Lupin phenology and yield responses to sowing date and water treatment – Wagga Wagga and Rankins Springs 2021

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Key findings

- Mandelup(Φ) and PBA Bateman(Φ) were the fastest maturing varieties at Wagga Wagga.
- Early sowing at both sites and water treatment (Wagga Wagga) prolonged the growth duration.
- At Wagga Wagga, sowing date had no effect on biomass accumulation, however, more biomass was accumulated in the water treatment.
- Early sowing increased biomass at Rankins Springs.
- PBA Jurien(Φ) showed a high and stable grain yield over the 2 locations in 2021. At Wagga Wagga, it was the highest yielding variety, while at Rankins Springs only PBA Bateman(Φ) yielded higher.
- PBA Jurien(Φ) and PBA Bateman(Φ) had the highest seed weight at Wagga Wagga, while Mandelup(Φ) and PBA Bateman(Φ) had the highest seed weight at Rankins Springs.
- Machine grain yield increased with irrigation and late sowing.

Keywords lupin, phenology, sowing date, water, Wagga Wagga, Rankins Springs, yield, southern

Introduction

In southern NSW, abiotic stresses such as heat and moisture stress late in the season and frost damage during the season limit lupin yield potential. To maximise yield, it is important to optimise sowing time to ensure that critical growth phases do not coincide with the high risks of abiotic stress. This paper presents results from the Wagga Wagga and Rankins Springs sites (southern NSW) in 2021 and discusses the influence of water treatment (WT) and/or sowing date (SD) on lupin phenology and grain yield responses.

Site details

Site details for Wagga Wagga and Rankins Springs in 2021 are detailed in Table 1.

Table 1 Summary of site conditions and experiment management.

Site	Wagga Wagga, NSW	Rankins Springs, NSW
Location	Wagga Wagga Agricultural Institute (WWAI)	Hillview, Pulletop Paddock
Soil type	Red kandosol	Sandy clay loam
Previous crop	Wheat	Wheat in 2020, canola in 2019
Rainfall	Fallow (November–March): 306 mm Fallow long-term average (LTA): 157 mm In-crop (April–October): 204 mm In-crop LTA: 329 mm	Fallow (November–March): 203 mm Fallow long-term average (LTA): 170 mm In-crop (April–October): 291 mm In-crop LTA: 232 mm
Water treatment	An additional 90 mm was applied periodically during the season for the irrigated treatment as follows: • 13 mm on 11 August • 9.9 mm on 23 August • 15.2 mm on 27 August • 8.7 mm on 9 September • 8.9 mm on 20 September • 4.5 mm on 21 September • 15.3 mm on 7 October • 14.5 mm on 28 October	An additional 6 mm was applied pre-emergent
Starter fertiliser	50% mono-ammonium phosphate (MAP), 50% single super phosphate (SSP) (nitrogen [N]: 5, phosphorus [P]: 15.4, potassium [K]: 0, sulfur [S]: 6.25) blend- Wengfu Australia	Utiliser pulse mix 120 kg/ha (N: 7.48; P: 17.64; K: 6.24; calcium [Ca]: 6.4; zinc [Zn]: 0.32; manganese [Mn]: 3.2)
Target plant density	40 plants/m^2	40 plants/m^2
Weed management	• Knockdown (24 February): BS1000® Bio-degradable (adjuvant) 60 mL/100mL + Spraytop® 250 SL (herbicide; mode of action (MOA) group 22) 2.4 L/ha • Pre-emergence (8 April, at sowing): Expedient® (adjuvant) 500 mL/ha + Panzer 450 (herbicide; MOA group 9) 2 L/ha + Striker® (herbicide; MOA group 14) 100 mL/ha + Simagen 900 WG (herbicide; MOA group 5) 2.1 kg/ha	• Pre-emergence (at sowing): Simazine 900 WG (herbicide, MOA group 5) 1.4 kg/ha on 27 April • SD1: Treflan™ (herbicide, MOA group 3) 1.2 L/ha on 26 April • SD2: Treflan™ (herbicide, MOA group 3) 1.2 L/ha on 19 May • SD2: Panzer 450 (herbicide; MOA group 9) 2 L/ha on 19 May
Disease management	• Dithane™ Rainshield™ NeoTec™ (fungicide; MOA group M3) 1 kg/ha on 23 June • Veritas® Opti (fungicide; MOA groups 3 and 11) 500 mL/ha on 23 June • Veritas® Opti (fungicide; MOA groups 3 and 11) 500 mL/ha on 21 July • Dithane™ Rainshield™ NeoTec™ (fungicide; MOA group M3) 1 kg/ha on 20 August	Nil
Pest management	• Trojan® (insecticide, MOA group 3A) 8 mL/ha on 21 June • Karate Zeon® (insecticide, MOA group 3A) 36 mL/ha on 22 October • Karate Zeon® (insecticide, MOA group 3A) 36 mL/ha on 11 November	• Mouse off at label rate on 26 April • Mouse off at label rate on 3 May • Astral® 250 EC (insecticide, MOA group 3A) 50mL/ha on 27 August • Karate Zeon® (insecticide, MOA group 3A) 36 mL/ha on 22 October
Desiccation	• Reglone® Non-Residual (herbicide, MOA group 22) 1.2 L/ha on 14 December • Spraytop® 250 SL (herbicide, MOA group 22) 0.8 L/ha on 14 December	Nil

Treatments

Table 2 Summary of the experiment treatments; variety, sowing date, and water treatment at Wagga Wagga and Rankins Springs, 2021.

Site	Wagga Wagga, NSW	Rankins Springs, NSW
Variety	PBA Jurien^{Ф}, Mandelup^{Ф}, PBA Bateman^{Ф} and Wonga^{Ф}	PBA Jurien^{Ф}, Mandelup^{Ф}, PBA Bateman^{Ф}, Wonga^{Ф}, PBA Jindalee^{Ф} and PBA Gunyidi^{Ф}
Sowing date	SD1: 29 April	SD1: 26 April
	SD2: 21 May	SD2: 19 May
Water treatment	Dryland and irrigated	Dryland only

Results

Seasonal conditions

Overall, in 2021 southern NSW had an atypical rainfall pattern, which included very late season rainfall, in October and November. This delayed crop maturity and slowed crop dry down. As a result, crops were desiccated to allow for machine harvesting.

Mouse damage, at Wagga Wagga, was higher in the later sowing date (SD2) when compared with the earlier sowing date (SD1) across all varieties.

Wagga Wagga

Phasic development

Generally, the growing season was longer in the early sown experiment (SD1) with the time to plant maturity being similar for the 2 sowing dates (Figure 1). The greatest difference was the increased time that early sown crops spent in the vegetative and pod filling phases (Figure 1).

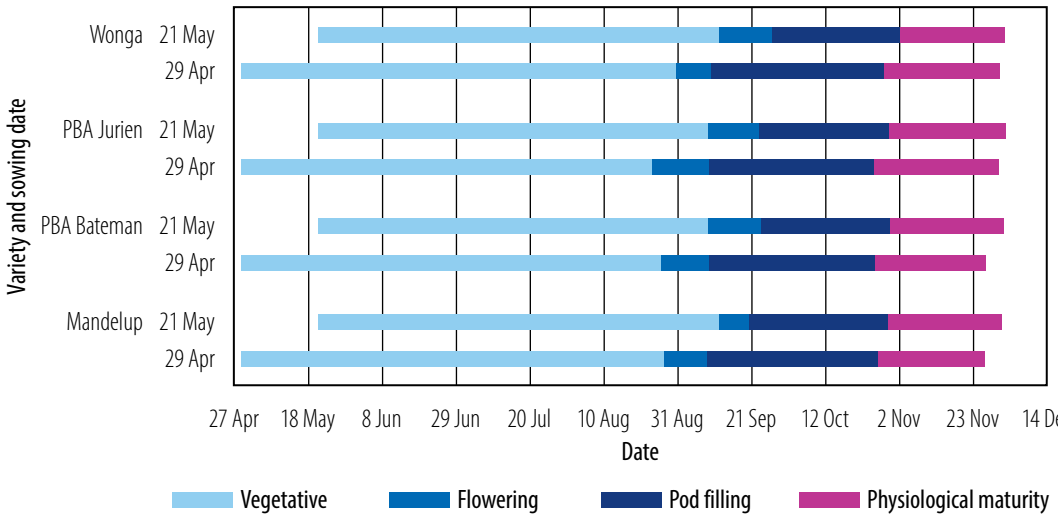

Figure 1 Duration and/or transition between growth phases of 4 lupin varieties, Wagga Wagga 2021.

Delaying sowing from late April (SD1: 29 April) to late May (SD2: 21 May) increased the time to establishment from 9.3 to 10.9 days respectively, due to the colder soil temperatures (Table 3). PBA Jurien^{Ф} and Mandelup^{Ф} had the lowest plant densities both below 40 plants/m^2. Variety × sowing date affected phenological traits (time to flowering and podding) (Table 3). This indicates common genetic control for these traits. Late sowing (SD2) accelerated phenological development with less time spent in the vegetative, flowering and pod filling development phases. PBA Jurien^{Ф} and PBA Bateman^{Ф} were the fastest to flowering (50%) at 113.9 days and 115.1 days after sowing, respectively, though Mandelup^{Ф} was the first to achieve 50% of plants containing a pod. Mandelup^{Ф} and PBA Bateman^{Ф} matured earliest, finishing approximately 203 days after sowing (Figure 1).

Table 3 Phenological response to sowing date and water treatment of 4 lupin varieties at Wagga Wagga, 2021.
DTEst = days to establishment; DT50F = days to 50% flowering; DT50P= days to 50% podding; DTPM = days to physiological maturity; Dry = dryland treatment, Wet = water treatment.

Variety	SD	DTEst		DT50F		DT50P		DTPM	
		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Mandelup	1	9.9	10.7	120.0	120.2	133.0	132.3	208.0	214.7
	2	11.6	10.9	114.0	114.0	122.7	122.0	192.0	196.0
PBA Bateman	1	8.7	8.2	119.5	119.5	133.8	133.1	208.5	214.7
	2	10.0	9.9	111.0	111.0	126.3	125.3	193.5	196.0
PBA Jurien	1	10.0	9.2	116.5	116.7	133.0	133.0	214.0	217.0
	2	11.7	10.8	111.0	111.0	124.4	126.3	194.2	196.0
Wonga	1	9.5	8.7	123.5	123.7	134.5	132.9	214.0	217.0
	2	11.1	11.0	114.0	114.0	129.0	129.0	194.2	196.0
Variety	l.s.d.	n.s.		0.5		2.3		0.6	
SD	l.s.d.	1.4		0.6		1.7		0.5	
WT	l.s.d.	n.s.		n.s.		n.s.		0.7	
Variety × SD	l.s.d.	n.s.		0.8		3.3		0.9	
Variety × WT	l.s.d.	n.s.		n.s.		n.s.		0.9	
SD × WT	l.s.d.	n.s.		n.s.		n.s.		n.s.	
Variety × SD × WT	l.s.d.	n.s.		n.s.		n.s.		n.s.	

l.s.d = least significant difference = l.s.d. ($P<0.05$); n.s. = not significant.

Grain yield

Differences in grain yield were observed due to variety, water treatment × sowing date and sowing date × variety (Table 4).

- Under ideal spring conditions in 2021, where the soil moisture was not significantly limiting, and temperatures were optimal, there was no loss in grain yield from delayed sowing or additional water treatments.
- PBA Jurien^{Φ} had the highest grain yield of the 4 varieties with 3.07 t/ha; Wonga^{Φ} had the lowest with 2.64 t/ha.
- There were contrasting effects on grain yield when sowing was delayed, and supplementary water was added.
    - When no supplementary water was applied sowing earlier had a 5% yield advantage over the later sowing date, with 2.82 t/ha for SD1 compared with 2.68 t/ha for SD2.
    - When supplementary water was applied sowing earlier resulted in a 13% or 0.4 t/ha yield reduction compared to the later sowing date, with 2.74 t/ha for SD1 and 3.15 t/ha for SD2.
- Varieties behaved differently in response to sowing date.
    - Mandelup^{Φ} and Wonga^{Φ} achieved their largest grain yields when sown later (SD2) with 2.95 t/ha and 2.94 t/ha, respectively. Sowing earlier reduced grain yields by 11% and 20% respectively for Mandelup^{Φ} and Wonga^{Φ}.
    - In contrast, PBA Bateman^{Φ} and PBA Jurien^{Φ} had higher grain yields when sown earlier (SD1) with 3.01 and 3.15 t/ha, respectively. Delaying sowing reduced yield by 8% and 5%, respectively for PBA Bateman^{Φ} and PBA Jurien^{Φ}.

Biomass accumulation

Sowing date had a small but significant effect on biomass accumulation, with 10 t/ha accumulated for SD1 and 9.3 t/ha for SD2. Adding supplementary water, increased biomass to 10.7 t/ha well above the 8.7 t/ha achieved in the dryland treatments. As with grain yield, there were differences in the amount of

biomass the varieties accumulated for the 2 sowing dates. Mandelup[Φ] and Wonga[Φ] accumulated more biomass when sown later (SD2) while PBA Bateman[Φ] and PBA Jurien[Φ] accumulated more when sown earlier (SD1).

Seed weight

PBA Jurien[Φ] and PBA Bateman[Φ] had the highest hundred seed weight with 14.0 g/100 seeds, which was significantly greater than 12.4 g/100 seeds for Wonga[Φ]. Supplementary water decreased the hundred seed weight from 13.6 to 13.2 g/100 seeds.

Harvest index

Variety, sowing date and water treatment affected harvest index (Table 4). Harvest index was lowest for Wonga[Φ] at 28% and highest for PBA Jurien[Φ] at 32%. Early sowing and supplementary water decreased the harvest index, due to relatively higher biomass accumulated, whilst grain yield was not similarly affected.

Table 4 Biomass and grain yield response to sowing date and water treatment of 4 lupin varieties at Wagga Wagga, 2021. *Dry = dryland treatment, Wet = irrigated treatment.*

Variety	SD	Biomass (t/ha)		Hundred seed weight (g)		Grain yield (t/ha)		Harvest Index	
		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Mandelup	1	8.89	9.36	13.4	12.8	2.72	2.51	0.30	0.27
	2	7.32	11.09	12.8	13.1	2.51	3.39	0.34	0.31
PBA Bateman	1	10.42	11.84	14.7	13.5	3.13	2.88	0.30	0.24
	2	8.15	9.93	14.1	13.8	2.73	2.82	0.34	0.29
PBA Jurien	1	9.45	11.21	14.4	13.5	3.13	3.17	0.33	0.30
	2	7.60	10.95	14.1	14.1	2.62	3.37	0.34	0.31
Wonga	1	9.08	10.01	12.4	11.8	2.29	2.38	0.25	0.24
	2	8.40	11.05	13.0	12.6	2.88	3.01	0.34	0.28
Variety	l.s.d	n.s.		0.33		0.31		0.01	
SD	l.s.d	0.62		n.s.		n.s.		0.01	
WT	l.s.d	0.81		0.50		n.s.		0.01	
Variety × SD	l.s.d	0.98		n.s..		0.43		0.02	
Variety × WT	l.s.d	n.s.		n.s.		n.s.		n.s.	
SD × WT	l.s.d	0.94		0.37		0.35		n.s.	
Variety× SD × WT	l.s.d	n.s.		n.s.		n.s.		n.s.	

l.s.d = least significant difference = l.s.d ($P<0.05$); n.s. = not significant.

Rankins Springs

The 6 varieties responded differently to the 2 sowing dates (SD1: 26 April and SD2: 19 May) at Rankins Springs. Early sowing (SD1) prolonged the crop duration to 190 days, for the time between sowing and physiological maturity, when compared with 172 days for SD2. Plant density differed between the varieties with PBA Gunyidi[Φ] having the highest establishment of 46.2 plants/m^2 and PBA Jurien[Φ] the lowest with 36.7 plants/m^2.

Seed weight

Seed weight responded to the variety × sowing date interaction (Table 5). Mandelup[Φ] and PBA Bateman[Φ] had the highest hundred seed weight, over 18 g/100 seeds and PBA Jindalee[Φ] the lowest at only 13.81 g/100 seeds. Hundred seed weight was higher for SD1 (17.8 g/100 seeds) than for SD2 (15.1 g/100 seeds).

Grain yield

Grain yield differed between varieties (Table 5). PBA Bateman$^{\Phi}$ (4.72 t/ha) yielded significantly higher than all the other varieties tested. Grain yield of PBA Jurien$^{\Phi}$, Mandelup$^{\Phi}$ and PBA Gunyidi$^{\Phi}$ was not as high as PBA Bateman$^{\Phi}$, but all achieved a yield over 4 t/ha.

Biomass

Only sowing date affected biomass (Table 5) with early sowing (SD1) increasing the amount of accumulated biomass by 1.2 t/ha over the later sown (SD2) amount of 10.42 t/ha.

Harvest index

Both variety and sowing date influenced harvest index. Mandelup$^{\Phi}$, PBA Bateman$^{\Phi}$ and PBA Gunyidi$^{\Phi}$ all had a harvest index over 0.40 (or 40%). Wonga$^{\Phi}$ had the lowest harvest index at only 33%. Late sowing (SD2) improved harvest index compared with early sowing (SD1), 41% to 37%, respectively. This was due to the higher biomass accumulated when sown early with no difference in grain yield between the 2 sowing dates.

Table 5 Biomass and grain yield response to sowing date and water treatment of 6 lupin varieties at Rankins Springs, 2021.

Variety	Sowing date	Crop duration (days)	Harvest biomass (t/ha)	Harvest Index	Grain yield (t/ha)	Plant height (m)	Hundred seed weight (g)	Plant density (plants/m^2)
Mandelup	1	193	11.34	0.38	4.19	0.74	19.87	40.2
	2	170	10.24	0.43	4.35	0.74	16.17	39.4
PBA Bateman	1	188	11.87	0.42	4.86	0.77	19.48	37.7
	2	171	10.06	0.46	4.58	0.69	16.65	40.0
PBA Gunyidi	1	187	11.93	0.34	4.03	0.76	17.49	45.7
	2	172	9.70	0.45	4.31	0.68	14.77	46.8
PBA Jindalee	1	195	10.83	0.37	3.98	0.93	14.48	38.8
	2	176	10.41	0.38	3.95	0.78	13.14	35.5
PBA Jurien	1	190	12.04	0.39	4.56	0.79	18.83	36.6
	2	172	11.11	0.39	4.34	0.73	15.63	36.8
Wonga	1	190	11.73	0.31	3.65	0.78	16.50	37.7
	2	172	11.00	0.34	3.76	0.71	13.95	36.3
Variety	l.s.d	n.s.	n.s.	0.05	0.28	0.04	0.54	5.4
SD	l.s.d	n.s.	0.56	0.03	n.s.	0.04	0.41	n.s.
Variety × SD	l.s.d	n.s.	n.s.	n.s.	n.s.	0.05	0.75	n.s.

l.s.d = least significant difference = l.s.d ($P<0.05$); n.s. = not significant.

Summary

Seasonal conditions significantly influenced phenology, grain yield and quality responses to sowing date, variety and/or water treatment in 2021. However, late sowing shortened growing season duration at both sites. Mild temperatures combined with unlimited soil moisture throughout the growing season masked potential differences in applied management practices, though genotypic differences were evident. For example, both sowing date and water treatment had no effect on grain yield at Wagga Wagga in 2021.

The early flowering PBA Jurien$^{\Phi}$ was one of the highest yielding varieties at both locations. PBA Jurien$^{\Phi}$ and PBA Bateman$^{\Phi}$ had the highest hundred seed weight at Wagga Wagga, while at Rankins Springs Mandelup$^{\Phi}$ and PBA Bateman$^{\Phi}$ had the highest hundred seed weight.

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