Department of Primary Industries

Lentil phenology and grain yield response to sowing date – Wagga Wagga and Leeton 2019

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Key findings

- There was diversity in phenology between varieties.
- Early sowing extended the crop vegetative period, but increased exposure to frost damage during flowering.
- Dry conditions severely limited lentil grain yield in 2019, but favoured early maturing varieties, particularly with mid May sowing.
- High yielding lentil varieties were PBA Ace$^{\phi}$, PBA Bolt$^{\phi}$ and PBA Hurricane XT$^{\phi}$ at Wagga Wagga, and PBA Hallmark XT$^{\phi}$ and PBA Bolt$^{\phi}$ at Leeton. Nipper$^{\phi}$ demonstrated broad adaptation at Wagga Wagga.

Introduction

Grain yield can be optimised by ensuring that critical growth phases such as flowering and podding avoid abiotic stresses such as frost, heat and drought.

In southern New South Wales (NSW), critical growth periods, overall phenology, and environmental effects on pulses are poorly understood. Experiments conducted in 2019 at Leeton and Wagga Wagga, aimed to determine the optimum sowing date for lentil to reduce effects from abiotic stresses and increase grain yield. These experiments also aimed to identify phenological drivers of crop development in lentil and determine which varieties are best adapted to the target environments.

Varieties were selected based on their prevalence in the growing area, performance, and diversity in phenology. Four sowing dates (SDs) were assessed: mid April (SD1), late April (SD2), mid May (SD3) and late May (SD4).

Site details – 1

Location	Wagga Wagga Agricultural Institute
Soil type	Red kandosol
Soil pH_{Ca}	6.6 (0–5 cm), 5.0 (5–10 cm), 4.6 (10–15 cm), 4.9 (15–20 cm), 5.4 (20–25 cm)
Previous crop	Wheat
Fertiliser	Granulock®Z Soygran 100 kg/ha (nitrogen [N]: 5.5, phosphorus [P]: 15.3, potassium [K]: 0.0, sulfur [S]: 7.5)
Post sowing water application	SD1: 15 mm on 16 April
Rainfall	• Fallow (November 2018–March 2019): 253 mm • In-crop (April 2019–October 2019): 145 mm • In-crop long-term average: 322 mm

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	Target plant density	120 plants/m^2
	Weed management	Knock down herbicide • 2 L/ha Gladiator® CT (450 g/L glyphosate), 1 L Amicide® Advance 700 (700 g/L 2,4D amine) on 25 January. • 2 L/ha Gladiator® CT (450g/L glyphosate) on 18 April. Pre-emergence (at sowing) • 900 g/ha Terbyne® Xtreme (875 g/kg terbuthylazine). • 1.7 L/ha Avadex® Xtra (500 g/L tri-allate), incorporated by sowing (IBS). • 300 g/ha Terbyne® Xtreme (875 g/kg terbuthylazine), post sowing pre-emergent (PSPE). Post-emergence (18 June) • 300 mL/ha Select® Xtra (360 g/L clethodim), 500 mL/ha Uptake™ spraying oil (582 g/L paraffinic oil). Disease management • Dithane® (750 g/kg mancozeb) 2.2 kg/ha on 2 July and 22 July. • Fortress® 500 (500 g/L procymidone) 500 mL/ha on 6 August and 23 August.
	Insect management	• Talstar® 250 EC (250 g/L bifenthrin) 30 mL/ha on 18 June. • Trojan® (150 g/L gamma-cyhalothrin) 20 mL/ha on 3 September and 4 October.
	Harvest date	Harvest index cuts were taken as varieties reached maturity and plots were machine harvested on 29 November 2019.
Site details – 2	**Location**	Leeton Field Station
	Soil type	Red dermosol
	Soil pH_{Ca}	6.0 (0–10 cm), 6.4 (10–30 cm)
	Previous crop	Barley
	Fertiliser	Utiliser pulse mix 55 kg/ha (N: 7.48, P: 17.64, K: 6.24, calcium [Ca]: 6.4, Zinc [Zn]: 0.32)
	Water application	• Pre sowing: flood irrigation on 8 April (approximately 2 ML/ha) • Post sowing water application: none
	Rainfall	• Fallow (November 2018–March 2019): 310 mm • In-crop (April 2019–October 2019): 162 mm • In-crop long-term average: 193 mm
	Target plant density	120 plants/m^2
	Weed management	Knock down herbicide • 3 L/ha Sprayseed® 250E (135 g/L paraquat dichloride, 115 g/L diquat dibromide) on 11 April.

	• 3 L/ha Roundup PowerMax® (540 g/L glyphosate) on 15 April. Pre-emergence (at sowing) • 900 g/ha Terbyne® Xtreme (875 g/kg terbuthylazine). • 1.6 L/ha Avadex® Xtra (500 g/L tri-allate), incorporated by sowing (IBS). • 2 L/ha Rifle® 440 (440 g/L pendimethalin). Post-emergence • 300 g/ha Terbyne® Xtreme (875 g/kg terbuthylazine), post sowing pre-emergent (PSPE). • 85 mL/ha Verdict® 520 (520 g/L haloxyfop) on 14 May (SD1), 6 June (SD2), 18 June (SD3) and 20 June (SD4). • 190 mL/ha Leopard® 200EC (200 g/L quizalofop-p-ethyl) on 2 August and 7 August.
Disease management	• Dithane® (750 g/kg mancozeb) 2.2 kg/ha on 14 May (SD1), 6 June (SD2), 26 June and 6 August. • Amistar® 250 SC (250 g/L azoxystrobin) 500 mL/ha, Oriuso® 430 SC (430 g/L tebuconazole) 500 mL/ha, Cheers® 720 (720 g/L chlorothalonil) 1.8 L/ha on 18 July and 25 July. • Veritas® (200 g/L tebuconazole, 130 g/L azoxystrobin) 1 L/ha on 2 August. • Dithane® (750 g/kg mancozeb) 2.2 kg/ha on 6 August. • Sumisclex® 500 (500 g/L procymidone) 1 L/ha on 8 August. • Veritas® (200 g/L tebuconazole, 130 g/L azoxystrobin) 1 L/ha, Cheers® 720 (720 g/L chlorothalonil) 2 L/ha on 8 August and 26 August. • Aviator® Xpro® (150 g/L prothioconazole, 75 g/L bixafen) 600 mL/ha on 4 September. • Veritas® (200 g/L tebuconazole, 130 g/L azoxystrobin) 1 L/ha, Cheers® 720 (720 g/L chlorothalonil) 2 L/ha on 15 September. • Cheers® 720 (720 g/L chlorothalonil) 2 L/ha on 26 September and 1 October.
Insect management	• Transform® (500 g sulfoxaflor) 300 mL/ha on 8 August. • Pirimidex (500 g/kg pirimicarb) 150 g/ha, Success® Neo (120 g/L spinetoram) 200 mL/ha on 4 September and 27 September.
Harvest date	• Hand cuts for harvest index: 28 October and 29 October; PBA Greenfield$^{\Phi}$ SD4 on 4 November. • Machine harvest: 31 October; PBA Greenfield$^{\Phi}$ SD4 harvested on 4 November.

Treatments

Eight lentil varieties were sown on four sowing dates.

Lentil varieties

PBA Ace$^{\Phi}$, PBA Blitz$^{\Phi}$, PBA Bolt$^{\Phi}$, PBA Greenfield$^{\Phi}$, PBA Hallmark XT$^{\Phi}$, PBA Hurricane XT$^{\Phi}$, PBA Jumbo 2$^{\Phi}$ and Nipper$^{\Phi}$

Sowing date (SD)

SD1: 15 April

SD2: 30 April

SD3: 15 May

SD4: 30 May

Results

Seasonal conditions

The drought conditions in the 2019 growing season reduced yield potential at both sites. Wagga Wagga received 145 mm rainfall from April to October, significantly lower than the 322 mm long-term average. Leeton received 162 mm rainfall from April to October, close to the long-term 193 mm average, in addition to the approximately 2 ML/ha of flood irrigation. Also, several severe frosts at both sites during winter and spring negatively affected crop growth and pod set.

Below average rainfall and above average temperatures also affected the September and October flowering and grain filling periods.

Also, at Leeton, ascochyta blight infection was seen in a neighbouring experiment, hence the disease management regime was increased to minimise any effects.

Phenology

Days to emergence were longer at both sites when sowing date was delayed, ranging from seven days (both sites) to 19 days at Leeton.

Overall phenological development (duration of vegetative phase, flowering, and podding) decreased with delayed sowing dates (Figure 1), at both sites and displayed variety (V) by sowing date (V × SD) interactions. PBA Blitz$^{\Phi}$ was the earliest to flower at both sites, with Nipper$^{\Phi}$ and PBA Greenfield$^{\Phi}$ the slowest. Sowing date had no effect on establishment at Wagga Wagga, while late sowing (SD3 and SD4) resulted in higher establishment at Leeton, with V × SD interaction at Leeton only (data not presented).

Grain yield and yield components

There was a significant interaction between variety and sowing date at both sites. Averaged across varieties, grain yield at Wagga Wagga was higher for the mid and late May sowing dates (SD3 and SD4; 0.70 t/ha and 0.76 t/ha) than mid and late April sowing dates (SD1 and SD2; 0.19 t/ha and 0.52 t/ha) respectively. At Leeton, grain yield was higher from late April to late May sowing dates (SD2, SD3 and SD4; 1.17 t/ha, 1.25 t/ha and 1.17 t/ha) than the mid April sowing date (SD1; 0.72 t/ha) (Table 1).

PBA Bolt$^{\Phi}$ and PBA Hallmark XT$^{\Phi}$ had consistently high yields from the end of April sowing (SD2) at Leeton. At Wagga Wagga, all varieties except PBA Ace$^{\Phi}$ and Nipper$^{\Phi}$ had high yields from SD3 whilst PBA Hallmark XT$^{\Phi}$, PBA Ace$^{\Phi}$ and PBA Bolt$^{\Phi}$ were also the highest yielding from SD4.

Averaged across sowing dates, the slower maturity PBA Greenfield$^{\Phi}$ was the lowest yielding at Leeton and all varieties except Nipper$^{\Phi}$ yielded similarly at Wagga Wagga. Nipper$^{\Phi}$ demonstrated broad adaptation at Wagga Wagga with the highest yield when averaged across all sowing dates and was the best performing variety when sown early (SD1).

At Wagga Wagga, which was not pre-watered, grain yields from the mid April sowing date (SD1) were very low, for example PBA Ace$^{\phi}$ and PBA Hallmark XT$^{\phi}$, yielded 0.07 t/ha and 0.08 t/ha respectively (Table 1). However, this could also be partly due to frosts, which were more severe at Wagga Wagga than at Leeton.

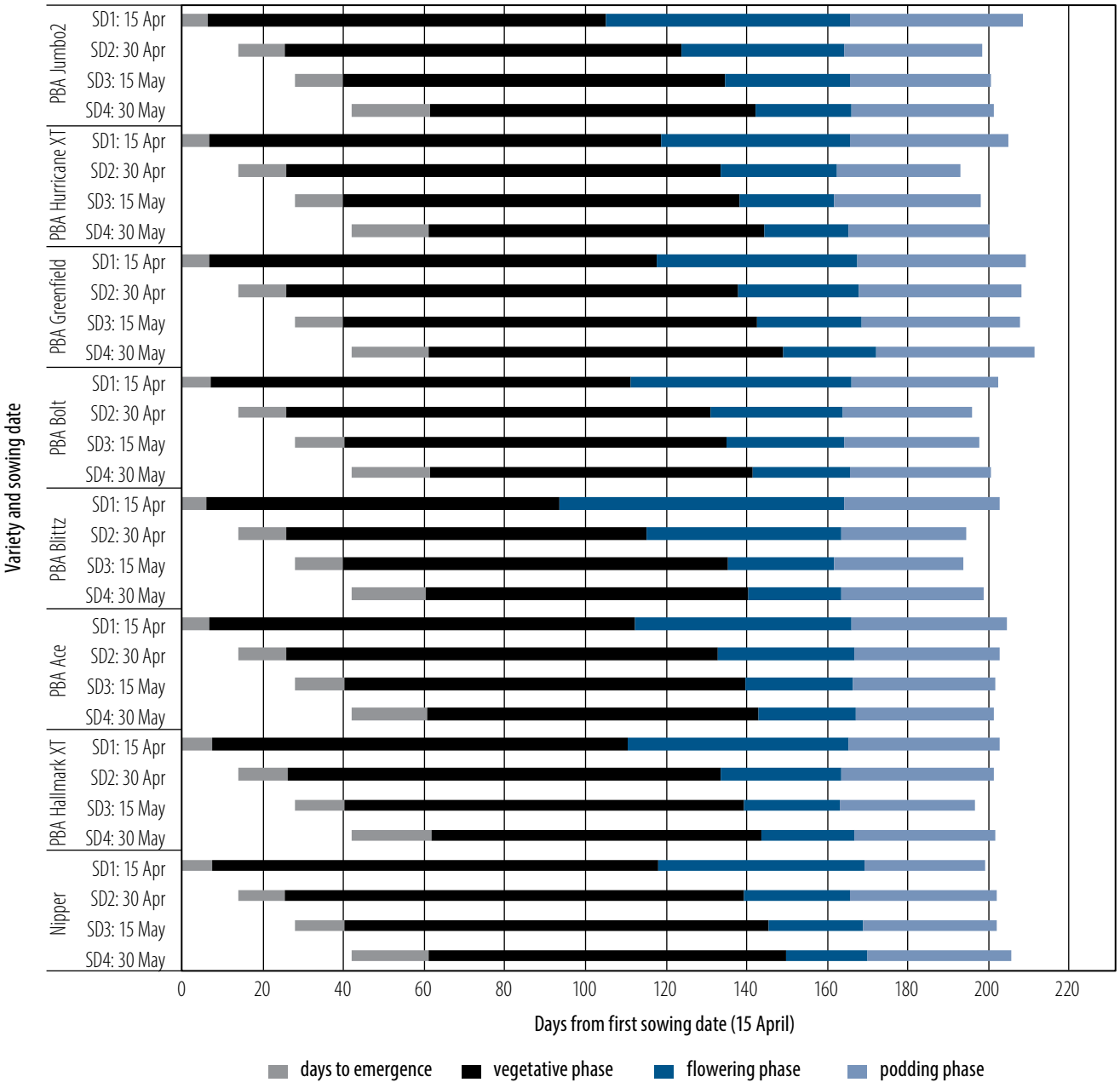


Figure 1 Influence of sowing date at Leeton on emergence, start and duration of key lentil growth stages.

Sowing date did not affect the grain weight of 100 seeds (100 gwt) at Leeton, while it decreased with delayed sowing at Wagga Wagga (data not presented). Yield components responded differently at each site, with filled pod number/seed number driving yield at Leeton and 100 gwt being the key driver at Wagga Wagga. Delaying sowing resulted in a higher harvest index, ranging from 0.10 (SD1) to 0.31 (SD4) at Leeton and 0.06 (SD1) to 0.34 (SD4) at Wagga Wagga, with V × SD interactions at both sites (data not presented).

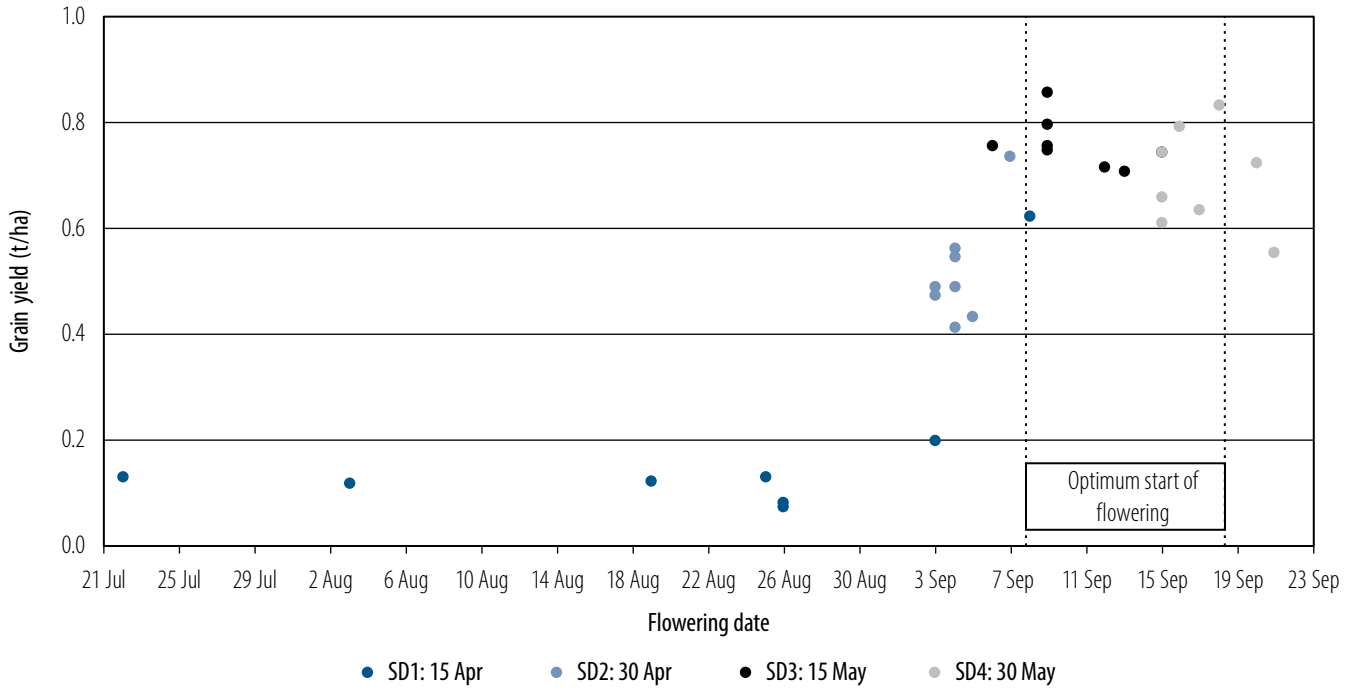
The bottom pod height measured from plant components (not field), was lower when sowing date was delayed, and ranged from 16.9 cm (SD4) to 25.0 cm (SD1) at Wagga Wagga, and 14.8 cm (SD4) to 25.6 cm (SD1) at Leeton, where it showed no V × SD interaction (data not presented).

Table 1 Grain yield at Leeton and Wagga Wagga in 2019.

Variety	Leeton					Wagga Wagga				
	Grain yield (t/ha)					Grain yield (t/ha)				
	SD1	SD2	SD3	SD4	Mean	SD1	SD2	SD3	SD4	Mean
Nipper	0.72	0.97	0.98	0.99	0.92	0.63	0.74	0.71	0.73	0.70
PBA Hallmark XT	0.74	1.53	1.52	1.41	1.30	0.08	0.55	0.76	0.79	0.55
PBA Ace	0.82	1.04	1.10	1.17	1.03	0.07	0.49	0.72	0.84	0.53
PBA Blitz	0.64	1.05	1.34	1.33	1.09	0.13	0.49	0.76	0.61	0.50
PBA Bolt	0.76	1.68	1.54	1.36	1.34	0.12	0.47	0.86	0.75	0.55
PBA Greenfield	0.59	0.60	0.71	0.55	0.61	0.20	0.43	0.75	0.56	0.49
PBA Hurricane XT	0.70	1.47	1.38	1.17	1.18	0.13	0.41	0.80	0.64	0.50
PBA Jumbo2	0.76	1.03	1.46	1.35	1.15	0.12	0.56	0.75	0.66	0.52
Mean	0.72	1.17	1.25	1.17	1.08	0.19	0.52	0.76	0.70	0.54
l.s.d. ($P \leq 0.05$)										
Variety	0.17					0.06				
SD	0.21					0.06				
Variety x SD	0.35					0.13				

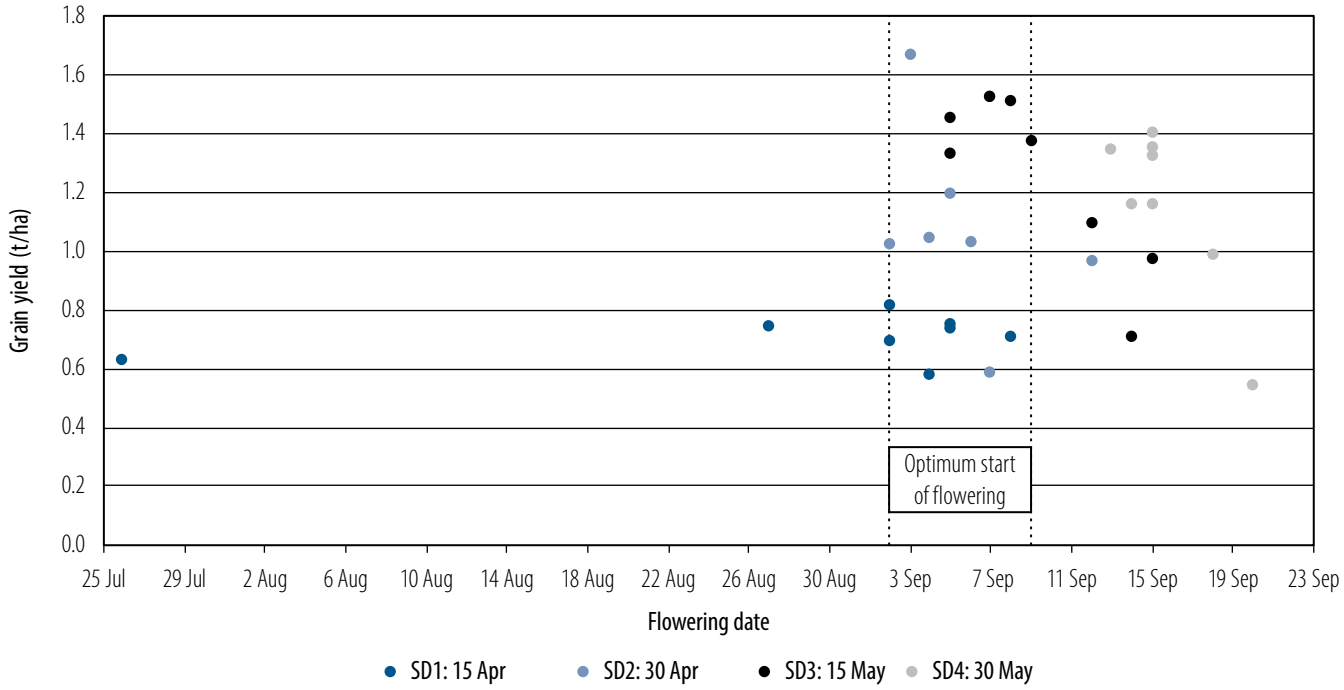
Relationship between phenology and grain yield

The optimum start of flowering was deduced to be in the period 8 September to 18 September for Wagga Wagga and 2 September to 9 September for Leeton from the 2019 data (figures 2 and 3). The later start at Wagga Wagga was driven by the slightly cooler weather at this location relative to Leeton. In 2019, starting flowering around these dates ensured that lentil avoided abiotic stresses, such as frost, early in the growing season, and heat and terminal drought later in the season.



Dots represent date of 50% flowering by varieties across sowing dates, optimal start of flowering is marked by vertical lines.

Figure 2 Optimum start of flowering for lentil at Wagga Wagga in 2019.



Dots represent date of 50% flowering by varieties across sowing dates, optimal start of flowering is marked by vertical lines.

Figure 3 Optimum start of flowering for lentil at Leeton in 2019.

Experiments conducted in 2019 have been combined with data collected in 2018; the variety phenology and performance was analysed to create a two-year average. This analysis was used to generate a preliminary guide for optimal sowing windows in southern NSW (Table 2). As data was collected in two years with low rainfall and increased incidences of abiotic stresses, these guidelines are only suitable for similar seasons.

Table 2 Preliminary guidelines for optimum sowing periods for selected lentil varieties, generated from 2018 and 2019 experiments.

Variety	Maturity	Optimum sowing period for yield (southern NSW, low rainfall season)			
		Mid April	Late April	Mid May	Late May
PBA Ace	Mid				
PBA Jumbo2	Mid				
PBA Hallmark XT	Early				
PBA Hurricane XT	Mid				
PBA Bolt	Early/mid				
Nipper	Mid/late				
PBA Blitz	Early				
PBA Greenfield	Mid/late				

Dark grey indicates unsuitable sowing time, light grey indicates earlier or later than recommended, with yield reduction likely, light blue indicates preferred sowing time. Guidelines only suitable for low rainfall seasons.

Conclusion

The 2019 experiments indicate that there is an optimum start of flowering for the different locations; sowing date can be optimised to target this. It is important to note that this data was collected during a year that was characterised by drier than average growing conditions, increased incidence of abiotic stresses and lower yields.

Matching sowing date and varietal phenology (sowing date × variety combination) ensures that the sensitive growth stages such as flowering and podding occur at optimal times. Results from 2019 indicate that sowing around mid May gives the varieties tested here the best opportunity to avoid abiotic stresses and allows efficient conversion of biomass to grain yield. In dry seasons PBA Greenfield(ɬ), with its longer total growth phase across all sowing dates, is at greater risk of exposure to adverse conditions such as terminal drought and heat stress. Early sowing in a dry season also results in low harvest index as most of the accumulated biomass is not converted to grain yield. However, the higher biomass will generally equate to greater nitrogen fixation.

Preliminary optimal sowing guidelines for lentil in southern NSW in low rainfall seasons have been developed using data from experiments in 2018 and 2019. Additional research is required to quantify the impact on lentil phenology and grain yield in average or high rainfall years.

Acknowledgements

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