Pulse adaptation – optimising grain yield of chickpea and lentils

Mark Richards*[1]*, Lance Maphosa*[1]*, Aaron Preston*[1]*, Tony Napier*[2] *and Iain Hume*[1]*.

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

GRDC project code: BLG112

Keywords

- chickpea, lentil, phenology, adaptation.

Take home messages

- Dry conditions severely limited grain yield for both chickpea and lentil in 2019.
- Results from 2018 and 2019 indicate that sowing around the mid-May period gave the varieties tested the best opportunity to avoid abiotic stresses and allows efficient conversion of biomass to grain yield. Earlier sowing resulted in greater biomass production, but less grain yield.
- Diversity in phenology was observed in both species. This presents opportunities for growers to exploit variety phenology to select varieties best suited to their sowing program and to optimise production.
- Higher yielding chickpea varieties were the desi varieties; PBA StrikerΦ, PBA SlasherΦ, PBA BoundaryΦ and CICA1521Φ at both sites.
- Highest yielding lentil varieties were PBA AceΦ, PBA BoltΦ and PBA Hurricane XTΦ at Wagga Wagga, and PBA Hallmark XTΦ and PBA BoltΦ at Leeton. NipperA demonstrated broad adaptation at Wagga Wagga.

Background

Grain yield can be optimised by ensuring that critical growth phases (flowering and podding) avoid stresses such as frost, heat and drought. In southern and central New South Wales (NSW), critical growth periods, phenology, and environmental effects on pulses are poorly understood.

Experiments were conducted over two years (2018 and 2019) at Leeton, Wagga Wagga and Trangie, aiming to determine the optimum sowing date to reduce the impact of abiotic stresses and increase grain yield. These experiments also aimed to identify phenological drivers of crop development in chickpea and lentil and determine which varieties are best adapted to the target environments. This paper presents the results from southern NSW (Wagga Wagga and Leeton). Varieties were selected based on prevalence in growing area, performance and diversity in phenology. Four sowing dates (SD) were assessed, mid-April (SD1), late April (SD2), mid-May (SD3) and late May (SD4), details presented in Table 1. The 2018 results have been presented at 2018 GRDC Grains Research Updates and in NSWDPI Southern Research Results 2018 (https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0009/1185480/SNSWRR2019-web-18Oct.pdf).

Table 1. Details of the experiment sites, varieties and sowing dates for the 2018 and 2019 chickpea and lentil experiments.

Experiment	Wagga Wagga	Leeton
Sowing dates (x4) for chickpea and lentil varieties	2018 (16 Apr, 30 Apr, 14 May, 28 May)	2018 (16 Apr, 30 Apr, 14 May, 28 May)
	2019 (15 Apr, 30 Apr, 15 May, 30 May)	2019 (15 Apr, 30 Apr, 15 May, 30 May)
Chickpea varieties	Genesis™090, Genesis™079, Kalkee, PBA HatTrickⓓ, PBA Boundaryⓓ, PBA Slasherⓓ, CICA1521A, PBA Strikerⓓ	
Lentil varieties	PBA Aceⓓ, PBA Boltⓓ, PBA Greenfieldⓓ, PBA Hurricane XTⓓ, PBA Hallmark XTⓓ, PBA Jumbo2ⓓ, PBA Blitzⓓ, Nipperⓓ	

Climate conditions and water

The 2018 and 2019 growing seasons at Wagga Wagga were very challenging for growing pulses with very low autumn and growing season rainfall. The long-term average growing season rainfall at Wagga Wagga is 322mm, however only 153mm and 193mm was received in 2018 and 2019, respectively. Likewise, the 2018 growing season rainfall at Leeton of 81mm was well below the 193mm long term average but improved in 2019 to 167mm.

Both sites received additional water, with 200mm applied to Leeton site pre-sowing. Wagga Wagga was not pre-watered, but 15mm supplementary water was applied using an overhead irrigator two days post sowing to SD1 to assist in establishment. Low soil moisture restricted crop growth throughout the entire growing season at the Wagga Wagga site and also at the Leeton site over spring. In addition, several severe frost events during winter and spring impacted crop growth and pod set. The flowering and grain filling periods of September and October were also greatly affected by the below average rainfall and above average temperatures.

Water stored in the active root zone (70cm) for chickpeas at Wagga Wagga at sowing was approximately 100mm for all sowing dates. Post-harvest, less water was retained under SD1 (82mm) than under the other three sowing dates (approximately 90mm). Starting stored water for lentils was similar to chickpeas, with approximately 115mm for all sowing dates. Stored water post-harvest was similar to chickpeas for SD1 and SD2, approximately 90mm. SD3 and SD4 plots had significantly more stored water, approximately 116mm and 122mm, respectively.

Pre-watering of chickpea and lentil at Leeton resulted in approximately 192mm of water stored to 70cm depth for all sowing dates. Soil water stored at harvest was similar for all sowing dates (approximately 120mm to 70cm) for both chickpea and lentil at Leeton.

These statistically significant but small differences in soil water are likely to be reduced over summer and have no consequences for the next crop grown. In more normal years these differences may be larger and have agronomic significance.

Results and discussion

Chickpea

Phenological development

Time to emergence took longer at both sites when sowing date (SD) was delayed, ranging from nine days (SD1 at Wagga Wagga) to 29 days (SD4 at Leeton) (Figure 1). The delay to emergence is due to decreased soil temperature in late autumn, requiring a longer time to satisfy the minimum growing degree days for emergence. The long term average reduction in mean daily temperature at Wagga Wagga between 15 April and 30 May is 2.1°C. Interactions between genotype (G) x environment (E) were found with PBA Strikerⓓ and Kalkee, first to emerge at Leeton, while GenesisTM079ⓓ and Kalkee emerged earlier at Wagga Wagga. Sowing date had different effects on establishment, for example SD4 had the lowest establishment at Wagga Wagga but was the highest at Leeton. Interestingly, SD had no effect on establishment in the 2018 experiments (results presented in previous GRDC Update). Generally, durations of the vegetative, flowering and podding phases shortened when sowing was delayed (Figure 1). However, podding initiation occurred generally at the same time, because chickpea are sensitive to pod set at mean daily temperatures below 15°C (Somes, 2017).

Yield and yield components in 2019

Averaged across varieties, SD2 and SD3 were highest yielding at Leeton, while at Wagga Wagga SD3 had the highest grain yields (Table 2). Varieties PBA HatTrickⓓ and Kalkee were the lowest yielding at Leeton, while at Wagga Wagga it was Kalkee and GenesisTM090ⓓ. Kalkee was consistently low

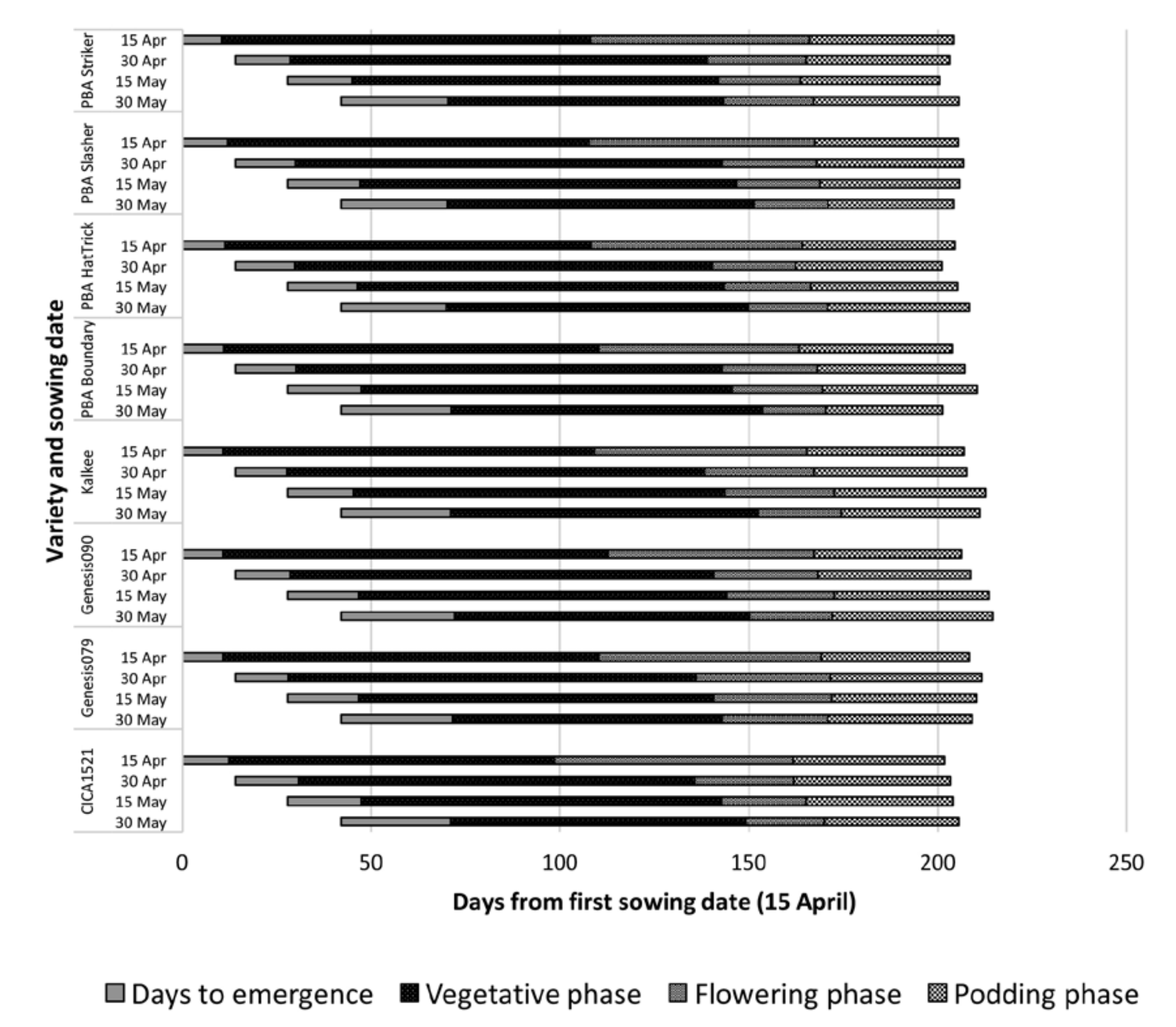

Figure 1. Influence of sowing date at Wagga Wagga on emergence and duration of key chickpea phasic growth stages (colour version of graph available on the GRDC website).

Table 2. Chickpea grain yield (t/ha) in 2019 at Leeton and Wagga Wagga sites.

	Leeton				Wagga Wagga			
	Grain Yield (t/ha)				Grain Yield (t/ha)			
Variety	SD1	SD2	SD3	SD4	SD1	SD2	SD3	SD4
CICA1521	1.05	1.44	1.90	1.63	0.14	0.65	0.91	0.94
Genesis™079	1.18	1.49	1.53	1.53	0.24	0.60	0.75	0.69
Genesis™090	0.94	1.56	1.23	1.20	0.17	0.61	0.63	0.65
Kalkee	0.85	1.3	1.27	1.12	0.15	0.59	0.76	0.58
PBA_Boundary⚘	0.85	1.92	1.38	1.60	0.14	0.46	0.87	0.71
PBA_HatTrick⚘	0.55	1.29	1.48	1.23	0.11	0.48	0.85	0.74
PBA_Slasher⚘	1.14	1.87	1.82	1.72	0.16	0.59	0.75	0.80
PBA_Striker⚘	1.32	1.87	1.80	1.76	0.28	0.81	0.98	0.86
Mean	0.98	1.59	1.55	1.48	0.17	0.60	0.81	0.75
Lsd (Genotype)	0.21					0.08		
Lsd (SD)	0.13					0.06		

yielding and showed stability across environments and is likely not suited to the environments of southern NSW. PBA Striker⁽ᵈ⁾, an early maturing variety was the highest yielding variety at both sites. This highlights the importance of early-mid season maturity in avoiding late season abiotic constraints. Filled pods, total pods and seed numbers per plant were lowest at SD1 at both sites but showed no G x E interaction at Leeton. The low number of pods may be due to pod abortion and/or drop during prolonged unfavourable conditions (frost/heat stress).

Harvest index increased with delayed sowing, with more biomass accumulated at SD1 producing bulkier and taller plants. However, higher biomass does not always convert to greater grain production. Greater biomass and taller plants consume limited resources such as water and nutrients but did not offer subsequent yield advantages. Later sowing resulted in lower biomass which ranged from 3.96 (SD4) to 7.36t/ha (SD1) at Leeton and 1.94 (SD4) to 4.58t/ha (SD1) at Wagga Wagga, with G x E interactions at Wagga Wagga only.

These results were combined with 2018 data to produce predicted means (Table 3) that indicate differing optimum sowing dates for different varieties. The late April to mid-May sowing dates produced higher yields overall at Leeton, while the mid to late May sowing date produced the higher yields at Wagga.

The height of the lowest pods (derived from plant components) was significantly lower when sowing time was delayed. Bottom pod height ranged from 24.56cm (SD4) to 33.42cm (SD1) and 25.05cm (SD4) to 41.62cm (SD1) at Wagga Wagga and Leeton, respectively, and showed no G x E interaction at Leeton.

Lentil

Phenological development

Days to emergence were longer at both sites when sowing time was delayed, ranging from seven days (both sites) to 19 days at Leeton. As with chickpea, overall phenological development (duration of vegetative phase, flowering, and podding) decreased with delayed sowing time (Figure 2), at both sites and had G x E interactions. PBA Blitz⁽ᵈ⁾ was the earliest to flower at both sites, and Nipper⁽ᵈ⁾ and PBA Greenfield⁽ᵈ⁾ were the slowest.

Yield and yield components in 2019

Grain yield was greater when averaged across varieties with later sowing dates (mid-late May), 0.70-0.76t/ha and 1.17-1.25t/ha, for Wagga and Leeton respectively (Table 4). The only exception was the early maturing PBA Bolt⁽ᵈ⁾ at Leeton, which yielded highest at the late April sowing. Earlier sowing resulted in the lowest yields (0.19t/ha and 0.72t/ha sown at mid-April) at Wagga Wagga and Leeton, respectively (Table 4). Amongst the varieties, PBA Greenfield⁽ᵈ⁾ was the lowest yielding at both sites (due to slower maturity and drier conditions), whilst PBA Ace⁽ᵈ⁾, PBA Bolt⁽ᵈ⁾ and PBA Hurricane XT⁽ᵈ⁾ yielded highest at Wagga Wagga, with PBA Hallmark XT⁽ᵈ⁾ and PBA Bolt⁽ᵈ⁾ yielding highest at Leeton. Nipper⁽ᵈ⁾ demonstrated broad adaptation at Wagga Wagga with the highest yield averaged over all SD and was the best performing variety when sown early (SD1). Grain weight of 100 seeds (100gwt) was not affected by SD at Leeton, while it decreased with delayed sowing at Wagga Wagga. Therefore, the yield components responded differently at the different sites, with filled pod number/seed number driving yield at Leeton and 100gwt being the key driver at Wagga Wagga. Delaying sowing time

Table 3. Predicted means of chickpea grain yield (t/ha) of seven chickpea varieties at four sowing times at Leeton and Wagga Wagga sites over 2018 and 2019 seasons.

Type	Variety	Leeton Grain Yield t/ha				Type	Variety	Wagga Wagga Grain Yield t/ha			
		Mid April	Late April	Mid May	Late May			Mid April	Late April	Mid May	Late May
Desi	CICA1521	1.50	1.90	2.26	2.07	Desi	CICA1521	0.67	1.05	1.28	1.16
Desi	PBA Striker⁽ᵈ⁾	1.85	2.24	2.11	2.11	Desi	PBA Striker⁽ᵈ⁾	0.83	1.05	1.25	1.06
Kabuli	Genesis™ 079	1.72	2.03	2.23	1.97	Desi	PBA Boundary⁽ᵈ⁾	0.60	0.93	1.17	1.02
Desi	PBA Slasher⁽ᵈ⁾	1.96	2.13	2.12	2.09	Desi	PBA Slasher⁽ᵈ⁾	0.76	1.00	1.07	1.00
Desi	PBA Boundary⁽ᵈ⁾	1.45	1.93	1.96	1.82	Kabuli	Genesis™079	0.71	0.87	1.01	1.03
Kabuli	Kalkee	1.47	1.45	1.70	1.74	Kabuli	Kalkee	0.64	0.86	1.03	0.76
Kabuli	Genesis™090	1.66	1.58	1.62	1.67	Kabuli	Genesis™090	0.59	0.94	0.91	0.91

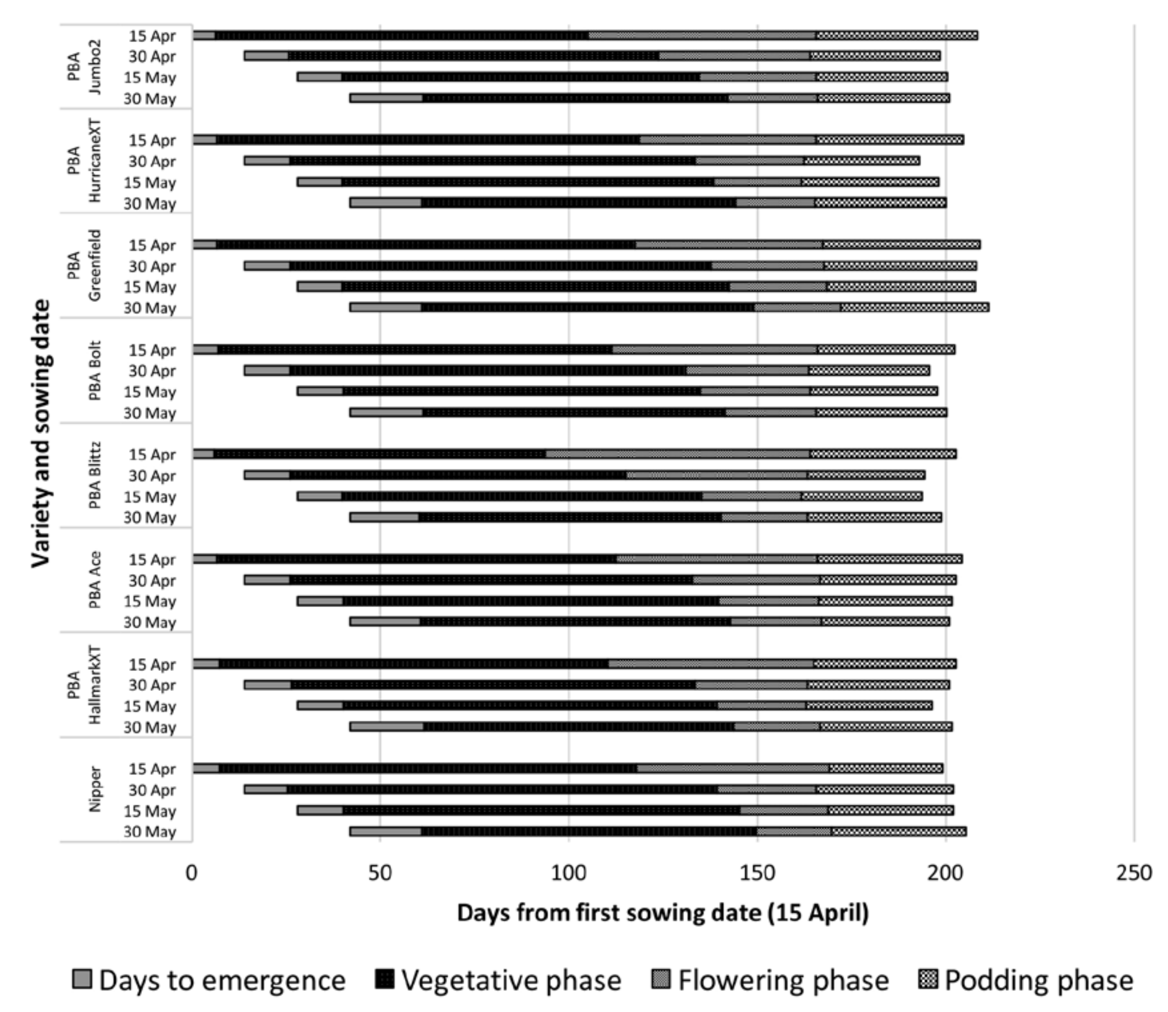

Figure 2. Influence of sowing date at Leeton on emergence and duration of key lentil phasic growth stages (colour version of graph available on the GRDC website).

resulted in higher harvest index. The bottom pod height derived from plant components, important for harvest efficiency, was lower when sowing time was delayed, and ranged from 16.87 (SD4) to 24.98cm (SD1) and 14.79 (SD4) to 25.60cm (SD1) at Wagga Wagga and Leeton respectively, and showed no G x E interaction at Leeton.

Table 4. Lentil grain yield (t/ha) in 2019 at Leeton and Wagga Wagga sites.

	Leeton				Wagga Wagga			
	Grain Yield (t/ha)				Grain Yield (t/ha)			
Variety	SD1	SD2	SD3	SD4	SD1	SD2	SD3	SD4
Nipper⁽ᴰ	0.72	0.97	0.98	0.99	0.63	0.74	0.71	0.73
PBA HallmarkXT⁽ᴰ	0.74	1.53	1.52	1.41	0.08	0.55	0.76	0.79
PBA_Ace⁽ᴰ	0.82	1.04	1.10	1.17	0.07	0.49	0.72	0.84
PBA_Blitz⁽ᴰ	0.64	1.05	1.34	1.33	0.13	0.49	0.76	0.61
PBA_Bolt⁽ᴰ	0.76	1.68	1.54	1.36	0.12	0.47	0.86	0.75
PBA_Greenfield⁽ᴰ	0.59	0.6	0.71	0.55	0.20	0.43	0.75	0.56
PBA_HurricaneXT⁽ᴰ	0.70	1.21	1.38	1.17	0.13	0.41	0.8	0.64
PBA_Jumbo2⁽ᴰ	0.76	1.03	1.46	1.35	0.12	0.56	0.75	0.66
Mean	0.72	1.14	1.25	1.17	0.19	0.52	0.76	0.70
Lsd (Genotype)	0.17					0.06		
Lsd (SD)	0.21					0.06		
Lsd (Genotype x SD)	0.35					0.13		

Table 5. Predicted means of lentil grain yield (t/ha) at Leeton and Wagga Wagga sites over 2018 and 2019 seasons.

Type	Leeton Grain Yield t/ha				Type	Wagga Wagga Grain Yield t/ha			
	Mid April	Late April	Mid May	Late May		Mid April	Late April	Mid May	Late May
PBA Bolt(b)	1.93	2.35	2.18	1.97	PBA Acev	0.74	1.07	1.20	1.16
PBA Jumbo 2(b)	1.62	1.56	2.13	1.84	PBA Jumbo 2(b)	0.73	1.02	1.19	1.00
PBA Hallmark XT(b)	1.83	1.85	2.04	1.90	PBA Hallmark XT(b)	0.78	1.07	1.19	1.09
PBA Hurricane XT(b)	1.70	1.76	1.98	1.79	PBA Hurricane XT(b)	0.73	0.90	1.18	1.02
PBA Blitz(b)	1.48	1.50	1.84	1.89	PBA Bolt(b)	0.79	1.05	1.18	1.04
PBA Ace(b)	1.51	1.33	1.65	1.86	Nipper(b)	1.08	1.11	1.18	1.01
Nipperv	1.62	1.61	1.78	1.73	PBA Blitz(b)	0.63	0.96	1.11	0.93
PBA Greenfield(b)	1.04	0.92	1.16	1.12	PBA Greenfield(b)	0.79	0.93	1.03	0.78

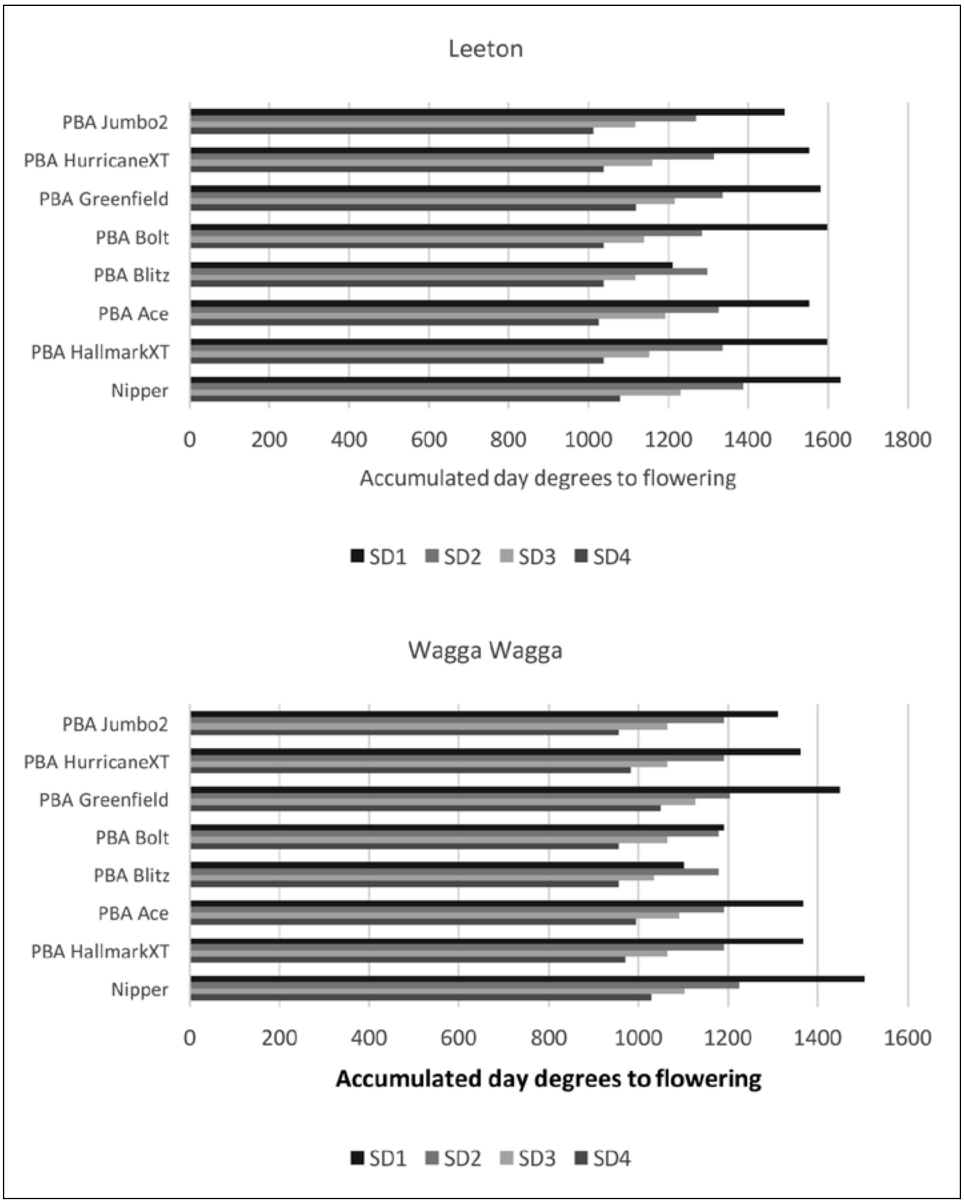

Figure 3. Accumulated growing day degrees to flowering for lentil varieties at Leeton and Wagga Wagga for four sowing dates (SD1-4)

These results were combined with 2018 data to produce predicted means (Table 5.) that indicate that the optimum sowing window for lentil over the past two seasons varies between Leeton and Wagga and also between varieties. Biomass accumulation was lower as sowing time was delayed and showed G x E interactions. The heavy and taller plants at SD1 tend to be susceptible to lodging, reducing harvestability. Later sowing time correlated with higher harvest index and lower biomass which ranged from 3.84t/ha (SD4) to 7.45t/ha (SD1) at Leeton and 2.04t/ha (SD4) to 3.25t/ha (SD1) at Wagga Wagga, and showed no G x E interaction at Wagga Wagga.

Impact of growing degree days

The impact of growing degree days (GDD) was the same for both chickpea and lentil at Wagga Wagga and Leeton, with the crops requiring more degree days to flower as sowing was delayed.

The GDD accumulated for chickpea ranged from 1477 (SD1) to 1114 (SD4) at Leeton and from 1578 (SD1) to 1087 (SD4) at Wagga Wagga. Crops emerging from SD1 emerge when day length is gradually decreasing (late April), while crops sown at SD4 emerge when days are starting to lengthen (late June). This demonstrates that all the varieties are photoperiod sensitive, with longer days reducing the thermal target, thus requiring fewer GDD to switch from vegetative to reproductive stage (Whish 2016).

A similar trend was observed for lentil, except for the early flowering PBA Blitz where at both sites SD1 required lower GDD to reach flowering (Figure 3). Additionally, PBA Bolt at Wagga had similar GDD requirements for SD1 and SD2. Growing degree days ranged from 1527 (SD1) to 1048 (SD4) at Leeton and from 1331 (SD1) to 986 (SD4) at Wagga Wagga (Figure 3).

Both chickpea and lentil were sown in autumn, when the temperatures were beginning to decrease, and it is likely that their vernalisation requirements, if they have any, were met, especially in SD4.

Conclusion

The 2018 and 2019 experiments indicate that there are differing optimum sowing windows between varieties and locations. It is important to note that this data was collected over two years that were characterised by drier than average growing conditions, increased incidence of abiotic stress events and lower yields. Matching sowing date and varietal phenology (genotype x sowing time combination) ensures that the sensitive growth stages such as flowering and podding occur at optimal times. Results from 2018 and 2019 indicate that sowing around the mid-May period gives the varieties tested the best opportunity to avoid abiotic stresses and allows efficient conversion of biomass to grain yield. Early sowing or longer maturing varieties such as PBA Greenfield$^{(\phi)}$ risk greater exposure to potential frost damage and late season adverse conditions such as terminal drought and heat stress. Early sowing also results in low harvest index as most of the accumulated biomass is not converted to grain yield. This often leads to higher incidence of plant lodging, especially for lentil. Diversity of genotypes was observed for both crops as seen with PBA Striker$^{(\phi)}$ (chickpea) and PBA Bolt$^{(\phi)}$ (lentil) expressing differing phenology responses.

Acknowledgements

This research is a collaborative project between the GRDC and NSW DPI under the Grains Agronomy and Pathology Partnership (GAPP). The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC; the authors would like to thank them for their continued support.

Sincere thanks for the technical assistance of Karl Moore, Scott Clark and Nelson West at the Wagga Wagga site, and Daniel Johnston and Reuben Burrough at the Leeton site. We also thank Maheswaran Rohan for his statistical designs and analysis assistance. We also acknowledge the support of NSW DPI and their cooperation at the Wagga Wagga Agricultural Institute and Yanco Agricultural Institute and Leeton Field Station.

Useful resources

NSW DPI Winter crop variety sowing guide 2019

NSW DPI Southern NSW Research Results 2018

NSW DPI & GRDC Bulletin: Legumes in acidic soils – maximising production potential in south eastern Australia, Burns H & Norton M

References

Somes, T 2017, 'Stubble load may impact chickpea yield' https://grdc.com.au/news-and-media/news-and-media-releases/north/2017/08/stubble-load-may-impact-chickpea-yield

Whish 2016, Accessing and using day degrees in field crops as a tool to assist crop management, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/accessing-and-using-day-degrees-in-field-crops-as-a-tool-to-assist-crop-management

Contact details

Mark Richards
NSW Department of Primary Industries, Wagga Wagga
Wagga Wagga Agricultural Institute
Pine Gully Road, Wagga Wagga 2650
02 69381831
mark.richards@dpi.nsw.gov.au
@NSWDPI_Agronomy

Return to contents