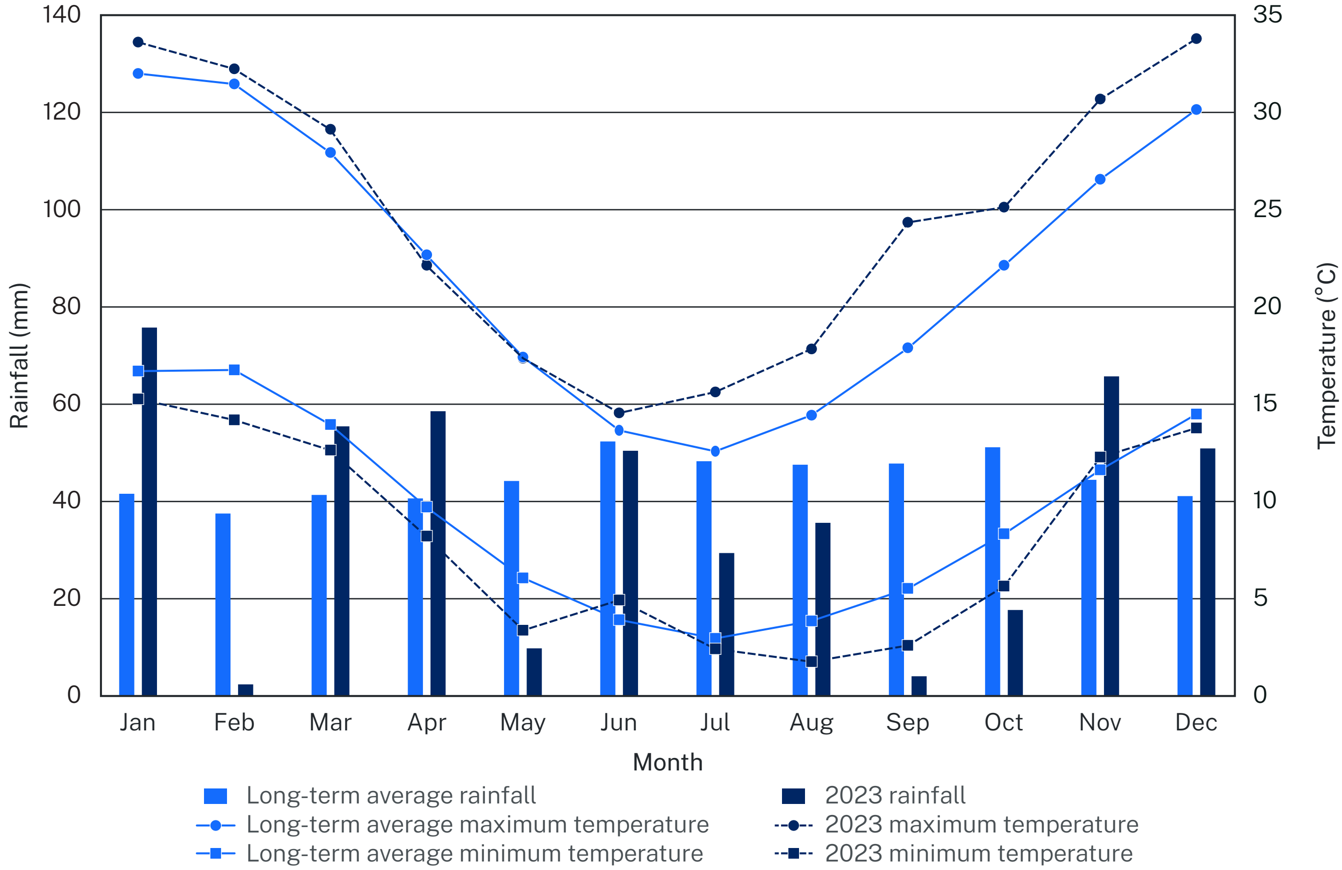
Species	Variety
Faba bean	FBA Ayla⍉, Cairo, Doza, PBA Amberley⍉, PBA Bendoc⍉, PBA Marne⍉, PBA Nanu⍉, PBA Nasma⍉, PBA Samira⍉, PBA Warda⍉
Lentil	ALB Terrier⍉, GIA Leader⍉, GIA Lightning⍉, GIA Thunder⍉, PBA Ace⍉, PBA Bolt⍉, PBA Hallmark XT⍉, PBA Highland XT⍉, PBA Jumbo2⍉, PBA Kelpie XT⍉, Nipper⍉
Narrow-leaf lupin	Coyote⍉, Lawler⍉, Mandelup⍉, PBA Bateman⍉, PBA Jurien⍉, Wonga
Field pea	APB Bondi⍉, PBA Butler⍉, PBA Noosa⍉, PBA Oura⍉, PBA Pearl, PBA Percy, PBA Taylor⍉, PBA Wharton⍉, Sturt
Desi chickpea	CBA Captain⍉, PBA Slasher⍉
Vetch	Morava, Studencia⍉, Timok⍉, Volga⍉

Seasonal conditions Significant soil water reserves were carried over from the very wet 2022 fallow season. Following above average rainfall in January, March and April, starting soil moisture at sowing was adequate for optimal crop establishment within the recommended sowing windows (Figure 8). Rain from May to October, 146 mm, was lower than the LTA (291 mm).

Wagga Wagga recorded 32 frosts during the growing season, with 17 frosts between August and mid October. Following several frosts in early September, there were 3 hot days above 30 °C from 16 to 18 September, reaching a high of 34 °C on 17 September. Daily maximum temperatures were regularly above 30 °C from 20 October.

Low soil moisture levels in spring, coupled with frequent frost and high temperatures during the grain-filling phase, reduced the yield potential in all crop types.

There were no significant disease issues at this site in 2023.



Monthly temperature and rainfall data for 2023 taken from on-site weather station.
Long-term data extracted from SILO.

Figure 8 Monthly minimum and maximum temperature, and total monthly rainfall in 2023, and long-term averages at Wagga Wagga.

Results

Faba bean

The average faba bean yield was 4.41 t/ha, varying between 4.97 t/ha (PBA Nasma$^{\phi}$) and 4.02 t/ha (PBA Samira$^{\phi}$ and PBA Amberley$^{\phi}$) (Table 31). The highest yielding varieties, PBA Nasma$^{\phi}$, FBA Ayla$^{\phi}$ and PBA Warda$^{\phi}$ were statistically similar. These varieties were bred for the northern growing region but significantly out-yielded southern bred varieties in this experiment. This is likely due to their early and longer flowering window and earlier maturity.

Table 31 Growing region, crop phenology and grain yield responses for faba bean varieties at Wagga Wagga in 2023.

Experiment conducted by NSW DPI as part of the National Faba Bean Breeding program.

Variety	Proposed NSW growing region	50% flowering (date)*	End of flowering (date)†	Yield (t/ha)‡	100 seed weight (g)
PBA Nasma	Northern	4 Aug	29 Sep	4.97 [a]	59.4
FBA Ayla		4 Aug	30 Sep	4.81 [abcde]	58.3
PBA Warda		2 Aug	28 Sep	4.54 [abcdef]	53.3
PBA Nanu		4 Aug	29 Sept	4.50 [bcdefg]	62.4
Cairo		3 Aug	1 Oct	4.41 [defg]	57.9
Doza		3 Aug	30 Sep	4.32 [efg]	52.2
PBA Bendoc	Southern	12 Aug	1 Oct	4.32 [efg]	57.4
PBA Marne		9 Aug	30 Sep	4.26 [efg]	63.2
PBA Amberley		16 Aug	1 Oct	4.02 [fg]	62.9
PBA Samira		17 Aug	1 Oct	4.02 [g]	67.7
Mean		9 Aug	30 Sep	4.41	61.7
l.s.d. (*P*<0.05)		2.8	1.1	0.48	2.01

* 50% flowering is the date when 50% of plants had one open flower.

† End of flowering is the date when only 5% of plants have an open flower.

‡ N.B. For grain yield interpretation, varieties with the same letter are statistically similar.

l.s.d. = least significant difference.

PBA Warda$^{\phi}$ was the first to flower (50% flowering) on 2 August (Table 31), with Cairo, Doza, PBA Nasma$^{\phi}$, FBA Ayla$^{\phi}$, and PBA Nanu$^{\phi}$ flowering 1–2 days later. These early flowering varieties, bred for northern NSW, flowered at least 5 days before the first southern variety, PBA Marne$^{\phi}$, which started flowering on 9 August. PBA Samira$^{\phi}$ was the last to flower, 15 days after PBA Warda$^{\phi}$, on 17 August. Flowering ended between 28 September and 1 October for all varieties. In 2023, early and longer flowering, and faster pod fill and maturity were associated with higher grain yield.

PBA Samira$^{\phi}$ recorded the heaviest hundred seed weight (HSW) of 67.7 g (Table 31). This was significantly higher than all other varieties. HSW ranged from 67.7 g for PBA Samira$^{\phi}$ to 52.2 g for Doza.

Lentil

The highest yielding lentil variety was PBA Jumbo2$^{\phi}$ at 2.81 t/ha (Table 32). There was no significant difference between the yields of PBA Kelpie XT$^{\phi}$, GIA Thunder$^{\phi}$, PBA Ace$^{\phi}$, GIA Lightning$^{\phi}$, PBA Hallmark XT$^{\phi}$ and ALB Terrier$^{\phi}$.

Table 32 Crop phenology and grain yield responses for lentil varieties at Wagga Wagga in 2023.

Experiment conducted by NSW DPI.

Variety	Classification (seed size)	50% flowering (date)*	End of flowering (date)†	Yield (t/ha)‡	100 seed weight (g)
PBA Jumbo2	large	8 Sep	15 Oct	2.81 ^{a}	5.2
PBA Kelpie XT	large	3 Sep	10 Oct	2.72 ^{ab}	5.0
GIA Thunder	small	9 Sep	15 Oct	2.71 ^{ab}	4.6
PBA Ace	medium	13 Sep	17 Oct	2.63 ^{abc}	4.6
GIA Lightning	small	14 Sep	17 Oct	2.63 ^{abc}	4.6
PBA Hallmark XT	medium	7 Sep	12 Oct	2.59 ^{abcd}	4.2
ALB Terrier	medium	7 Sep	15 Oct	2.58 ^{abcd}	4.4
PBA Highland XT	small	3 Sep	11 Oct	2.47 ^{bcd}	4.4
PBA Bolt	medium	10 Sep	9 Oct	2.46 ^{bcd}	4.8
Nipper	small	16 Sep	14 Oct	2.33 ^{cd}	3.8
GIA Leader	medium	11 Sep	20 Oct	2.29 ^{d}	5.2
Mean		10 Sep	14 Oct	2.54	4.7
l.s.d. (P<0.05)		2.48	2.13	0.34	0.7

* 50% flowering is the date when 50% of plants had one open flower.

† End of flowering is the date when only 5% of plants have an open flower.

‡ N.B. For grain yield interpretation, varieties with the same letter are statistically similar.

l.s.d. = least significant difference.

The earliest lentil varieties to flower were PBA Kelpie XT⌽ and PBA Highland XT⌽ on 3 September (Table 32). Nipper was the last to flower on 16 September. PBA Bolt⌽ finished flowering first on 9 October, 11 days earlier than GIA Leader⌽, the final variety to finish flowering on 20 October.

Lentil varieties are grouped for marketing into small, medium, and large seed size categories. In this experiment, HSW for:

- small varieties was between 3.8 g and 4.6 g
- medium varieties was between 4.2 g and 5.2 g
- large varieties was between 5.0 g and 5.2 g.

PBA Jumbo2⌽ and GIA Leader⌽ had the heaviest HSW at 5.2 g, while Nipper⌽ had the lightest at 3.8 g.

Narrow-leaf lupin

There was no significant difference in the yield of all narrow-leaf lupin varieties (Table 33). Yields varied between 2.83 t/ha (PBA Jurien⌽) and 2.54 t/ha (Lawler⌽). The average site yield was 2.70 t/ha.

Table 33 Crop phenology and grain yield responses for narrow-leaf lupin varieties at Wagga Wagga in 2023.

Experiment conducted by NSW DPI.

Variety	50% flowering (date)*	End of flowering (date)†	Yield (t/ha)	100 seed weight (g)
PBA Jurien	31 Aug	4 Oct	2.83	16.7
Mandelup	1 Sep	4 Oct	2.79	16.2
PBA Bateman	2 Sep	4 Oct	2.74	16.9
Coyote	3 Sep	4 Oct	2.66	15.6
Wonga	7 Sep	11 Oct	2.56	14.4
Lawler	31 Aug	4 Oct	2.54	15.4
Mean	2 Sep	5 Oct	2.70	15.9
l.s.d. (*P*<0.05)	2.97	0.56	n.s.	0.72

* 50% flowering is the date when 50% of plants had one open flower.

† End of flowering is the date when only 5% of plants have an open flower.

l.s.d. = least significant difference

n.s. = not significant.

PBA Jurien⏀ and Lawler⏀ started flowering on 31 August, 8 days earlier than Wonga, the last variety to start flowering (Table 33). All varieties finished flowering on 4 October, except Wonga which finished on 11 October.

There was a significant difference in HSW among the varieties (Table 33) yet PBA Bateman⏀, Mandelup⏀ and PBA Jurien⏀, had similar HSW – significantly higher than the other varieties.

Field pea

The average site yield was 3.22 t/ha (Table 34). PBA Taylor⏀ was the highest yielding variety at 3.61 t/ha. The yields of PBA Taylor⏀, PBA Percy, PBA Wharton⏀, PBA Noosa⏀ and APB Bondi⏀ were statistically similar.

Table 34 Crop phenology and grain yield responses for field pea varieties at Wagga Wagga in 2023.

Experiment conducted by NSW DPI.

Variety	Type	50% flowering (date)*	End of flowering (date)†	Yield (t/ha)‡	100 seed weight (g)
PBA Taylor	kaspa	9 Sep	10 Oct	3.61 [a]	17.1
PBA Percy	dimpled dun	28 Aug	13 Oct	3.51 [ab]	17.5
PBA Wharton	kaspa	6 Sep	9 Oct	3.51 [ab]	17.7
PBA Noosa	blue	6 Sep	12 Oct	3.42 [abc]	16.5
APB Bondi	kaspa	8 Sep	12 Oct	3.39 [abc]	16.1
PBA Pearl	white	4 Sep	11 Oct	3.29 [bcd]	19.1
PBA Oura	dimpled dun	2 Sep	10 Oct	3.03 [def]	16.5
PBA Butler	kaspa	12 Sep	8 Oct	2.87 [ef]	16.1
Sturt	white	2 Sep	14 Oct	2.81 [f]	16.4
Mean		6 Sep	11 Oct	3.22	17.1
l.s.d (*P*<0.05)		1.24	1.04	0.35	n.s.

* 50% flowering is the date when 50% of plants had one open flower.

† End of flowering is the date when only 5% of plants have an open flower.

‡ N.B. For grain yield interpretation, varieties with the same letter are statistically similar.

l.s.d. = least significant difference.

n.s. = not significant.

There were notable differences in flowering dates. PBA Percy was the first variety to flower on 28 August, 4 days before PBA Oura$^{\phi}$ and Sturt (Table 34). PBA Butler$^{\phi}$ was the last variety to start flowering on 12 September, 15 days after PBA Percy. All varieties finished flowering within a 6-day window, from 8 October (PBA Butler$^{\phi}$) to 14 October (Sturt).

HSW ranged from 16.1 g for PBA Butler$^{\phi}$ and APB Bondi$^{\phi}$ to 19.1 g for PBA Pearl (Table 34). There was no significant difference between varieties.

Chickpea

The average site yield was 2.41 t/ha (Table 35). There was no significant difference in yield, flowering window, or HSW between CBA Captain$^{\phi}$ and PBA Slasher$^{\phi}$.

Table 35 Crop phenology and grain yield responses for chickpea varieties at Wagga Wagga in 2023.

Experiment conducted by NSW DPI as part of the Chickpea Breeding Australia program.

Variety	50% flowering (date)*	End of flowering (date)†	Yield (t/ha)‡	100 seed weight (g)
CBA Captain	15 Sep	17 Oct	2.57	18.5
PBA Slasher	15 Sep	18 Oct	2.40	17.6
Mean	15 Sep	18 Oct	2.41	19.4
l.s.d. (*P*<0.05)	n.s.	n.s.	n.s.	n.s.

* 50% flowering is the date when 50% of plants had one open flower.

† End of flowering is the date when only 5% of plants have an open flower.

l.s.d. = least significant difference.

n.s. = not significant.

Vetch

Volga$^{\phi}$ recorded a yield of 1.91 t/ha, significantly higher than all other varieties (Table 36). Morava was the lowest yielding variety yielding at 1.15 t/ha, the equivalent of 39% less than Volga$^{\phi}$.

Studencia$^{\phi}$ was first to flower on 5 September; Morava was the last, flowering 15 days later, on 20 September (Table 36). The delayed flowering exposed Morava to heat and moisture stress, reducing its yield potential. All varieties finished flowering with a 3-day period, between 1 October and 3 October.

Table 36 Crop phenology and grain yield responses for vetch varieties at Wagga Wagga in 2023.

Experiment conducted by NSW DPI as part of the National Vetch Breeding program.

Variety	50% flowering (date)*	End of flowering (date)†	Biomass (t/ha) (9/10/2024)	Yield (t/ha)‡
Volga	11 Sep	1 Oct	8.0	1.91 [a]
Studencia	5 Sep	2 Oct	7.1	1.54 [b]
Timok	16 Sep	2 Oct	7.9	1.51 [b]
Morava	20 Sep	3 Oct	5.9	1.15 [c]
Mean	14 Sep	2 Oct	7.3	1.65
l.s.d. (*P*<0.05)	0.73	0.69	n.s.	0.17

* 50% flowering is the date when 50% of plants had one open flower.

† End of flowering is the date when only 5% of plants have an open flower.

‡ N.B. For grain yield interpretation, varieties with the same letter are statistically similar.

l.s.d. = least significant difference.

n.s. = not significant.

Conclusion

The results of these experiments need to be considered in the context of unfavourable spring conditions, with severe moisture stress affecting all experiments throughout the reproductive window. The site only received 146 mm of rain from May to October inclusive, around 50% of the long-term average of 291 mm over the same period. Moisture stress, combined with some severe frosts in August to mid October, restricted yield potential for all species. Immediately following the several frosts in early September there were 3 hot days, averaging above 30 °C, from 16 to 18 September.

Species with large differences in growth phases, (e.g. the flowering window), such as faba bean, lentil, field pea, and vetch, appeared better able to take advantage of the slightly more favourable conditions earlier in the reproductive period. Early formed pods in these species were less affected by the heat and moisture stress later in the spring, enabling higher grain yield.

For contrasting species that show little phenotypic variation in the varieties tested, such as lupin and chickpea, there was little variation in yield as the main limiting factor at this site was heat and moisture stress during the grain filling period, which occurred simultaneously for all varieties.

Despite the unfavourable spring conditions, the average grain yield across the 5 species was above average at 3.1 t/ha. Significant contributing factors included a full moisture profile at the start of the season and minimal soil constraints in the experiment paddock. Considering a good liming history, the lowest pH_{Ca} in the profile was 4.9 at 10–15 cm. This had a beneficial effect on plant health, nodulation and vigour contributing to plants accessing soil water available at depth in a dry spring, which then significantly increased yield potential.

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Faba bean data presented is part of the National Faba Bean Breeding program (UOA1606-009RTX).

Chickpea data presented is part of the Chickpea Breeding Australia program (DPI2003-009OPX).

Vetch data presented is part of the National Vetch Breeding program (UOA2104-011RTX).

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Find results from other pulse agronomy experiments in previous editions of Southern NSW research results (https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/southern-nsw-research-results).

Faba bean phenology and yield responses to environment and management practices – Wagga Wagga and Rankins Springs 2023

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Key findings

- The late April sowing increased crop biomass, grain yield and hundred seed weight (HSW) at Rankins Springs and Wagga Wagga when compared with the mid May sowing.
- FBA Ayla⍉, PBA Nanu⍉ and PBA Nasma⍉ were the highest yielding varieties at Rankins Springs, while PBA Nasma⍉ and PBA Marne⍉ were the highest at Wagga Wagga. In 2023, higher grain yield was associated with an earlier and longer flowering period.
- Supplemental irrigation at Wagga Wagga increased late biomass and grain yield while reducing seed weight.

- **Important note:** while all seasons are unique, it is important to consider long-term phenology and yield data to determine varietal responses and adaptation to growing environment.

Keywords Wagga Wagga, Rankins Springs, 2023, faba bean, sowing date, phenology, grain yield

Introduction

Pulses play a critical role in the Australian grains industry. They enhance the diversity and resilience of cropping systems, currently dominated by cereals and canola. To maximise yield and profit while effectively managing production risks, it is essential to match well-adapted genotypes with the specific soil, climate, and management practices in each cropping region. This approach enables improved adaptation to optimise crop water use and minimise vulnerability to environmental constraints such as frost, heat, terminal drought and soil limitations.

These faba bean experiments are part of a nationwide project aimed at understanding the non-water limited yield potential of pulses. The focus is to study crop performance under best practice agronomy. Moreover, the project seeks to enhance our understanding of the relationships between phenology, water stress, temperature and the critical period for yield formation in pulses.

This paper presents selected findings from the detailed experiment conducted at Wagga Wagga and satellite experiment at Rankins Springs in southern NSW in 2023. The discussion focuses mainly on the effect of different sowing dates on the phenology and grain yield response in faba bean.

Site details

Table 37 provides details about the experiment sites.

Table 37 Summary of site conditions and experiment management.

Location: site	Wagga Wagga: Wagga Wagga Agricultural Institute	Rankins Springs: Hillview, Stringy Bark paddock
Soil type	Red kandosol	Red chromosol
Soil pH_{Ca}	6.5 (0–5 cm), 5.5 (5–10 cm), 4.9 (10–15 cm), 5.2 (15–20 cm), 5.6 (20–25 cm), 5.8 (25–30 cm)	6.2 (0–5 cm), 4.8 (5–10 cm), 4.6 (10–15 cm), 5.6 (15–20 cm), 6.1 (20–25 cm), 6.3 (25–30 cm)
Previous crop	Wheat	Wheat
Rainfall	Fallow (November 2022 – March 2023): 239 mm	Fallow (November 2022 – March 2023): 216 mm
	Fallow long-term average (LTA): 204 mm	Fallow LTA: 165 mm
	In-crop (April–October 2023): 205 mm	In-crop (April–October 2023): 165 mm
	In-crop LTA: 331 mm	In-crop LTA: 238 mm
Fertiliser*	100 kg/ha, SuPerfect® Grain Legume (N5:P15:S7:Ca11)	100 kg/ha, SuPerfect® Grain Legume (N5:P15:S7:Ca11)

*N = nitrogen, P = phosphorus, S = sulfur, Ca = calcium

Experiment details

Table 38 provides details of the treatments and timing of experiment activities for each site.

Table 38 Summary of the experiment details at Wagga Wagga and Rankins Springs, 2023.

Location	Wagga Wagga	Rankins Springs
Variety	PBA Amberley⊕, PBA Marne⊕, PBA Nasma⊕ and PBA Samira⊕	PBA Amberley⊕, FBA Ayla⊕, PBA Marne⊕, PBA Nanu⊕, PBA Nasma⊕ and PBA Samira⊕
Sowing date (SD)	SD1: 26 April SD2: 31 May	SD1: 24 April SD2: 18 May
Irrigation	44 mm from 29 August to 14 September	
Maturity biomass date cut	SD1: 3 November SD2: 6 November	SD1: 19 October SD2: 30 October
Harvest date	21 November	SD1: 13 November SD2: 22 November

Seasonal conditions

Above average rain fell from January to March at both locations combined with significant levels of residual soil moisture carried over from above average rainfall in 2022, particularly at the Wagga Wagga site. Soil moisture was favourable at sowing, for optimal crop establishment. May to October rainfall recorded at Wagga Wagga and Rankins Springs was 50% and 67% respectively of the LTA rainfall.

At Wagga Wagga, 32 frosts were recorded during the growing season, with 17 occurring between August and mid October. Temperatures rose above 33 °C on 17 September and regularly reached above 30 °C after 20 October.

At Rankins Springs, there were 27 frosts recorded between mid July to September. Following 4 consecutive days of frost from 9 to 12 September, there was a week of hot weather at the site where the daily temperature averaged 32 °C. A high of 36 °C was reached on 18 September.

Low soil moisture levels in spring, coupled with frequent frost and high temperatures during the grain-filling phase, significantly reduced grain yield potential.

There were no significant disease issues at either site in 2023.

Results

Wagga Wagga

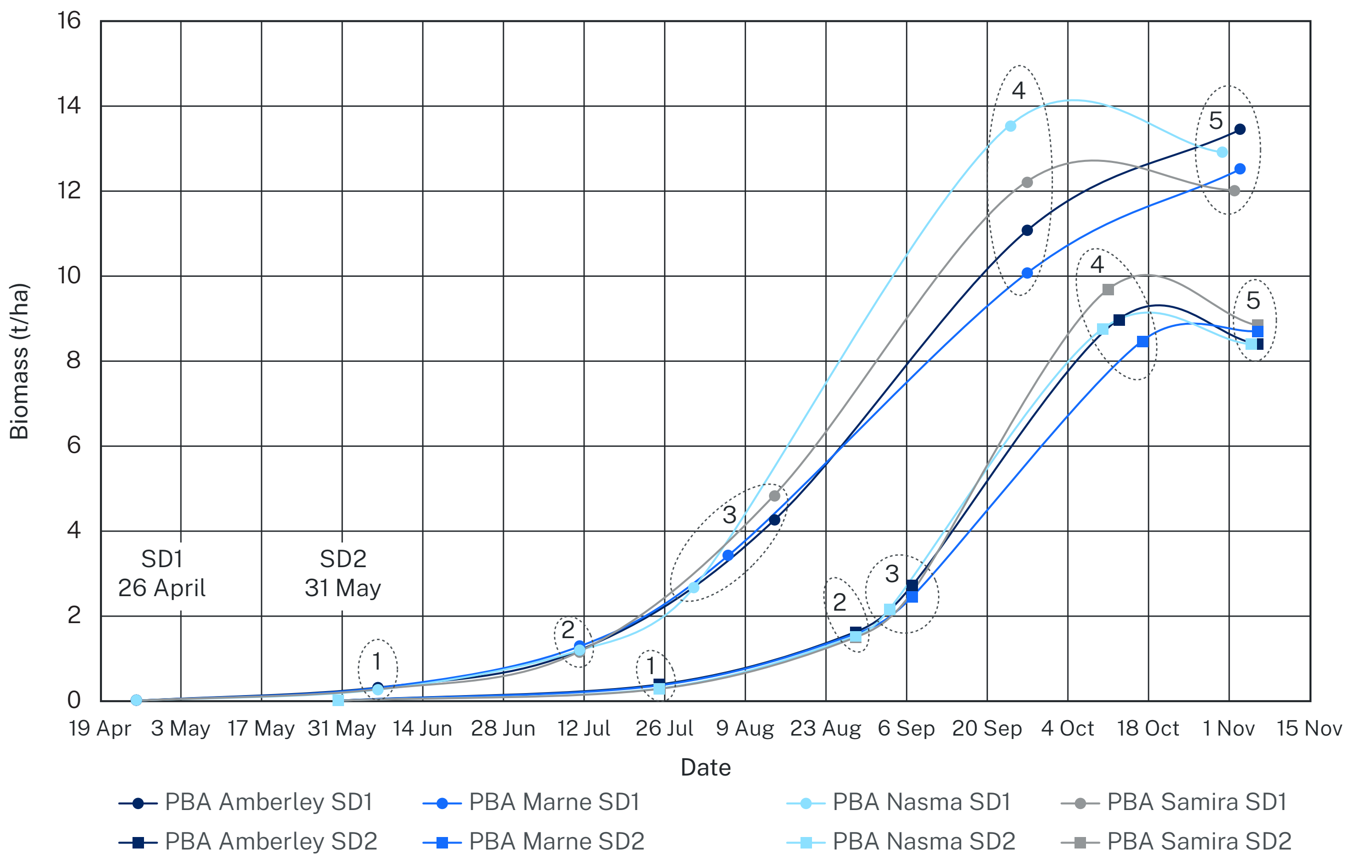
The Wagga Wagga experiment studied the effect of variety, sowing date and irrigation on 4 faba bean varieties: PBA Amberley⁽ᴾ⁾, PBA Marne⁽ᴾ⁾, PBA Samira⁽ᴾ⁾ (southern varieties), and PBA Nasma⁽ᴾ⁾ (a northern variety). During the season, measurements included crop phenology and biomass, grain yield, and soil water. This report focuses on biomass, crop phenology and grain yield.

Biomass was sampled at 5 stages:

1. 300 growing degree days (GDD)*
2. 600 GDD
3. flowering (80% of plants have an open flower)
4. podding (80% of plants have a fully expanded pod)
5. maturity (90% of pods are brown).

**GDD is calculated as the average of the daily maximum and minimum air temperatures.*

Sowing date significantly affected biomass at flowering, podding and maturity, with earlier sowing resulting in higher biomass (Figure 9). For example, for SD1 (26 April), biomass at flowering, podding and maturity was 3.8 t/ha, 11.7 t/ha and 12.7 t/ha, respectively, which was an increase of 35%, 24% and 33% respectively, compared with SD2 (31 May).



Points on graph from left to right(1) 300 GDD, (2) 600 GDD, (3) flowering biomass – when 80% of plants had open flowers; (4) pod biomass – when 80% of plants had a pod with a fully sized pod inside and (5) maturity biomass – when 90% of the pods had turned brown.

Figure 9 Biomass during the growing season for 4 faba bean varieties and 2 sowing dates at Wagga Wagga, 2023.

Supplemental irrigation to simulate a non-water limited treatment, applied with an overhead lateral move irrigator between 29 August and 14 September, added 44 mm of water. The irrigated treatment had significantly higher biomass at podding and maturity

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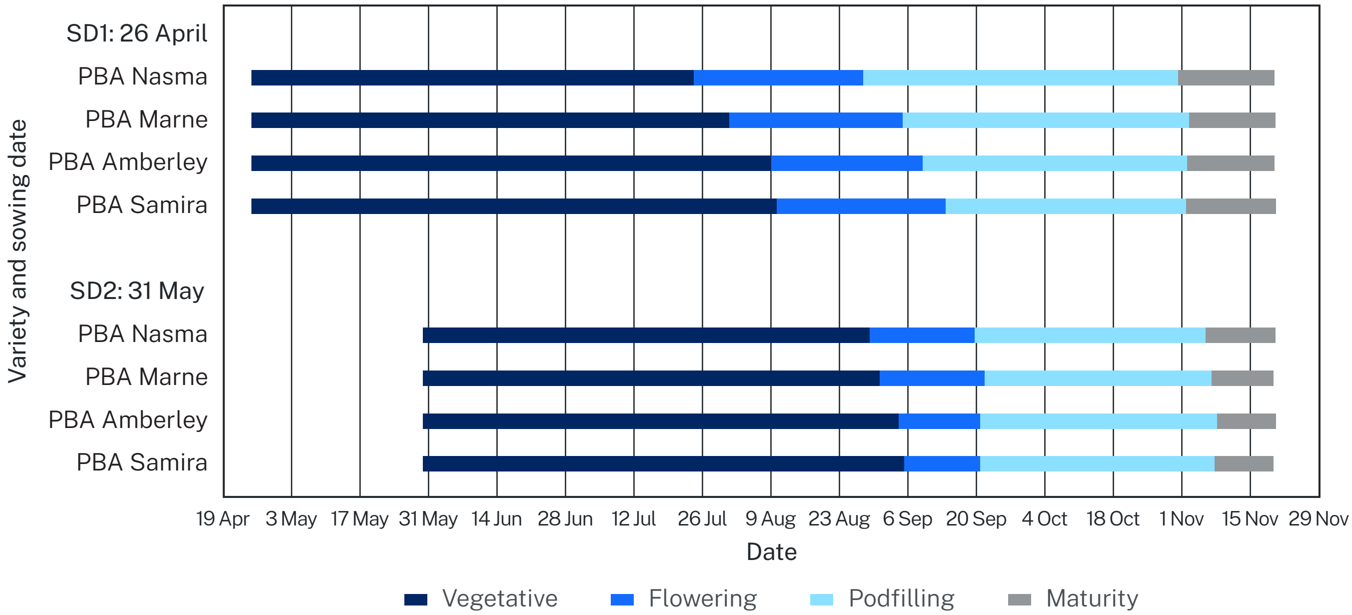
than the rainfed treatment. Biomass at podding and maturity for the rainfed treatment was 9.3 t/ha and 8.6 t/ha, respectively, increasing to 11.3 t/ha and 12.6 t/ha respectively with irrigation.

PBA Amberley⊕ and PBA Marne⊕ recorded the highest early biomass at 300 GDD, with 0.34 t/ha and 0.32 t/ha respectively. In contrast, at podding PBA Nasma⊕ and PBA Samira⊕ had the highest biomass (11.1 t/ha and 10.9 t/ha, respectively). High early biomass varieties such as PBA Amberley⊕ and PBA Marne⊕ had the lowest biomass at podding, showing that early biomass does not necessarily influence later growth stages.

Understanding how different sowing dates affect crop phenology can improve grain yield potential through aligning seed development with optimal environmental factors. Later sowing delayed flowering, pod initiation and maturity when compared with earlier sowing (Figure 10). Varieties also differed in their timing for these stages; PBA Nasma⊕ was significantly faster than other varieties to flower, set pods and mature.



Flowering bar represents the time between when most plants have a single open flower until they have a fully sized pod; pod filling bar represents the time between observing full sized pods until 80% of pods are brown; maturity bar represents the time between when 80% of pods are brown to when crop is harvestable.

Figure 10 Duration and/or transition between growth phases of faba bean varieties at Wagga Wagga in 2023.

In response to delayed sowing PBA Amberley⊕, PBA Samira⊕ and PBA Marne⊕ recorded between 4% and 8% reduction in days to flowering while PBA Nasma⊕ showed no change (Table 39). This suggests that the drivers for flowering are different between the varieties.

PBA Amberley⊕ and PBA Samira⊕ recorded the largest delay in pod set, 17% and 19%, respectively when sowing was delayed. PBA Nasma⊕ and PBA Marne⊕ were delayed by 10% and 14% respectively when sowing was delayed.

Table 39 Crop establishment, phenology and yield responses of faba bean varieties to sowing date at Wagga Wagga in 2023.

Variety	Sowing date	Establishment (plants/m²)	50% flowering (date)*	Pod set (date)†	Maturity (date)‡	Maturity biomass (t/ha)	Grain yield (t/ha)§	100 seed weight (g)
PBA Nasma	26 Apr	24.6	25 Jul	28 Aug	1 Nov	12.9	3.85 [a]	60.4
PBA Marne		25.6	1 Aug	6 Sep	3 Nov	12.5	3.78 [a]	61.1
PBA Amberley		29.3	10 Aug	10 Sep	3 Nov	13.4	3.19 [b]	63.9
PBA Samira		26.2	11 Aug	14 Sep	2 Nov	12.0	3.07 [b]	65.4
PBA Nasma	31 May	24.4	30 Aug	20 Sep	6 Nov	8.4	3.14 [b]	57.9
PBA Marne		28.1	1 Sep	22 Sep	8 Nov	8.7	3.02 [bc]	58.4
PBA Amberley		29.0	5 Sep	21 Sep	9 Nov	8.4	2.88 [c]	62.4
PBA Samira		25.9	6 Sep	22 Sep	9 Nov	8.8	2.99 [bc]	63.4
Site mean		26.6	19 Aug	14 Sep	5 Nov	10.6	3.24	61.6
l.s.d. (*P*>0.05)		n.s.	2.0	1.5	1.3	1.2	0.22	n.s.

* 50% flowering is the date when 50% of plants had one open flower.

† Pod set is the date when only pods are visible on plants.

‡ Maturity is the date when 90% of the pods are brown.

§ N.B. For grain yield interpretation, varieties with the same letter are statistically similar.

l.s.d. = least significant difference.

n.s. = not significant.

Crop establishment varied significantly with variety, ranging from 24.4 plants/m² for PBA Nasma⁽ᴾ⁾ to 29.0 plants/m² for PBA Amberley⁽ᴾ⁾ (Table 39). These populations are within the recommended guidelines of 20–30 plants/m² for southern NSW faba bean crops.

Sowing date did not significantly affect crop establishment.

Sowing early significantly increased grain yield (13%), from 3.0 t/ha to 3.5 t/ha (Figure 11). Supplemental irrigation significantly increased grain yield (23%), from 2.8 t/ha (rainfed) to 3.7 t/ha (irrigated). PBA Nasma⁽ᴾ⁾ (3.5 t/ha) and PBA Marne⁽ᴾ⁾ (3.4 t/ha) had the highest grain yields.

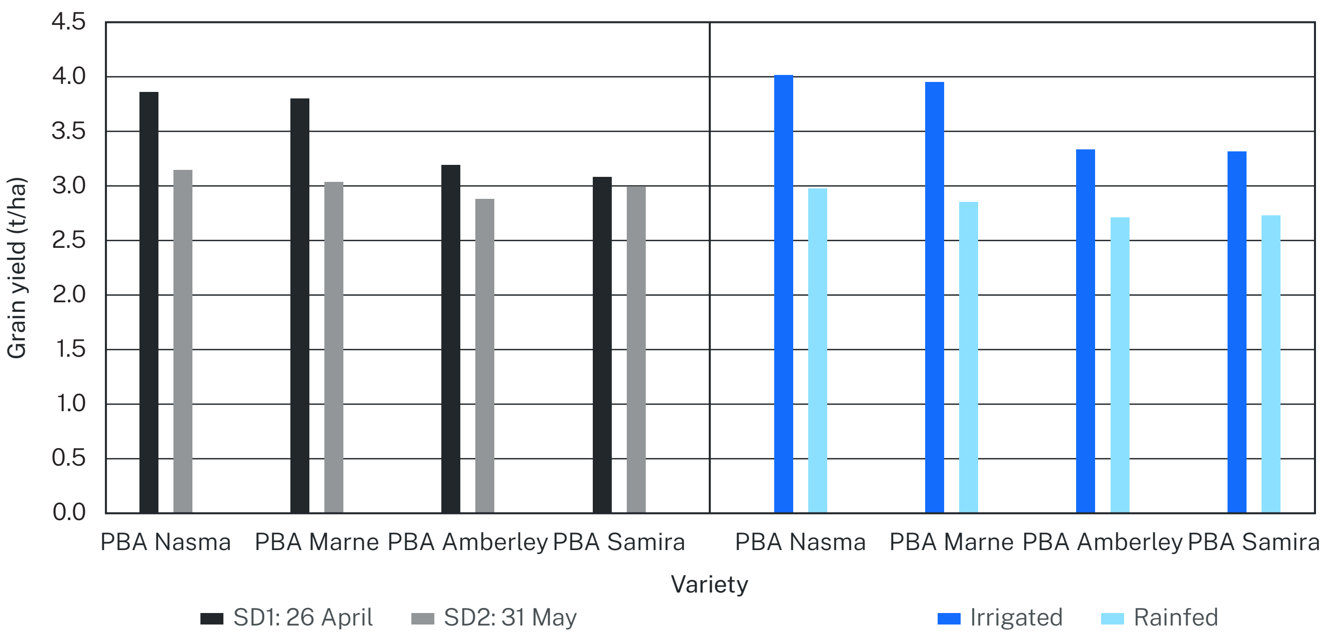


Figure 11 Sowing date and irrigation effects on the yield of faba bean varieties at Wagga Wagga, 2023.

PBA Nasma⁽ᴾ⁾ and PBA Marne⁽ᴾ⁾ had the highest grain yield when sown early but yield was reduced by 18% and 20%, respectively when sowing was delayed. In comparison, PBA Samira⁽ᴾ⁾ had the lowest yield when sown early but lost only 3% with delayed sowing (Table 39; Figure 11). Yield response to sowing date indicates that varieties such as PBA Nasma⁽ᴾ⁾ and PBA Marne⁽ᴾ⁾ have an advantage when sown in late April, yet PBA Samira⁽ᴾ⁾ shows a yield stability over time.

The increase in grain yield in response to supplemental water varied across varieties. PBA Marne⁽ᴾ⁾ and PBA Nasma⁽ᴾ⁾ were more responsive to irrigation with a 35% increase in grain yield while PBA Amberley⁽ᴾ⁾ and PBA Samira⁽ᴾ⁾ increased by 20% (Figure 11).

Average HSW decreased by 3% when sowing was delayed, from 62.7 g to 60.5 g (Table 39). Rainfed crops recorded a 4% increase in HSW when compared with irrigated crops. Under rainfed conditions, the number of grains set was lower with each grain achieving a larger weight, while under irrigation the number of grains set increased while each were filled to a lower seed weight.

Rankins Springs

The experiment at Rankins Springs investigated the effect of 2 sowing dates on 6 faba bean varieties: 3 southern (PBA Amberley⁽ᴾ⁾, PBA Marne⁽ᴾ⁾, PBA Samira⁽ᴾ⁾) and 3 northern (FBA Ayla⁽ᴾ⁾, PBA Nasma⁽ᴾ⁾ and PBA Nanu⁽ᴾ⁾). During the year measurements were made on grain yield and crop development.

The average grain yield was significantly higher for SD1 (24 April) compared with SD2 (18 May), at 1.43 t/ha and 1.00 t/ha respectively (Table 40). Early sowing resulted in the highest yields for FBA Ayla⁽ᴾ⁾, PBA Nanu⁽ᴾ⁾ and PBA Nasma⁽ᴾ⁾. Each variety showed a yield reduction when sown later.

Table 40 Crop establishment, phenology and yield responses of faba bean varieties to sowing date at Rankins Springs in 2023.

Variety	Sowing date	Establishment (plants/m²)	50% flowering (date)*	Maturity (date)†	Maturity biomass (t/ha)	Harvest grain yield (t/ha)‡	100 seed weight (g)
FBA Ayla	24 Apr	26.7	18 Jul	2 Oct	5.3	1.67 a	51.6
PBA Nanu		29.9	19 Jul	2 Oct	6.2	1.55 a	55.2
PBA Nasma		25.8	17 Jul	2 Oct	5.3	1.52 ab	63.4
PBA Marne		29.3	19 Jul	3 Oct	5.4	1.35 bc	57.7
PBA Samira		26.0	5 Aug	3 Oct	3.8	1.23 cd	55.7
PBA Amberley		30.7	8 Aug	3 Oct	5.8	1.26 cd	61.0
FBA Ayla	18 May	29.0	9 Aug	20 Oct	3.6	1.11 de	49.2
PBA Nanu		26.4	12 Aug	21 Oct	3.1	0.98 ef	50.6
PBA Nasma		24.4	10 Aug	21 Oct	3.4	1.01 ef	56.0
PBA Marne		25.7	10 Aug	21 Oct	3.5	0.97 ef	54.9
PBA Samira		26.4	15 Aug	19 Oct	2.9	0.97 ef	55.0
PBA Amberley		29.9	17 Aug	21 Oct	3.4	0.98 ef	52.4
Site mean		27.5	3 Aug	11 Oct	4.3	1.22	55.2
l.s.d. (P>0.05)		n.s.	2.3	n.s.	0.6	0.18	1.9

* 50% flowering is the date when 50% of plants had one open flower.

† Maturity is the date when 90% of the pods are brown.

‡ N.B. For grain yield interpretation, varieties with the same letter are statistically similar.

l.s.d. = least significant difference.

n.s. = not significant.

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Conclusion

The environmental conditions in 2023 were very challenging, with declining soil moisture and heat stress during the reproductive development phases in spring. From May to October, Wagga Wagga received only 50% of its LTA rainfall, with just 2.4 mm in September. Wagga Wagga had 15 frosts from 1 August to 22 September, and a high temperature of 33.9 °C on 17 September.

Rankins Springs received 67% of its LTA rainfall from May to October, with 18 frosts recorded between 5 August and 12 September, and temperatures above 30 °C on 15 September. This sharp rise in temperatures coupled with declining soil moisture placed significant terminal stress on crops and reduced grain yield potential.

The late April sowing in 2023 allowed crops to accumulate more biomass. The differences between sowing dates became more apparent as the season progressed. At Wagga Wagga, significant contributing factors included a full moisture profile at the start of the season and minimal soil constraints in the experiment paddock. Considering a good liming history, the lowest pH_{Ca} in the profile was 4.9 at 10–15 cm. This had a beneficial effect on plant health, nodulation and vigour contributing to plants accessing soil water available at depth in a dry spring, which then significantly increased yield potential. At Rankins Springs, the experiment site had a full moisture profile from summer rains. The lowest pH_{Ca} in the profile was 4.6 at 10–15 cm, which might have impeded root growth, limiting access to soil moisture at depth during dry spring conditions reducing yield potential.

FBA Ayla$^{\phi}$, PBA Nanu$^{\phi}$ and PBA Nasma$^{\phi}$ had the highest yields at Rankins Springs when sown in late April (SD1). These northern varieties flowered 2 weeks earlier than the southern varieties. At Wagga Wagga, PBA Nasma$^{\phi}$ and PBA Marne$^{\phi}$ were the highest yielding varieties with PBA Marne$^{\phi}$ flowering one week after PBA Nasma$^{\phi}$. Earlier flowering varieties had a longer reproductive period, allowing them to make the most of the less favourable spring conditions. They developed more yield during the more favourable early spring period, compared with the later flowering varieties.

Supplemental water at Wagga Wagga in early September increased biomass and grain yield but decreased HSW. This could be due to a higher number of seeds set with supplemental water yet the capacity to fill each seed was limited. In contrast, rainfed conditions resulted in fewer seeds developed but they were filled to a heavier weight.

As this national project is still undertaking field experiments, combined results and associated findings will be published in due course. Further analysis of the southern NSW based experiments in combination with the national data set is required to better understand the relationships between phenology, water stress, temperature and the critical period for yield formation in faba bean across varieties and environments.

Acknowledgements

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Find results from other pulse agronomy experiments in previous editions of Southern NSW research results (https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/southern-nsw-research-results).

Lupin phenology and yield responses to environment and management practices – Wagga Wagga and Rankins Springs 2023

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Key findings

- Below average rainfall, frequent frosts, and high temperatures during the grain filling phase significantly reduced grain yield potential at both experiment locations.
- Early sowing at Wagga Wagga increased biomass and grain yield without affecting seed weight. At Rankins Springs, early sowing increased biomass but did not affect yield or seed weight. The average grain yield was 2.5 t/ha at Wagga Wagga compared with 0.8 t/ha at Rankins Springs, a 68% reduction due to more adverse spring conditions.
- Higher-yielding conditions (Wagga Wagga): PBA Jurien⌽, PBA Bateman⌽, and Mandelup⌽ had the highest yields. Constrained conditions (Rankins Springs): Jindalee had the highest yield, especially with early sowing.

- **Important note:** while all seasons are unique, it is important to consider long-term phenology and yield data to determine varietal responses and adaptation to growing environment.

Keywords Wagga Wagga, Rankins Springs, 2023, lupin, sowing date, phenology, grain yield

Introduction

Pulses play a critical role in the Australian grains industry. They enhance the diversity and resilience of cropping systems, currently dominated by cereals and canola. To maximise yield and profit while managing risk, it is important to use species and varieties that are adapted to the climate, soil and farming systems of the cropping region. This reduces the effects of environmental constraints such as frost, heat, drought and soil limitations and optimises crop water use.

This lupin experiment is part of a nationwide project that aims to understand the non-water-limited yield potential of pulses, grown using best management practices. The aim is to improve the understanding of how factors such as growth and development stages, water stress, and temperature interact in crop yield formation.

This paper presents selected findings from the detailed experiment conducted at Wagga Wagga and satellite experiment at Rankins Springs in southern NSW in 2023. It reports the effects of sowing date on phenology and yield response in lupin.

Site details

Table 41 provides details about the experiment sites.

Table 41 Summary of site conditions and experiment management.

Location: site	Wagga Wagga: Wagga Wagga Agricultural Institute	Rankins Springs: Hillview, Stringy Bark paddock
Soil type	Red kandosol	Red chromosol
Soil pH_{Ca}	6.5 (0–5 cm), 5.5 (5–10 cm), 4.9 (10–15 cm), 5.2 (15–20 cm), 5.6 (20–25 cm), 5.8 (25–30 cm)	6.2 (0–5 cm), 4.8 (5–10 cm), 4.6 (10–15 cm), 5.6 (15–20 cm), 6.1 (20–25 cm), 6.3 (25–30 cm)
Previous crop	Wheat	Wheat
Rainfall	Fallow (November 2022 – March 2023): 239 mm	Fallow (November 2022 –March 2023): 216 mm
	Fallow long-term average (LTA): 204 mm	Fallow LTA: 165 mm
	In-crop (April–October 2023): 205 mm	In-crop (April–October): 165 mm
	In-crop LTA: 331 mm	In-crop LTA: 238 mm
Fertiliser*	100 kg/ha, SuPerfect® Grain Legume (N5:P15:S7:Ca11)	100 kg/ha, SuPerfect® Grain Legume (N5:P15:S7:Ca11)

*N = nitrogen, P = phosphorus, S = sulfur, Ca = calcium

Experiment details

Table 42 provides details of the treatments and timing of experiment activities at each site.

Table 42 Summary of the experiment details at Wagga Wagga and Rankins Springs, 2023.

Location	Wagga Wagga	Rankins Springs
Variety	PBA Bateman⁽ᴾ⁾, PBA Jurien⁽ᴾ⁾, Mandelup⁽ᴾ⁾ and Wonga	PBA Bateman⁽ᴾ⁾, PBA Gunyidi⁽ᴾ⁾, Jindalee, PBA Jurien⁽ᴾ⁾, Mandelup⁽ᴾ⁾ and Wonga
Sowing date (SD)	SD1: 26 April SD2: 31 May	SD1: 24 April SD2: 18 May
Maturity biomass date cut	SD1: 8 November SD2: 12 November	SD1: 1 November SD2: 2 November
Harvest date	23 November	4 December

Seasonal conditions

January to March rainfall was above average at both sites, leading to adequate soil moisture for sowing. May to October rainfall at Wagga Wagga was 50% of the LTA, and at Rankins Springs, 67% of the LTA. These deficits caused severe crop moisture stress in spring during grain filling.

Wagga Wagga recorded 32 frosts during the growing season, with 17 between August and mid October. Several frosts in early September were followed by temperatures above 30 °C (16–18 September), with a maximum of 34 °C on 17 September.

Rankins Springs recorded 27 frosts between mid July and September. In the week following 4 consecutive days of frost (9–12 September), daily maximum temperatures averaged 32 °C. The maximum daily temperature reached 36 °C on 18 September.

At both experiment locations, low soil moisture levels in spring, combined with frequent frost and high temperatures during the grain filling phase, significantly reduced grain yield potential.

There were no significant disease issues at either site in 2023.

Results

Wagga Wagga

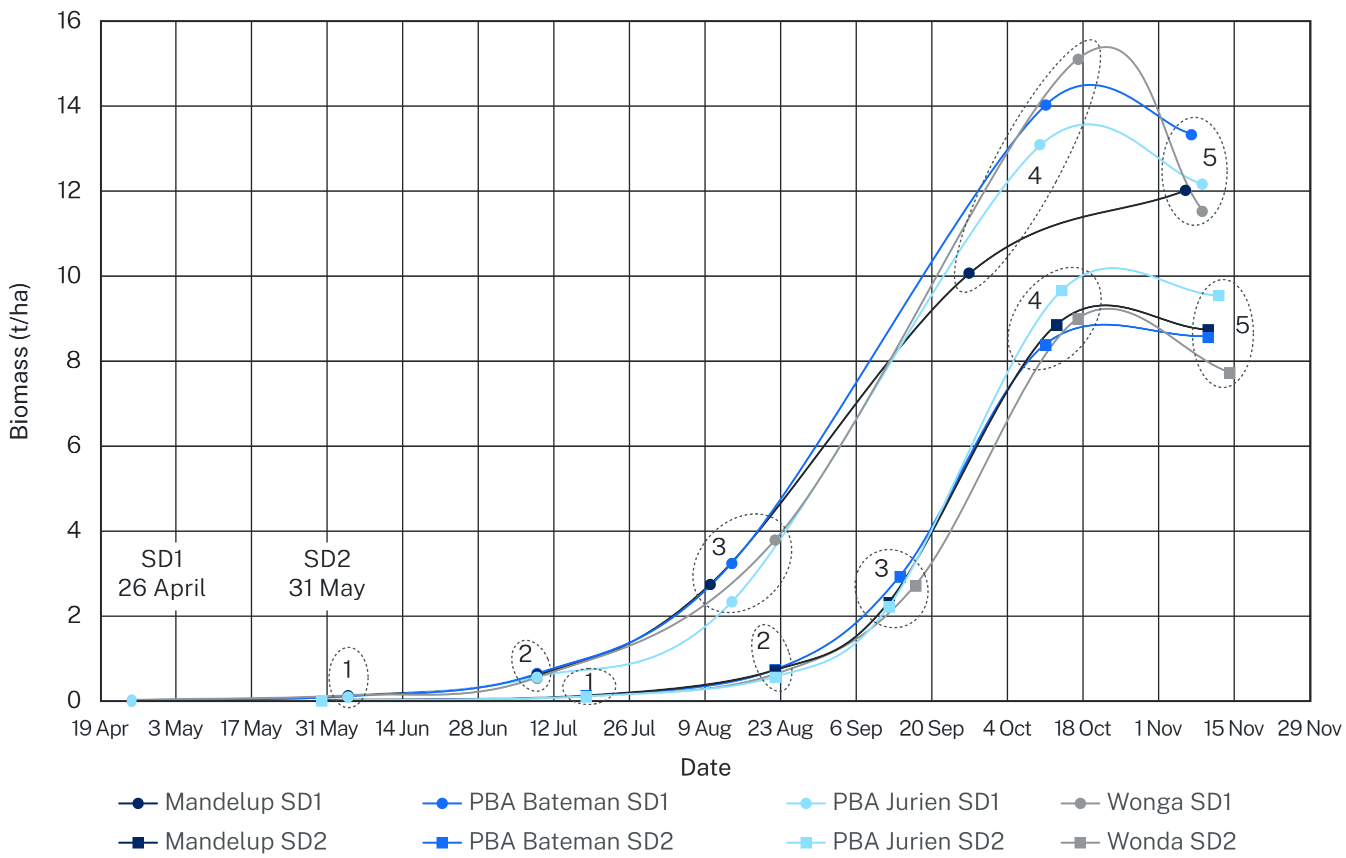
The experiment at Wagga Wagga studied the effect of variety and sowing date on 4 varieties, (PBA Bateman⁽ᵖ⁾, PBA Jurien⁽ᵖ⁾, Mandelup⁽ᵖ⁾ and Wonga) (Table 42). Measurements included crop phenology and biomass, grain yield, and soil water. This report focuses on biomass, crop phenology and grain yield.

Biomass was sampled 5 times between sowing and harvest:

1. 300 growing degree days (GDD)*
2. 600 GDD
3. Flowering (80% of plants have an open flower)
4. Podding (80% of plants have a fully expanded pod)
5. Maturity (90% of pods are brown).

**GDD is calculated as the average of the maximum and minimum daily air temperatures.*

Sowing date significantly affected biomass. Biomass at flowering, podding and maturity increased by 16%, 31% and 29% respectively for SD1 (late April) compared with SD2 (end of May) (Figure 12). Early biomass production was similar in all varieties.



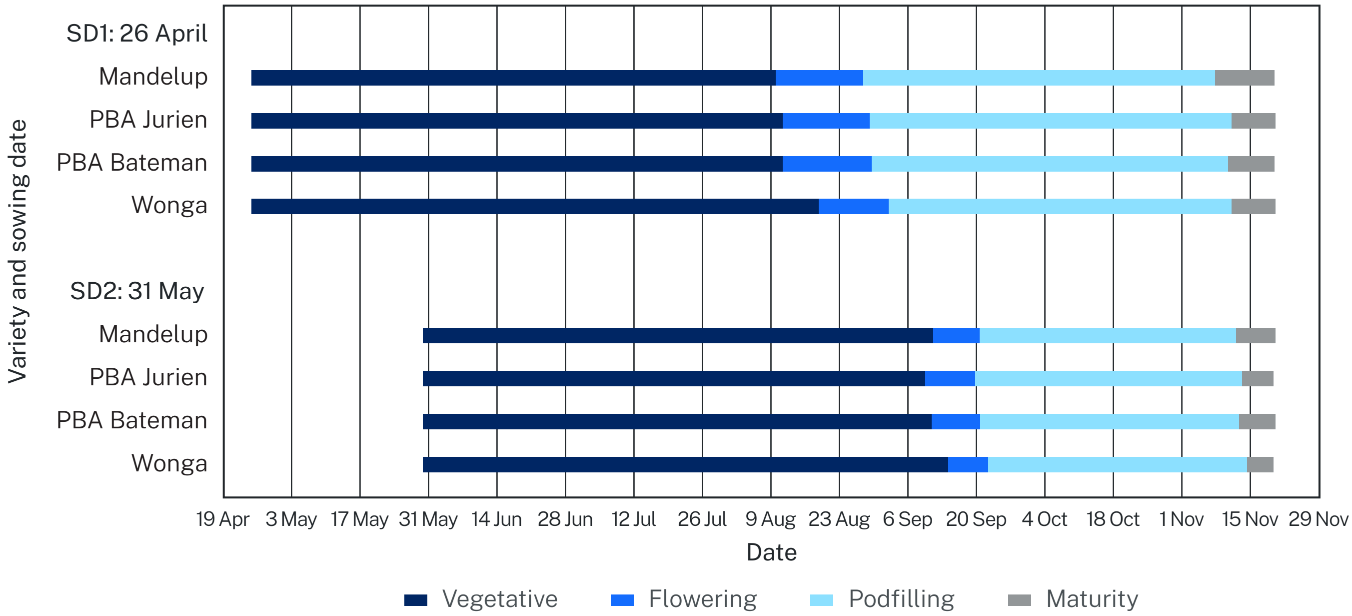
Points on graph from left to right (1) 300 GDD, (2) 600 GDD, (3) flowering biomass – when 80% of plants had open flowers; (4) pod biomass – when 80% of plants had a pod with a fully sized pod inside and (5) maturity biomass – when 90% of the pods had turned brown.

Figure 12 Lupin variety biomass production dynamics during the growing season at Wagga Wagga, 2023.

Sowing date significantly affected individual variety biomass (Figure 12). Varietal biomass differences were evident at start of flowering when sown earlier, but not when sowing was delayed. At flowering early sown (SD1) Wonga and PBA Bateman⁽ᵖ⁾ biomasses exceeded 3 t/ha, which was significantly greater than Mandelup⁽ᵖ⁾ and PBA Jurien⁽ᵖ⁾. There was no difference in flowering biomass between any variety when sowing was delayed (SD2).

For SD1, Wonga, PBA Bateman⦶ and PBA Jurien⦶ recorded similar biomass production, all exceeding 11 t/ha at podding (Figure 12). Generally, early sowing (SD1) increased biomass production in all varieties when compared with delayed sowing (SD2).

Understanding how crop development stages differ by variety and sowing date can help align seed development with optimal environmental factors. Figure 13 shows how sowing date changes the timing of developmental phases. For example, later sowing delayed flowering, pod initiation and maturity compared with earlier sowing.



Flowering bar represents the time between when most plants have a single open flower until they have a fully sized pod; pod filling bar represents the time between observing full sized pods until 80% of pods are brown; maturity bar represents the time between when 80% of pods are brown to when crop is harvestable.

Figure 13 Duration and/or transition between phases of lupin varieties at 2 sowing dates at Wagga Wagga in 2023.

There was a significant interaction between variety and sowing date for days to flowering. The vegetative phase was shorter for all varieties when sowing was delayed (SD2).

Three of the 4 varieties, Mandelup⦶, PBA Bateman⦶ and PBA Jurien⦶, flowered on 26 or 27 August, while Wonga flowered later, on 2 September (Table 43). A similar pattern was observed at pod set where Mandelup⦶, PBA Bateman⦶ and PBA Jurien⦶, at 9–10 September, were statistically similar and earlier than Wonga (13 September). Wonga's response to environmental cues for flowering and pod set is potentially different to the other varieties.

Table 43 Plant establishment, date of flowering, pod set and maturity, maturity biomass, grain yield and hundred seed weight for 4 lupin varieties at Wagga Wagga in 2023.

Variety	Plant establishment (plants/m²)	50% flowering (date)*	Pod set (date)†	Maturity (date)‡	Maturity biomass (t/ha)	Grain yield (t/ha)§	100 seed weight (g)
PBA Jurien	37.8	26 Aug	9 Sep	13 Nov	12.5	2.74 [a]	15.3
PBA Bateman	37.3	27 Aug	10 Sep	12 Nov	12.4	2.61 [ab]	15.5
Mandelup	39.8	26 Aug	9 Sep	10 Nov	11.8	2.60 [ab]	14.9
Wonga	40.4	2 Sep	13 Sep	13 Nov	11.1	2.26 [c]	13.1
Site mean	38.8	28 Aug	10 Sep	12 Nov	11.9	2.55	14.7
l.s.d. (*P*>0.05)	n.s.	1.1	1.4	1.0	n.s.	0.15	0.2

* 50% flowering is the date when 50% of plants had one open flower.

† Pod set is the date when pods are visible on a plant

‡ Maturity is the date when 90% of the pods are brown.

§ N.B. For grain yield interpretation, varieties with the same letter are statistically similar.

l.s.d. = least significant difference.

n.s. = not significant.

Sowing date affected lupin establishment. Delaying sowing from 26 April to 31 May reduced establishment by 14% (42 plants/m² to 36 plants/m²). Lupin establishment was still within the recommended range of 35–45 plants/m² for southern NSW.

There was no significant difference in yield between PBA Jurien⦶, PBA Bateman⦶, and Mandelup⦶ (Table 43), while Wonga, a longer seasoned variety, was significantly less than the other varieties. Delaying sowing reduced grain yield from 2.77 t/ha to 2.34 t/ha, with no significant interaction between sowing date and variety for grain yield.

Hundred seed weight (HSW) 14.7 g, was the same for both sowing dates. It could follow that the reduction in grain yield from delayed sowing was due to lower numbers of seed per unit area.

Rankins Springs

The experiment at Rankins Springs investigated the effect of 2 sowing dates on 6 narrow-leaf lupin varieties: PBA Bateman⦶, PBA Gunyidi⦶, Jindalee, PBA Jurien⦶, Mandelup⦶ and Wonga (Table 42). During the year, measurements were made on crop phenology, maturity biomass and grain yield. This report focuses on establishment, maturity biomass and grain yield.

The average grain yield for the site was low in 2023 (0.87 t/ha) (Table 44) due to the challenging seasonal conditions of low in-crop rainfall, frosts, high temperatures and terminal drought. Jindalee and PBA Bateman⦶ had significantly higher yields than the other 4 varieties.

Table 44 Plant establishment, maturity biomass, yield and hundred seed weight response for 6 lupin varieties at 2 sowing dates at Rankins Springs in 2023.

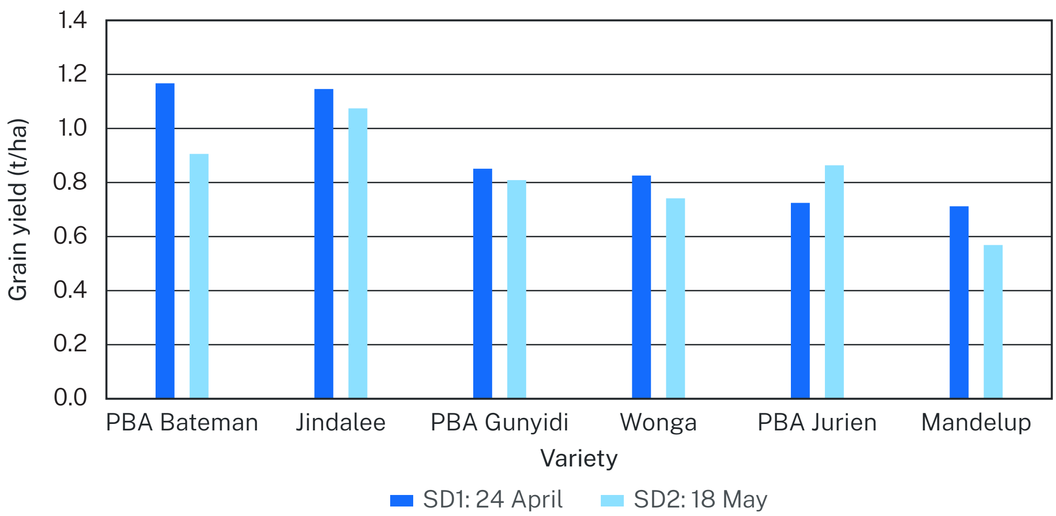
Variety	Sowing date	Establishment (plants/m²)	Maturity biomass (t/ha)	Grain yield (t/ha)*	100 seed weight (g)
PBA Bateman	24 April	48.4	6.5	1.17 [a]	13.7
Jindalee		41.1	7.1	1.15 [a]	13.6
PBA Gunyidi		42.8	6.5	0.85 [bc]	12.7
Wonga		46.6	6.6	0.83 [bcd]	12.3
PBA Jurien		41.0	6.1	0.72 [cdef]	14.0
Mandelup		39.0	6.8	0.71 [cdef]	14.1
PBA Bateman	18 May	39.2	5.2	0.90 [bc]	14.4
Jindalee		43.0	4.7	1.08 [a]	13.0
PBA Gunyidi		36.5	5.1	0.81 [bcde]	13.7
Wonga		39.8	5.0	0.74 [cdef]	13.6
PBA Jurien		42.2	4.6	0.86 [bc]	15.8
Mandelup		39.2	5.3	0.57 [f]	16.2
Site mean		41.6	5.8	0.87	13.9
l.s.d. (*P*>0.05)		6.9	n.s.	0.17	1.1

* N.B. For grain yield interpretation, varieties with the same letter are statistically similar.

l.s.d. = least significant difference.

n.s. = not significant.

Jindalee was the highest yielding variety for both sowing dates (Table 44; Figure 14). PBA Bateman⁽ᵈ⁾'s number one equal ranking with Jindalee for SD1 (late April) changed significantly when sowing was delayed (SD2; mid May), recording a 22% yield reduction. While severely stressed, like all treatments at the time, the longer flowering and slower maturing Jindalee was able to show a slight, positive yield response to the 37 mm rainfall in early October.



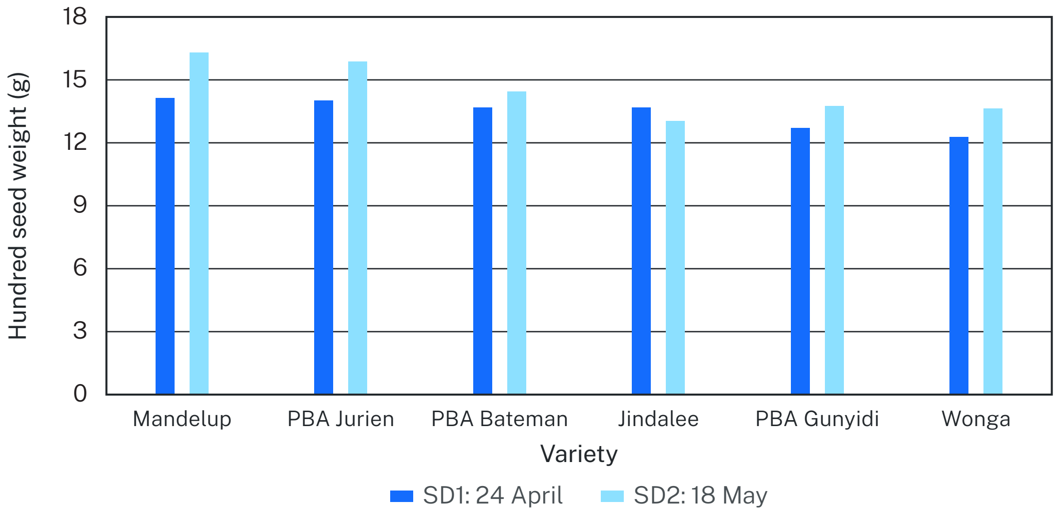
Grain yield average l.s.d. = 0.2 t/ha

Figure 14 Grain yield for 2 sowing dates for 6 lupin varieties at Rankins Springs, 2023.

PBA Jurien⁽ᵈ⁾ showed no significant yield response to sowing date. These results indicate that the timing and severity of the heat and moisture stress, especially during the reproductive stage, can have different effects on variety performance and can vary from season to season.

Plant establishment was within the recommended guidelines of 35–45 plants/m^2. Biomass at maturity was driven by sowing date, with a 24% reduction for SD2 (5.0 t/ha) compared with 6.6 t/ha for SD1 (Table 44).

Mandelup⫚ had the heaviest HSW, with PBA Jurien⫚ being statistically similar (Table 44; Figure 15). Sowing date affected HSW differently across varieties. Mandelup⫚, PBA Jurien⫚ and Wonga showed significant increases in HSW when sowing was delayed (SD2). No significant changes were recorded for PBA Bateman⫚, Jindalee and PBA Gunyidi⫚ over the 2 sowing dates.



Hundred seed weight average l.s.d. = 1.1 g

Figure 15 Hundred seed weight for 2 sowing dates for 6 lupin varieties at Rankins Springs, 2023.

Conclusion

The results of these experiments need to be taken in the context of the 2023 winter growing season, which had 2 distinct periods. Both Wagga Wagga and Rankins Springs had above average rainfall from January to April, but below average rainfall from May to October.

At Rankins Springs terminal drought affected all treatments, with severe moisture and heat stress during September. The first significant in-crop rainfall (37 mm) was on 3 and 4 October. Yield potential at Wagga Wagga was higher due to generally less intense abiotic stress across the growing season.

At Wagga Wagga, significant contributing factors included a full moisture profile at the start of the season and minimal soil constraints in the experiment paddock. Considering, a good liming history, the lowest pH_{Ca} in the profile was 4.9 at 10–15 cm. This had a beneficial effect on plant health, nodulation and vigour contributing to plants accessing soil water available at depth in a dry spring, which then significantly increased yield potential. At Rankins Springs, the experiment site had a full moisture profile from summer rains. The lowest pH_{Ca} in the profile was 4.6 at 10–15 cm which could have impeded root growth, limiting access to soil moisture at depth during dry spring conditions reducing yield potential.

As this national project is still undertaking field experiments, combined results and associated findings will be published in due course. Further analysis of the southern NSW based experiments in combination with the national data set is required to better understand the relationships between phenology, water stress, temperature and the critical period for yield formation in lupin across varieties and environments.

Acknowledgements

These experiments were conducted as part of the National Pulse Agronomy (NaPA) project 'Matching pulse crop designs to site and expected seasonal conditions to maximise yield and profit: a crop ecophysiology approach' (CSP2107-011RTX), a joint investment by GRDC and NSW DPIRD, led by CSIRO.

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Find results from other pulse agronomy experiments in previous editions of Southern NSW research results (https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/southern-nsw-research-results).

The residual effect of dual phosphorus placement on grain yield in southern NSW

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Key findings

- Responses to residual phosphorus (P) were evident during the fourth cropping season.
- Increase in grain yield is attributed to the higher P rates rather than placement depths.
- The dual P placement provided little evidence of yield advantage (only in 2 out of 44 datasets) when compared with the same total P rate with shallow placement.
- Shallow P was as effective or more effective than the dual P placement.
- Placing P deeper in the soil profile might not be a reliable way of improving crop performance and P use efficiency in southern NSW.

Keywords Phosphorus placement, deep banded P, shallow P, dual P, residual P, cumulative effect

Introduction

Deep banding of phosphorus (P) in the subsurface layer has been reported to increase grain yield of winter crops in the northern growing regions (southern and central Queensland), where rainfall is summer dominant and topsoils can remain dry for extended periods of time during the growing season (Bell et al. 2012; Singh et al. 2005). In southern growing regions (southern NSW, Victoria and South Australia), available P can be highly stratified at the soil surface but very low in lower soil layers. In contrast to the northern region however, rainfall is winter dominant, raising the question of whether winter crops in the southern region will also respond to deep P banding. In 2020 NSW DPI collaborated with the Grains Research and Development Corporation (GRDC) to develop a project (Maximising the uptake of phosphorus by crops to optimise profit in central and southern NSW, Victoria and South Australia; DPI2001-033RTX) to investigate the effectiveness of dual (deep and shallow) placed P on crop performance in the southern region.

This paper will report on findings from the experiments in southern NSW that tested the effectiveness of different combinations of dual placement of shallow (~5 cm) and deep (~20 cm) banded P. Both the effect of P placement on grain yield and the residual P effect on different crops over the last 4 seasons are presented.

Site details

Location	French Park, southern NSW
Soil type	Red kandosol
Design	• Experiment plots were arranged in a row-column design • Replications: 4

Sowing	• Species: Faba bean (cv. PBA Samira⊕) • Seed rate: 228 kg/ha • Sowing date: 5 May 2023 • Spacing: 25 cm
Fertilisation	Urea at 30 kg/ha at sowing (to balance for mono-ammonium phosphate [MAP] applied in a particular treatment)
Rainfall	• Fallow rainfall: – November 2022 – March 2023: 348 mm – Long-term average: 195 mm • In-crop rainfall: – April–October 2023: 200 mm – Long-term average: 325 mm
Harvest date	20 November 2023

Treatments

The experiment was established in 2020 with a range of P rates and 2 placement strategies. Phosphorus was either applied as a dual placement strategy or shallow only:

- Dual P placement – a portion placed below each seed row (shallow band) combined with a portion banded at approximately 20 cm below the surface at 50 cm spacings (deep band).
- Shallow P only – all placed below each seed row.

These 2 strategies are described as dual P or shallow P, respectively.

The shallow banded P treatments had rates of 0, 10, 20 and 40 kg P/ha. Except for 0 kg P/ha, each shallow banded treatment also had 4 deep banded P rates such as 0, 20, 30 and 40 kg P/ha. A very high rate of shallow banded P (80 kg P/ha) was included to estimate P deficiency severity.

An additional treatment where P was supplemented with Granulock®Z (shown by '+' with P rates) was included to cover any possible deficiencies in zinc and sulfur. Another treatment had 30 kg P/ha applied annually (referred to as 30 P).

All treatments were disturbed to ~20 cm deep to account for any apparent ripping effect. An additional control 0/0 undisturbed (no ripping) was included.

Phosphorus was applied as MAP and balanced for nitrogen (N) for different placement depths.

In 2021, the site received a blanket application of 5 kg P/ha. In 2022, the original undisturbed 0/0 treatment (0 UD/0) was treated with a shallow band of P at the maximum rate used in the initial experiment year (i.e. 80 kg P/ha) to examine fresh versus residual P effects. The remaining plots were balanced for N only.

In 2023, only the 30 P treatment received 30 kg P/ha.

The crop sequence during the last 4 seasons was:

- wheat (2020)
- lentil (2021)
- wheat (2022)
- faba bean (2023).

Results

Growing conditions

The experiment was established at French Park, southern NSW in 2020. Soil pH at the site is 6.2 (pH_{Ca} 0–10 cm) with pH increasing with depth (pH_{Ca} 6.9 at 10–30 cm and exceeds 8.2 below 30 cm). The site has a Colwell P of 49 mg/kg at 0–10 cm but only 4 mg/kg at 10–30 cm.

In the 2023 season, summer fallow rainfall totalled 348 mm, which was almost double the long-term average (195 mm). At sowing, the site had a gravimetric water content of 556 mm (up to 150 cm deep). The site received only 200 mm of rainfall during the growing season (April–October), which is lower than the long-term average for the same period (325 mm), and had a dry finish.

There were no establishment issues. Recorded plant density was 41 plants/m^2.

In the 2023 season, faba bean growth responded to both fresh P i.e. 30 P treatment (Figure 16) as well as residual P applied in the 2020 season.

The plot on the left is a 0/0 control receiving no P over the last 4 seasons (2020–23). The plot on the right is the 30 P treatment that had 30 kg P/ha applied annually. Both treatments were disturbed to ~20 cm deep at 50 cm spacing at sowing in 2020 to account for ripping effects of other deep-placed P treatments in this experiment.

Figure 16 Faba bean (cv. PBA Samira⁽ᵈ⁾) response to different P management strategies during flowering at French Park, southern NSW in 2023.

Grain yield in 2023

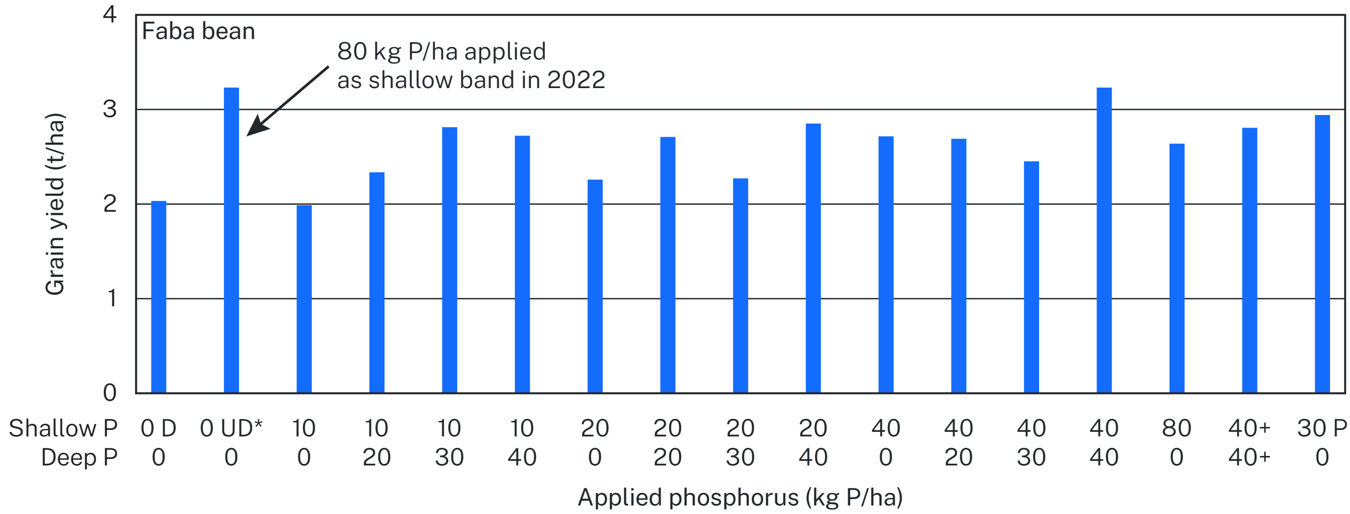
Faba bean yield was significantly (P<0.001) increased by P management (including rate and depth) strategies (Figure 17). Compared with the 0 D/0 (shallow/deep kg P/ha) control, applying 30 kg/ha shallow P annually (30 P treatment) increased the grain yield from 2 t/ha to 2.9 t/ha.

The effect of the residual P (either from the 2020 or 2022 seasons) on yield was significant in 2023. When compared with the 0 D/0 control, faba bean in 2023 treated with 80 kg P/ha in the 2020 and 2022 seasons yielded 30% and 59% higher, respectively.

The residual effect of deep banded P was evident only with low rates of shallow banded P. For example, with 10 kg P/ha shallow banded P, the residual from deep banding 30 kg P/ha and 40 kg P/ha resulted in a significantly higher yield than the 10/0 (shallow/deep kg P/ha) treatment. However, with higher rates of shallow banded P, i.e. 20 or 40 kg P/ha, these differences disappeared.

Crop nutrition

In some cases, the residual effect of dual banded P (40/40; shallow/deep kg P/ha) was significantly higher than its corresponding comparison of shallow banded P (80/0). However, this trend was not consistent for the 10/30 and 20/20 treatments when compared with its equivalent rates of shallow banded P (40/0; Figure 17).

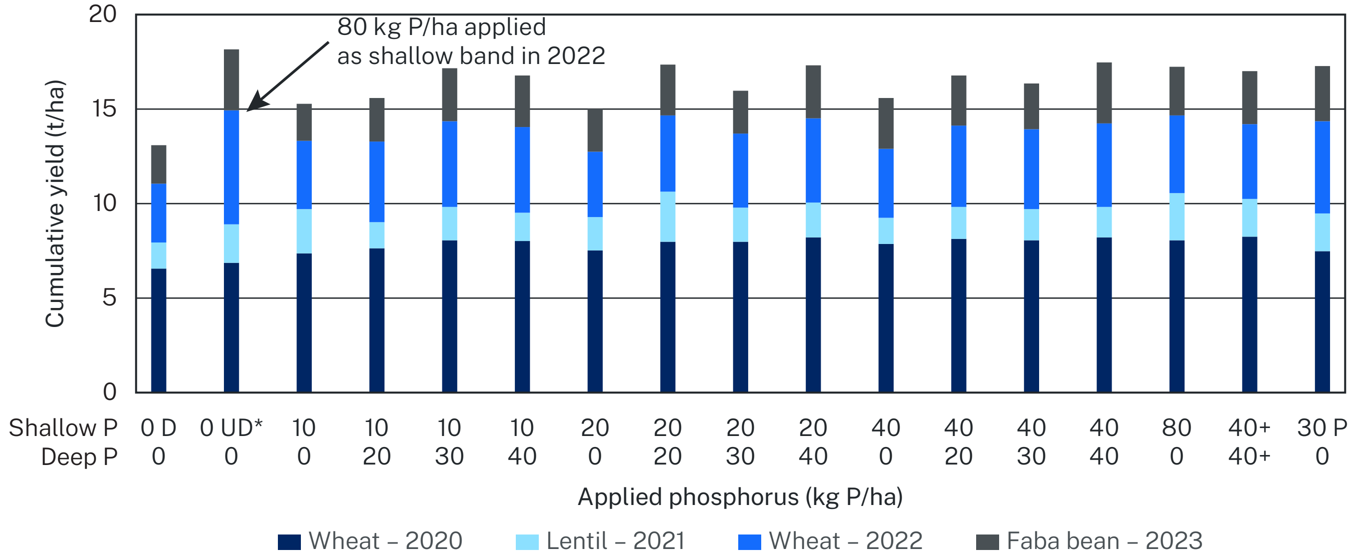


Treatment with '+' indicates P was supplemented with Granulock®Z fertiliser. All treatments except the 0 UD/0 (UD = undisturbed control) had been disturbed to ~20 cm deep at 50 cm spacing in 2020 as part of the deep P application.
Each data point is a mean value of n = 4. l.s.d. (P = 0.05) = 0.55 t/ha.
* UD: 0 UD/0 plots were treated with 80 kg P/ha as shallow bands in 2022 to compare with the residual effects of other treatments from 2020.

Figure 17 The residual effect of shallow and dual banded P (kg/ha) on faba bean (cv. PBA Samira⁽ᶦ⁾) grain yield during the fourth season (2023) after the initial application of P fertiliser in 2020 at French Park, southern NSW.

Cumulative yield response over 4 seasons

The effect of P management strategies on the cumulative grain yield of different crops was significant (P<0.001) over the last 4 seasons (Figure 18). Compared with 0 D/0 control, different P rates increased the cumulative grain yield by up to 39%. The cumulative residual effect of higher P rates (i.e. 40 kg P/ha or higher) resulted in more than 30% grain yield over the last 4 seasons. This cumulative yield response was rate-dependent, but was not affected by the placement depths (Figure 18).



Treatment with '+' indicates P was supplemented with Granulock®Z fertiliser. All treatments except the 0 UD/0 (UD = undisturbed control) had been disturbed to ~20 cm depth at 50 cm spacing in 2020 as part of the deep P application.
Each data point is a mean value of n = 4. l.s.d. (P = 0.05) = 1.7 t/ha.
* UD: 0 UD/0 plots were treated with 80 kg P/ha as shallow bands in 2022 to compare with the residual effects of other treatments from 2020.

Figure 18 The effect of shallow and dual banded P (kg/ha) on cumulative grain yield of different crops over the last 4 seasons (2020–23) after the initial application of P fertiliser in 2020 at French Park, southern NSW.

Summary

Despite having a high background Colwell P, in the fourth season (2023) this site was responsive to both fresh P applied annually as well as to the residual P. This suggests there could be an opportunity to improve farming productivity and profitability through P management. However, the phosphorus buffering index (PBI) should be considered along with the Colwell P to optimise P rates (Sandral et al. 2019).

In line with earlier findings from the northern growing regions (Sands et al. 2022) the residual effect of higher rates of deep banded P is carried through into the fourth season following the year of band placement. The relative yield responses to deep banded P observed in this experiment were much higher than the earlier reported values from the northern growing regions. However, this observed trend was evident only with low shallow P rates and disappeared with a higher or corresponding comparison of shallow P rates (Bell et al. 2012). This suggests that applying commercially acceptable higher rates of shallow banded P can overcome the subsoil P limitation in the southern growing regions.

In this experiment, there was little evidence of the yield advantage of dual banded P when compared with the same total P rate with shallow placement (i.e. 40/40 vs 80/0; shallow/deep kg P/ha), but this trend was not consistent across other treatments (i.e. 10/30 and 20/20 vs 40/0; shallow/deep kg P/ha). Even the cumulative yield response over the last 4 seasons did not demonstrate any yield advantage from dual banded P when compared with its corresponding comparison of shallow banded P.

Over the last 4 seasons the project has generated 44 experiment datasets comparing the effectiveness of dual banded P over shallow banded across southern NSW, Victoria and South Australia. About two-thirds (31 out of 44 datasets) showed a significant P response to grain yield. In all situations where P responses were observed, shallow P was as effective, or more so, than dual P placement. There was very limited evidence (only 2 out of 44 datasets) of dual banded P being more effective than shallow P.

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Acknowledgments

This experiment was part of the 'Maximising the uptake of phosphorus by crops to optimise profit in central and southern NSW, Victoria and South Australia', project (DPI2001-033RTX, 2020–25). The project is a collaborative partnership between GRDC, NSW DPIRD, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Agriculture Victoria (AgVIC), the South Australian Research and Development Institute (SARDI), The University of Adelaide (UoA), Charles Sturt University (CSU) and Agronomy Solutions.

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The residual effect of dual phosphorus placement was evident on canola yield but not wheat in Central West NSW

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Key findings

- Phosphorus (P) rates but not placement depth interacted with the studied crop species.
- Canola displayed a stronger response to both fresh P and residual P than wheat.
- Increase in grain yield is attributed to the higher P rates rather than placement strategies.
- Shallow P was as effective as dual P placement.
- Placing P deeper in the soil profile might not be a reliable way of improving crop performance in Central West NSW.

Keywords Phosphorus placement, deep banded P, shallow P, dual P, residual P, crop species

Introduction

Deep banding of phosphorus (P) in the subsurface layer has been found to increase winter crop grain yield in the northern growing regions (southern and central Queensland), where rainfall is summer dominant and topsoils can remain dry for extended periods during the growing season (Bell et al. 2022). In contrast to the northern growing regions, cropping in the southern growing regions (southern NSW, Victoria and South Australia) is dominated by winter rainfall, but periods of prolonged dry topsoils still occur particularly during drier years. Additionally, highly stratified surface P and low P reserves below the cultivated layer led to the prediction that dual P banding in the southern growing regions would be more efficient than current strategies of P placement in or around the sowing rows. A joint investment between the Grains Research and Development Corporation (GRDC) and NSW DPI began in 2020 (Maximising the uptake of phosphorus by crops to optimise profit in central and southern NSW, Victoria and South Australia; DPI2001-033RTX) to investigate the effectiveness of dual placed P on crop performance in the southern growing region.

Part of this project investigated the interactions between P placement strategies and crop species on P uptake and grain yield at different locations across southern NSW, Victoria and South Australia. This paper reports experiment findings from Central West NSW during the third season (2023) after the initial application of P fertiliser in 2021.

Site details

Location	Condobolin, Central West NSW
Soil type	Red kandosol

Design	• A split-plot design with crop species as the main plots and P treatments as sub-plots • Replications: 4
Sowing	• Species: – Wheat (cv. Rockstar⁽ᵈ⁾) – Canola (cv. HyTTec® Trident) • Seed rate: – Wheat – 92 kg/ha – Canola – 3.1 kg/ha • Sowing date: 2 May 2023 • Spacing: 25 cm
Fertilisation	• Urea at 50 kg/ha at sowing • Urea at 158 kg/ha at tillering
Rainfall	• Fallow rainfall: – November 2022 – March 2023: 253 mm – Long-term average: 218 mm • In-crop rainfall: – April–October 2023: 127 mm – Long-term average: 248 mm
Harvest date	2 November 2023

Treatments

P treatments

The experiment was established in 2021 in a split-plot design with 2 crop species (wheat and canola) as main plots and 6 phosphorus treatments: 5/0, 5/60, 20/0, 20/60, 60/0 and 5/0 UD (shallow/deep P kg/ha) as the sub-plots (Table 45).

Phosphorus was either applied as a dual placement strategy; some under every seed row (shallow band) and some banded at approximately 20 cm below the surface in 50 cm spacings (deep band) or it was all placed under every seed row. These 2 strategies are described as dual P (e.g. 5/60 and 20/60; shallow/deep P kg/ha) or shallow P (e.g. 5/0, 20/0, 60/0 and 5/0 UD; shallow/deep P kg/ha), respectively.

Table 45 Summary of phosphorus treatments (kg P/ha) applied in 2021 and any additional features.

Shallow P	Deep P	Additional features
5	0	Disturbed
5	60	Disturbed
20	0	Disturbed
20	60	Disturbed
60	0	Disturbed
5	0	Undisturbed (UD)

All plots except the undisturbed (UD) one were disturbed to ~20 cm deep. UD plots were treated with 60 kg P/ha and 20 kg P/ha, respectively in 2022 and 2023.

Phosphorus was applied as mono-ammonium phosphate (MAP) and balanced for nitrogen applied as urea. All treatments (even where no deep P was applied for example 5/0, 20/0 and 60/0) were disturbed to ~20 cm deep to account for any apparent ripping effect.

In 2022 and 2023, the undisturbed 5/0 (shallow/deep kg P/ha) plots were treated with 60 kg P/ha and 20 kg P/ha respectively, as a shallow band to compare with the residual effects of high P rates supplied previously.

Results

Growing conditions

The key feature of the soil at the Condobolin site is stratified P with Colwell P of 24 mg/kg at the soil surface (0–10 cm) and 7.8 mg/kg in the subsoil (10–30 cm). The site is acidic with pH_{Ca} values of 4.83 and 4.92, respectively for 0–10 cm and 10–30 cm depths.

In the 2023 season, summer fallow rainfall (253 mm) was above the long-term average (218 mm). At sowing, the site had about 472 mm of water and 53 kg/ha of mineral nitrogen (up to 150 cm deep).

There were no establishment issues with 115 plants/m^2 of wheat and 37 plants/m^2 of canola.

Despite having a wet fallow, the site received only half (127 mm) of the long-term average growing season rainfall (248 mm) with October being very dry. Many local crops did not produce a harvestable yield due to the dry spring.

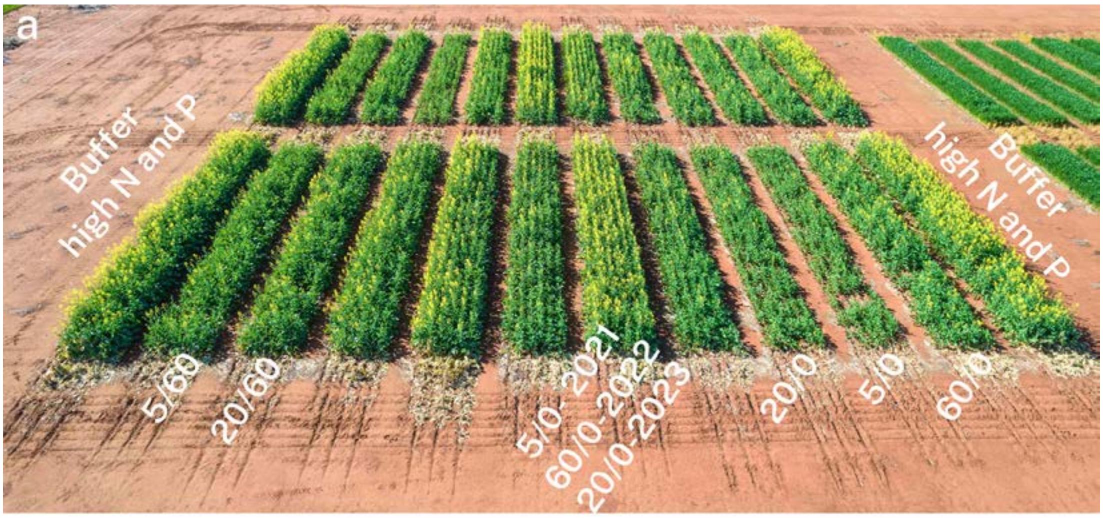
In the 2023 season, canola growth responded to both fresh P (applied in 2023) and residual P (applied in 2021; Figure 19a), whereas wheat growth responded to the fresh P but not to residual P applied in 2021 (Figure 19b).

P uptake at flowering

Phosphorus uptake at flowering (Figure 20) was significantly affected by P application strategies (P<0.001) and crop species (P<0.001) as well as their interactions (P<0.001). In 2023, wheat only responded to the annual supplementation of the fresh P and did not respond to the residual P applied in the 2021 season. In contrast, the P uptake in canola was significantly increased by both fresh P and the residual P applied in the 2021 season. However, responses to residual P were rate-dependent but not placement depth-dependent.

Grain yield

Annual P supplementation to wheat (i.e. 5+60+20/0 shallow/deep kg P/ha) resulted in a 1.0 t/ha yield advantage over the 5/0 (shallow/deep kg P/ha) applied in the 2021 season (Figure 21). The residual effect of the other P rates was not significantly different from the 5/0 treatment. In contrast, canola yield responded to both fresh P (annual supplementation) and the higher rates of residual P applied in 2021. However, the yield response of canola to the residual P was rate-dependent but not placement depth-dependent. The grain yield of both species showed a strong correlation with P uptake at flowering (Figure 22).

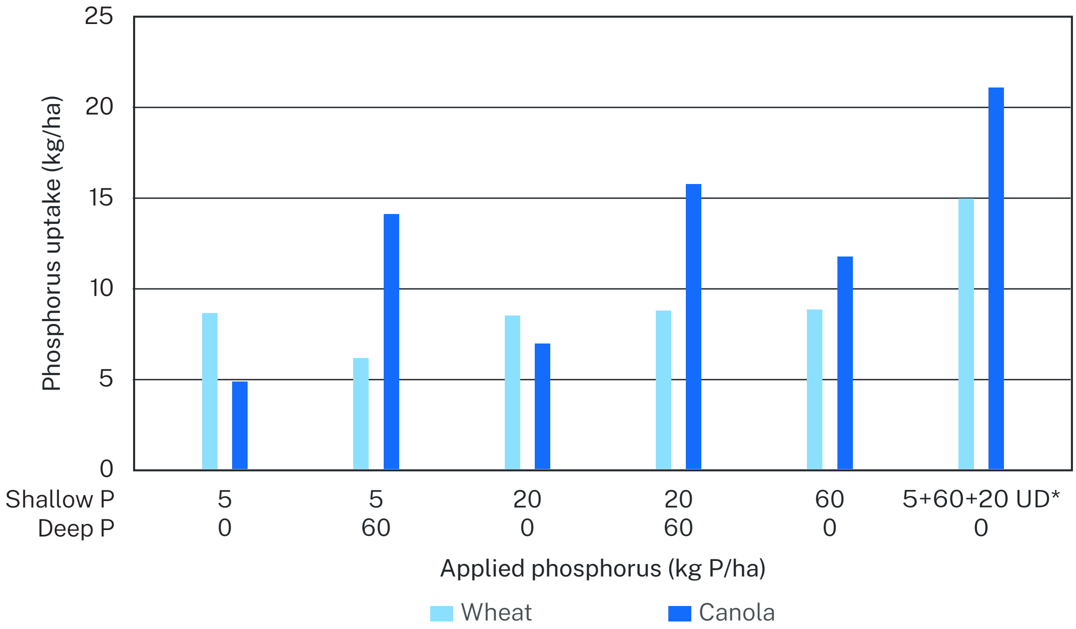


Phosphorus rates applied at sowing in the 2021 season are indicated shallow/deep as kg P/ha.

All treatments had been disturbed to ~20 cm deep at sowing in 2021 at 50 cm spacing as part of the deep P application except the undisturbed treatments, which received annual P supplementation as a shallow band.

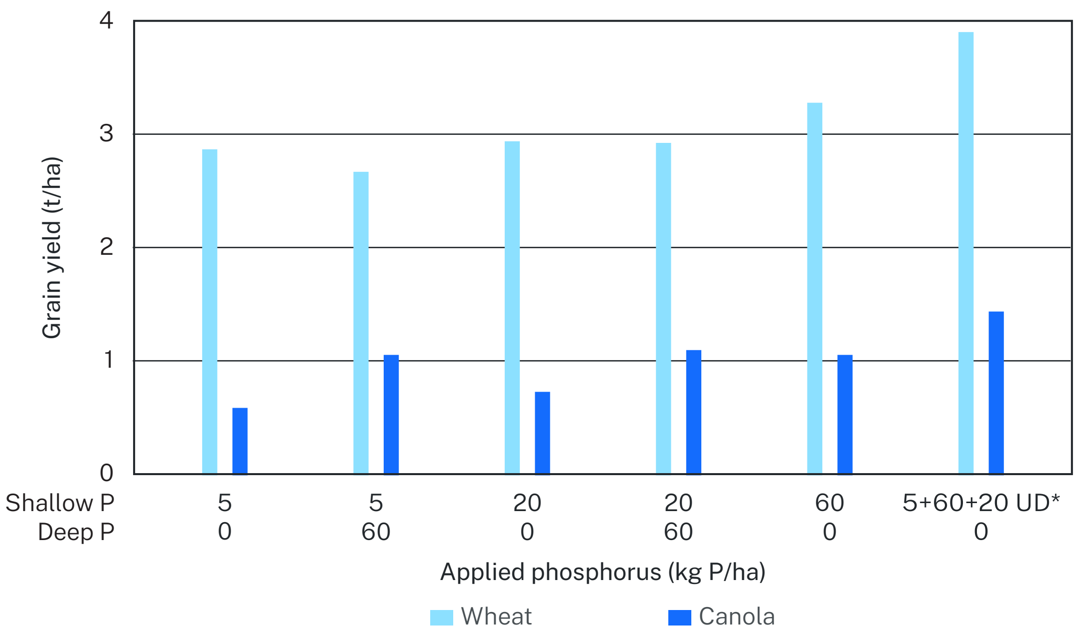
Unmarked plots are part of PhD student's research project.

Figure 19 Drone photo over the experiment at Condobolin, NSW taken on 8 August 2023 showing the effect of shallow and deep banded P on canola (a) and wheat (b) growth.



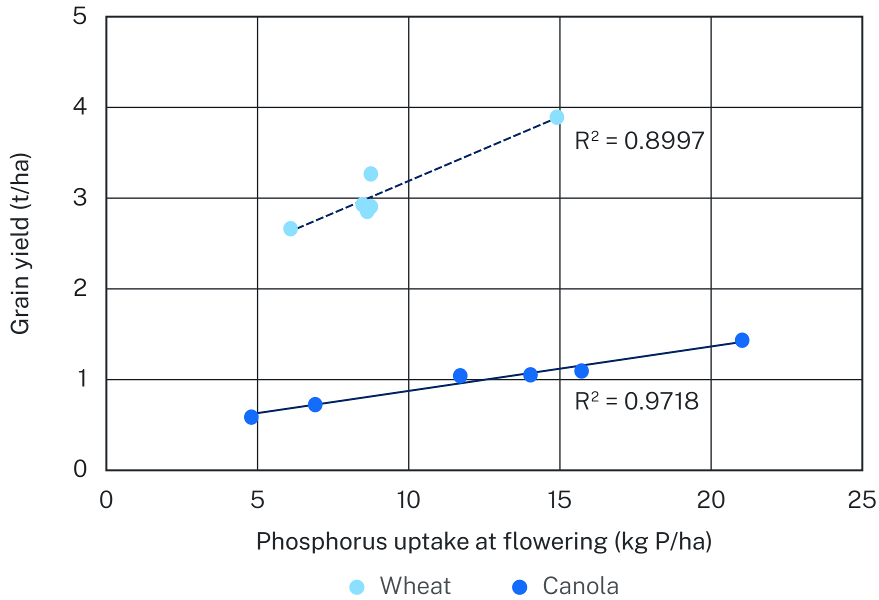
All treatments except the 5/0 UD (undisturbed control) had been disturbed to ~20 cm deep at 50 cm spacing.
Each data point is a mean value of n = 4. l.s.d. (P = 0.05) = 3.87 kg/ha.
* UD: 5/0 Undisturbed plots were treated with 60 kg P/ha and 20 kg P/ha, respectively in 2022 and 2023 as shallow bands to compare with the residual effects of other treatments from 2021.

Figure 20 Phosphorus uptake at wheat and canola flowering affected by shallow and deep banded P (kg/ha) at Condobolin, NSW in 2023.



All treatments had been disturbed to ~20 cm depth at sowing in 2022 at 50 cm spacing as part of the deep P application.
Each data point is a mean value of n = 4. l.s.d. (P = 0.05) = 0.23 t/ha.
* UD: 5/0 Undisturbed plots were treated with 60 kg P/ha and 20 kg P/ha, respectively in 2022 and 2023 as shallow bands to compare with the residual effects of other treatments from 2021.

Figure 21 The effect of shallow and dual banded P (kg/ha) on grain yield of wheat and canola at Condobolin, NSW in 2023.



Each data point is a mean value of n = 4.

Figure 22 The relationship between P uptake at flowering with grain yield of wheat and canola.

Summary

Phosphorus uptake at flowering was a function of both biomass and tissue P concentration. At flowering, both biomass and tissue P concentration responded similarly of P uptake to different P treatments (data not presented). Under dryland conditions, P uptake at flowering has a strong correlation with grain yield (Bell et al. 2022), as observed in this experiment (Figure 22).

Canola had a stronger grain yield response than wheat to both fresh P (applied in 2023) and residual P (applied in 2021). This observed species variability to different P treatments might be attributed to canola being more efficient than wheat in using low-concentration residual P and high-concentration fresh P applied as bands (Brennan and Bolland 2004). Further, the efficiency of different species in foraging shallow and/or deep banded P depends on their root architectural traits, which a PhD student is currently investigating as a part of this project.

Despite the contrasting responses of wheat and canola to both annually applied P and residual P there was no evidence of better performance or effectiveness of dual P placement over shallow P. This finding is consistent with earlier P placement experiment results from the Riverina region in NSW (Uddin et al. 2023) and in South Australia (Wilhelm 2022).

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Crop nutrition

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Septoria tritici blotch – risk and management considerations for 2024

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Key findings

- Favourable climatic conditions early in the 2023 growing season resulted in widespread and the increased prevalence of septoria tritici blotch (STB) in southern NSW (sNSW).
- With resultant high stubble loads from the 2021–2023 seasons, STB risk levels are likely to be elevated again in 2024.
- STB infection and epidemic development is highly dependent on climatic conditions throughout the season. Climatic conditions in 2024 will dictate the severity of any STB epidemic.
- If there are optimal climatic conditions and early STB infection is evident, apply fungicide at GS31–32 to suppress the epidemic and enable flexibility with later fungicide applications.
- Not all fungicide active ingredients are equal when it comes to controlling STB and fungicide choice is becoming increasingly important.
- NSW DPIRD plant pathologists can assist with correct diagnosis and advice on appropriate integrated disease management (IDM) options.

Keywords Correct diagnosis, leaf disease, STB, pycnidia, integrated disease management (IDM)

Introduction

Septoria tritici blotch (STB) is a necrotrophic disease in bread wheat, durum wheat and triticale, caused by the pathogen *Zymoseptoria tritici* (*Z. tritici*). STB is considered the third most significant wheat disease globally, threatening large areas of wheat production. Studies at the Wagga Wagga Agricultural Institute (2020–2021) revealed that in regions with moderate to high rainfall, the disease could lead to a considerable reduction in crop yield, ranging from 19% to 49%.

STB has a fungal structure produced on wheat stubble (pseudothecia) that releases airborne spores (ascospores) under ideal environmental conditions. The ascospores produced can spread over long distances (kilometres) on the wind to infect susceptible crops. Following an infection event, lesions appear up to 28 days later and produce pycnidia (small black structures inside tan leaf lesions that give a speckled appearance). The pycnidia produce a different type of spore called conidia, which are then splash-dispersed by rainfall within the wheat canopy, causing new infections and further driving the STB epidemic.

Under the NSW DPI project DPI2207-002RTX (completed) – a joint investment with the Grains Research and Development Corporation (GRDC) – diagnostic and management advice services were offered at no cost to growers and advisors. STB, for the third year in a row, was the fourth most queried disease during 2023 (data not shown), further emphasising the importance of this disease in southern and central NSW. This project was recently co-invested for a further 5 years under code DPI2404-007RTX; diagnostic and management advice services are still offered at no cost for growers and advisors as part of the project.

Septoria epidemic during the 2022 and 2023 growing seasons

The start of the 2023 growing season for much of sNSW was characterised by widespread STB infection in the lower canopy of susceptible wheat varieties. However, unlike 2022 this early infection did not generally progress to the upper canopy during grain filling nor result in significant yield loss. Several climatic and management differences during 2023, as opposed to 2022 can help explain this.

STB development is highly driven by climatic conditions. It requires extended periods of leaf wetness (>24 hours) and optimal cycling temperatures of 15–20 °C for infection. Rainfall was below mean during winter and spring at Wagga Wagga in 2023 (Figure 23). The long-term cumulative historical mean annual rainfall for August, September and October at Wagga Wagga is 129.9 mm. During 2022, rainfall for that period was 335.2 mm compared with only 61.8 mm in 2023. These 3 months are crucial for the development of STB epidemics, as this is when STB moves from the lower to mid canopy and onto the upper leaves (flag, flag-1, flag-2). This is important because the upper leaves contribute the most to yield accumulation. The 2023 spring rainfall during those critical months was less conducive to STB cycling than in 2022, resulting in reduced STB infection levels in the mid and upper canopy of wheat crops.

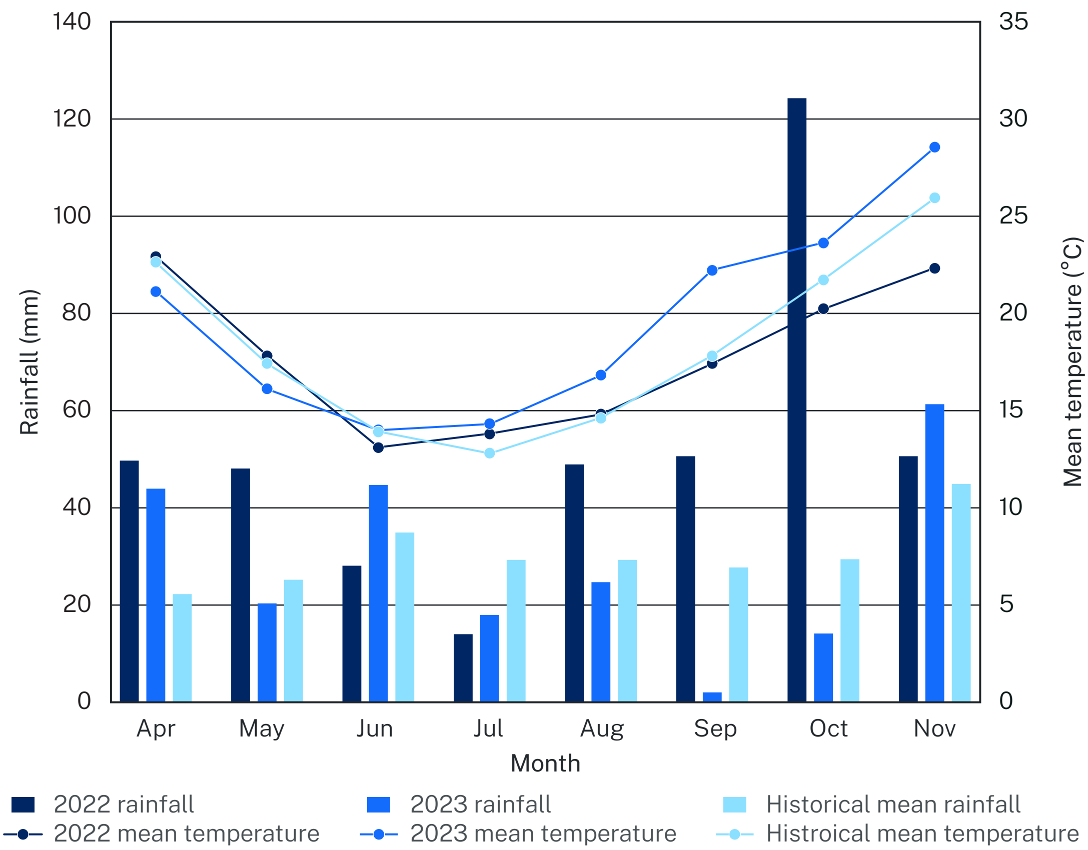


Figure 23 Growing season (April–November) rainfall and temperature at Wagga Wagga during 2022 and 2023 compared with the long-term mean monthly rainfall and temperature (BoM, 2023).

The halt in STB infection levels during the second half of the 2023 growing season can be explained by the below mean rainfall and above mean temperatures during winter and spring months, particularly September and October.

The mean temperature during the spring months of 2023 was much higher than in 2022 (Figure 23). Table 46 outlines the deviation from historical mean temperature for August, September and October during the 2022 and 2023 growing seasons. In 2022, temperatures were much cooler, facilitating STB infection and cycling, whereas in 2023, much earlier in the season, temperatures were outside the ideal cycling temperatures for STB development resulting in shortened leaf wetness duration. These factors reduced the number of cycles STB could undertake in 2023, helping to curb the levels of infection despite the extreme inoculum loads that had built up during the previous 2–3 years.

Table 46 Deviation from historical mean temperature for August, September, and October 2022 and 2023.

Month	Historical mean temperature (°C)	2022 deviation from historical mean temperature (°C)	2023 deviation from historical mean temperature (°C)
August	14.6	+0.2	+2.2
September	17.8	−0.4	+4.4
October	21.7	−1.5	+1.9

Temperature and rainfall are key factors that drive disease epidemics. However, for STB infection, leaf wetness and, importantly, the duration of leaf wetness also play a crucial role. Figure 24 outlines the number of rainfall days and the consecutive number of rainfall days (>2 days) during the growing seasons of 2022 and 2023. A rainfall day is categorised as a fall of >5 mm in a 24-hour period and/or >5 mm falling during a single event over consecutive days (>2 days).

During the crucial 3 months for disease development – August, September and October – there were significantly fewer rain days along with fewer consecutive rainfall days in 2023 compared with 2022. For example, September 2022 had 4 rainfall events that lasted >2 days, compared with zero during September 2023. October 2022 had 4, and October 2023 had one rainfall day. This limitation in leaf wetness duration meant that the moisture requirement for STB to cycle was only partially met or not met at all, resulting in a net reduction in infection levels in 2023.

Generally, the lack of rainfall, decrease in leaf wetness duration, higher-than-average temperatures and proactive fungicide use all contributed to STB staying in the lower to mid canopy of wheat crops in sNSW during the 2023 season. This was not the case for the entire cropping area of sNSW, particularly in the higher rainfall slopes regions, where STB continued to be a problem throughout the entire 2023 season.

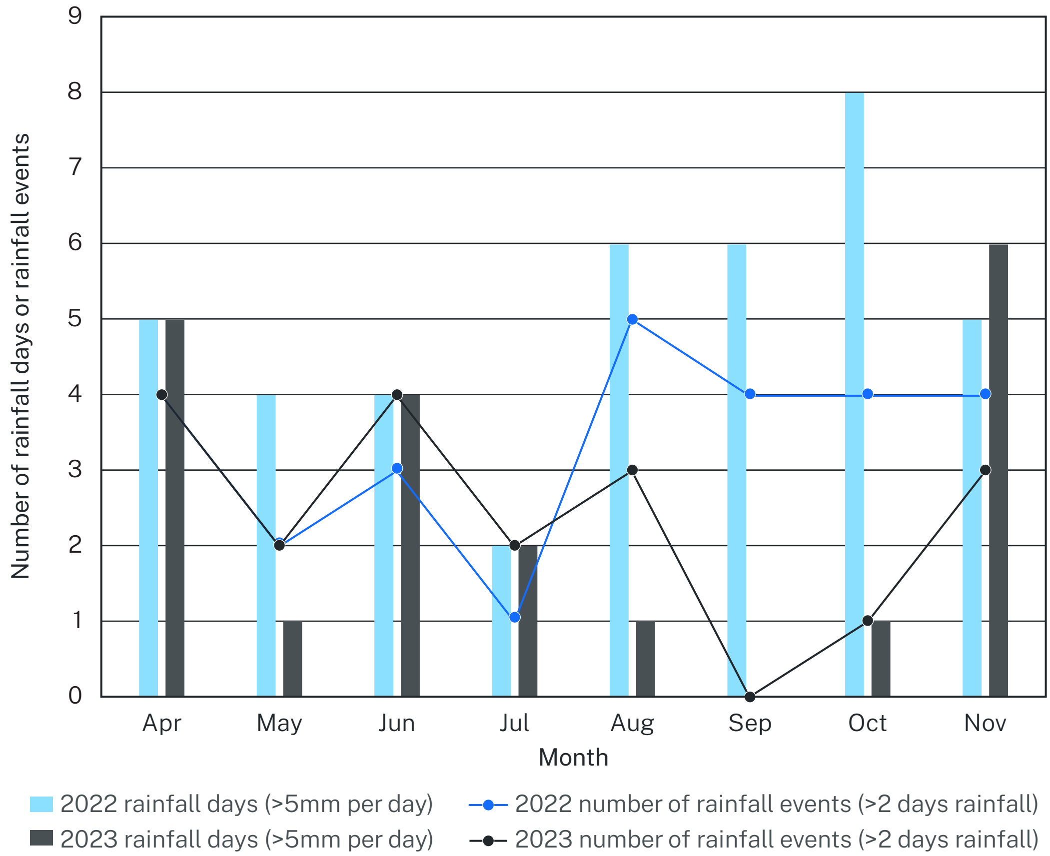


Figure 24 Growing season (April–November) number of rainfall days and number of consecutive rainfall days (>2 days) in 2022 and 2023 at Wagga.

Septoria tritici blotch (STB) management considerations for 2024

Even though STB did not pose a major threat in many regions in the latter half of 2023, the inherent risk is still elevated. An IDM system, comprising the factors outlined below, should be implemented to reduce the risk of economic losses.

Stubble colonisation and associated management considerations

Research (data not shown) conducted at Wagga Wagga Agricultural Institute during 2020 and 2021 has found that:

- the resistance rating of the wheat variety grown has little influence on the ability of *Z. tritici* (STB) and *Pyrenophora tritici-repentis* (Yellow leaf spot; YLS) to colonise senescent stubble and inoculum levels produced from retained stubble, i.e. the number of spores released, the following season. Therefore, any infected stubble from 2021–2023 must be considered a risk for the following wheat crop or crops nearby.
- stubble infected with the STB-causing pathogen *Z. tritici* can generate enough ascospores to initiate an epidemic 2 years after the wheat crop was grown, irrespective of the varietal resistance rating. This suggests that a single break crop such as canola, might not be enough to reduce the risk of STB or YLS infection. If possible, avoid sowing wheat-on-wheat, but if forced into a situation where this must happen, plan an IDM program to reduce the risk of yield loss.
- a net reduction in inoculum levels can be achieved by manipulating harvest cut height to reduce the standing stubble available for the STB pathogen to colonise. However, excess material must be removed from the paddock to result in a net reduction and the cost benefit risks of the removal method and other system impacts must be weighed before being undertaken.

The distinction also needs to be made between managing disease in the current wheat crop to minimise yield loss and inoculum risk from the stubble in subsequent seasons. Even though the number of ascospores released from the senescent stubble does not significantly change with varietal resistance rating, variety choice remains critical to minimising losses from STB and other diseases within the growing season.

Note: Data from these experiments has been published in previous editions of *Southern NSW research results* (Baxter et al. 2023; Baxter et al. 2022).

Variety selection

Research undertaken at Wagga Wagga Agricultural Institute confirms that a more resistant variety develops less disease compared with a more susceptible variety. In the absence of fungicide use, the difference in infection levels between a moderately susceptible (MS) variety and a susceptible to very susceptible (S–VS) variety with an early May sowing time can be as much as 30% less in the MS variety, resulting in a reduction of 10–15% in yield loss compared to the S–VS variety (data not shown).

Choosing a wheat variety with a higher resistance level will protect yield in the presence of STB, while also reducing the number of fungicide applications required. This in turn decreases machinery, labour, and input costs. Minimising fungicide use also lowers the risk of fungicide resistance developing within both target and off-target fungal pathogen populations.

It is important to stay up to date with the latest variety resistance ratings as they can change from year to year. These ratings are developed through the National Variety Trial (NVT) pathology screening project and are released annually on the GRDC NVT website (https://nvt.grdc.com.au/) and in state-based sowing guides such as the *NSW Winter crop variety sowing guide*.

Fungicide application

Not all fungicide active ingredients are equal when it comes to controlling STB, and fungicide choice is becoming increasingly important. Figure 25 shows the geographical spread of 57 samples sent to Curtin University's Centre for Crop and Disease Management (CCDM) for fungicide resistance screening in 2022 and 2023. Primarily, the results reveal that the G143A mutation, which confers resistance to Group 11 (QoI, strobilurin) fungicides such as azoxystrobin, was not detected in any of the samples submitted from NSW.

However, the G143A mutation was detected in an STB sample from Tasmania in 2022 (not shown), making it the first detection outside South Australia. It is unclear if this is the result of gene flow (wind dispersion) or an independent mutation. This detection should act as a warning for NSW growers to use fungicide resistance management strategies to prolong the effectiveness of Group 11 (QoI, strobilurin) chemistry against STB.

Unsurprisingly, mutations that confer reduced sensitivity to Group 3 fungicides (DMI, triazoles) were found in 85% of samples from NSW. Specifically, the mutation Cyp51 G1 (formerly identified as Cyp51 Isoform 11) was present in most leaf samples. This mutation is particularly significant because it leads to elevated levels of reduced sensitivity to some Group 3 fungicides such as tebuconazole, flutriafol and propiconazole. It is not unexpected since Cyp51 G1 was the predominant mutation in the STB population from a previous NSW study conducted in 2016.

These results support our recommendation that Group 11 (QoI, strobilurin) fungicides are effective in preventing STB infection in NSW. We continue to advise that if your goal is to specifically target STB curatively with fungicides, it is best to avoid using cheaper Group 3 triazole actives such as tebuconazole and propiconazole. Instead, opt for stronger Group 3 fungicides such as prothioconazole or epoxiconazole.

Table 47 outlines a decision-support matrix and suggested fungicide regime for STB management if the 2024 season is conducive to infection and disease development. The table also outlines the efficacy status of any fungicide application on stripe rust, as many fungicides registered for use on STB will also be effective on stripe rust. There is very little data showing a yield benefit from using fungicides before stem elongation starts. That said, any sprays applied before stem elongation starts will at best only have a suppressive effect on inoculum load, as none of the leaves that contribute significantly to grain yield emerge until after this growth stage. Therefore, crops that include a fungicide with the herbicide application during tillering (GS25) still require a dedicated fungicide spray at GS31–32 to protect the flag-2 leaf. Not all applications might be needed depending on seasonal conditions, growth stage, infection levels and economic considerations, particularly if fungicide treatments are applied to seed and/or flutriafol is applied to the fertiliser to protect seedlings from early STB or stripe rust infection.

Table 47 Decision-support matrix and suggested fungicide regime for STB management if the 2024 season is conducive to infection and disease development. The table also outlines how effective fungicide applications are on stripe rust.

Growth stage (GS)	STB present	Fungicide application required	Fungicide activity on stripe rust?
GS 25	Yes	No	Flutriafol activity if used
GS 31	Yes	Yes*	Yes
GS39	Yes	Yes/No*	Yes
GS50–59	Yes	Yes/No*	Yes

* Not all applications might be needed pending seasonal conditions, growth stage, infection levels and economic considerations.

If the 2024 season is not conducive to STB development, and stripe rust is the primary foliar fungicide application target, consider products containing active ingredients such as tebuconazole or propiconazole to alleviate the selection pressure on prothioconazole and epoxiconazole after repeated use patterns during the 2021–2023 growing seasons. In dry conditions, fungicide applications might not be needed at all.

The fungicide resistance screening results reiterate the need to protect fungicide modes of action when targeting all pathogens, but particularly those prone to developing resistance to diseases such as STB and wheat powdery mildew. To help prolong a fungicide's useful life:

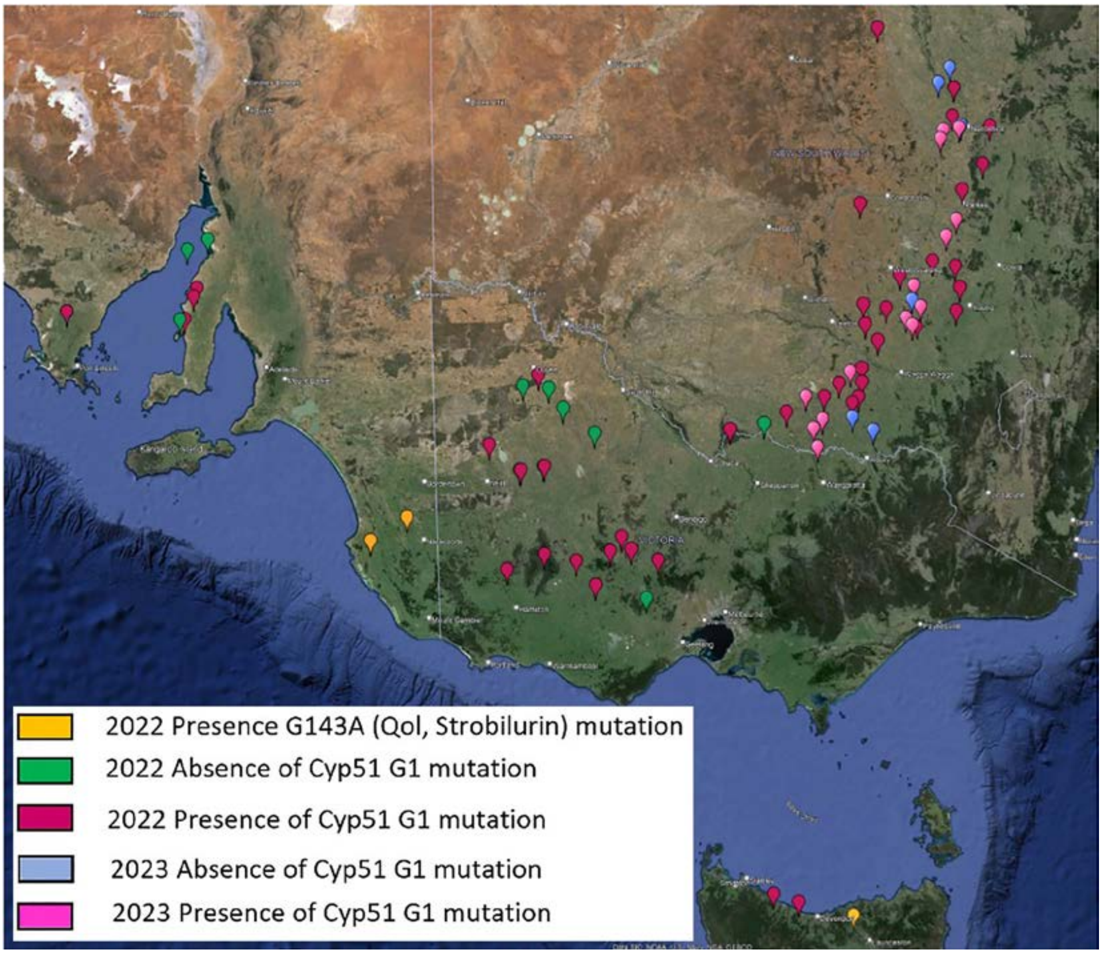
- avoid susceptible varieties
- implement crop rotation
- consider non-chemical means of controlling inoculum sources
- get a correct diagnosis if in doubt before applying a fungicide
- rotate fungicide active ingredients and groups
- adhere to label rates and use patterns.

Further resistance management advice can be found at The Australian Fungicide Resistance Extension Network (https://afren.com.au/).

Conclusions

With high wheat stubble loads from high yielding years from 2021 through to 2023, the STB inoculum risk for next season is elevated. However, the incidence of STB is highly dependent on climatic conditions; the 2024 growing season conditions will dictate the severity of any epidemic. To help counter these factors, components of the research outlined above can be implemented into an IDM plan to suppress and control STB. Acknowledging the risk and duration of the risk (i.e. >2 years) that any STB infected stubble can have on subsequent cereal crops can guide crop rotation decisions. If growing wheat-on-wheat, a plan can be implemented to appropriately manage the risk of STB, but it is best avoided. Cultural practices, such as variety selection, stubble cut height and stubble removal should be used in the first instance to reduce the resistance pressure on fungicides and prolong their effective lifespan.

NSW DPIRD is here to support growers with correct diagnosis and discussions of management options before sowing and as required throughout the season.



Note: Not all samples submitted appear on the map, as some leaf samples did not recover DNA of sufficient quality to be used for screening.

Figure 25 STB fungicide resistance screening results for 2022 and 2023. Note: only NSW data has been updated for 2023. Victoria, Tasmania and South Australia data is 2022 only. Source: CCDM.

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Matthews P, Hertel K and Jenkins L (2024) *NSW winter crop variety sowing guide*, NSW Department of Primary Industries (https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/nsw-winter-crop-variety-sowing-guide-2023).

Useful links

NSW DPI Southern NSW research results: https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides

NVT Online: https://nvt.grdc.com.au/nvt-disease-ratings

Australian Cereal Rust Survey: https://www.sydney.edu.au/science/our-research/research-areas/life-and-environmental-sciences/cereal-rust-research/rust-reports.html

Australian Fungicide Resistance Extension Network (AFREN): https://afren.com.au/

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