The effects from surface residue on the phenology and grain yield of chickpea and lentil – Wagga Wagga 2018

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Key findings

- Total number, severity and length of frosts increased as surface residues increased.
- Increasing the amount of surface residue delayed plant growth, lengthened growth phase duration, and overall time to maturity for both chickpea and lentil.
- For both chickpea and lentil, high surface residues, above 9 t/ha, significantly reduced biomass accumulation and grain yield.

Introduction

Some modern equipment such as stripper fronts and disc seeders allow for high levels of stubble residue from previous crops to be retained. This increases the retention of soil water following rainfall, however, the effects of stubble residue on following pulse crop growth and development are poorly understood.

Retained stubble affects thermal profiles in the crop growth environment, both above the stubble surface and below the soil surface. Stubble acts as an insulator, limiting the soil's heat absorption during the day, and reduces stored heat from radiating back into the crop canopy at night. This results in cooler soil during the day and lower air temperature above the stubble at night (compared with bare soil), potentially increasing the severity of chilling and/or frost (Verrell, 2016). This experiment, which was part of a larger project based at Tamworth (BLG106), was conducted to determine the effect on chickpea and lentil crop development and grain yield from varying amounts of cereal surface residue (mimicking stubble load) and the resulting lower temperatures.

The experiment was conducted in 2018 at Wagga Wagga, NSW under dryland conditions. The surface residue treatments (baled wheat stubble) were applied uniformly immediately after sowing to ensure there was no treatment effect on stored soil water at sowing. It is important to note that the treatments simulated a flattened surface residue, not standing cereal stubble.

Site details

Location	Wagga Wagga Agricultural Institute
Sowing date	15 May
Soil type	Red kandosol
Soil pH_{Ca}	6.5 (0–5 cm), 5.3 (5–10 cm), 4.8 (10–15 cm), 5.1 (15–20 cm), 5.5 (20–25 cm)
Fertiliser	Granulock®Z Soygran 100 kg/ha (nitrogen, [N]: 5.5, phosphorus [P]: 15.3, potassium [K]: 0.0, sulfur [S]: 7.5)
Previous crop	Barley
Rainfall	• Fallow (November 2017–March 2018): 310 mm • In-crop (1 April 2018–31 October 2018): 162 mm • In-crop long-term average: 330 mm

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Post sowing water application	
	5.1 mm – 25 May
Target plant density	40 plants/m² chickpea; 120 plants/m² lentil.
Weed management	Pre-emergence • 900 g/ha Terbyne® Xtreme (875 g/kg terbuthylazine), 1.6 L/ha Avadex® Xtra (500 g/L tri-allate), 1.7 L/ha TriflurX® (480 g/L trifluralin), incorporated by sowing (IBS). Post emergence • 300 mL/ha Select® Xtra (360 g/L clethodim), 500 mL/ha Uptake™ spraying oil (582 g/L paraffinic oil).
Insect pest management	• Astound® (100 g/L alpha-cypermethrin) 300 mL/ha – 23 May, 21 September. • Astral 250EC (250 g/L bifenthrin) 40 mL/ha – 29 September.
Harvest date	Harvest index cuts were taken as varieties reached maturity; plots were machine harvested on 19 November 2018.

Treatments

Chickpea varieties

CICA1521, PBA Slasher⁽ᵈ⁾ and PBA HatTrick⁽ᵈ⁾

Lentil varieties

PBA Ace⁽ᵈ⁾ and PBA Jumbo2⁽ᵈ⁾

Wheat surface residue applied

Five surface residue treatments were tested; 0 t/ha, 3 t/ha, 6 t/ha, 9 t/ha, and 12 t/ha.

The temperature was measured across three replicates at surface residue level.

Results

Effect of surface residue on soil water

Moisture levels at sowing were measured using EM38 technology and were confirmed to be consistent across all surface residue treatments. A subsequent decline in EM values across the growing season was attributed to crop water use and losses through evaporation, as shown by greater declines in bare soil and 3 t/ha surface residue.

Between 5 September 2018 and the final measurement after harvest (4 December 2018), soil moisture increased due to rainfall. Final EM38 measurements (Figure 1) indicated that available water was higher (i.e. EM value is higher) with increasing surface residue, with no significant difference between the 3 t/ha, 6 t/ha and 9 t/ha treatments, but all the others were statistically different. More water remained with higher surface residue, as surface residue would have prevented water loss through evaporation, but also intensified frosts, which resulted in less biomass accumulation. Due to their smaller biomass, these plants would have used less water from the soil and had reduced transpiration losses.

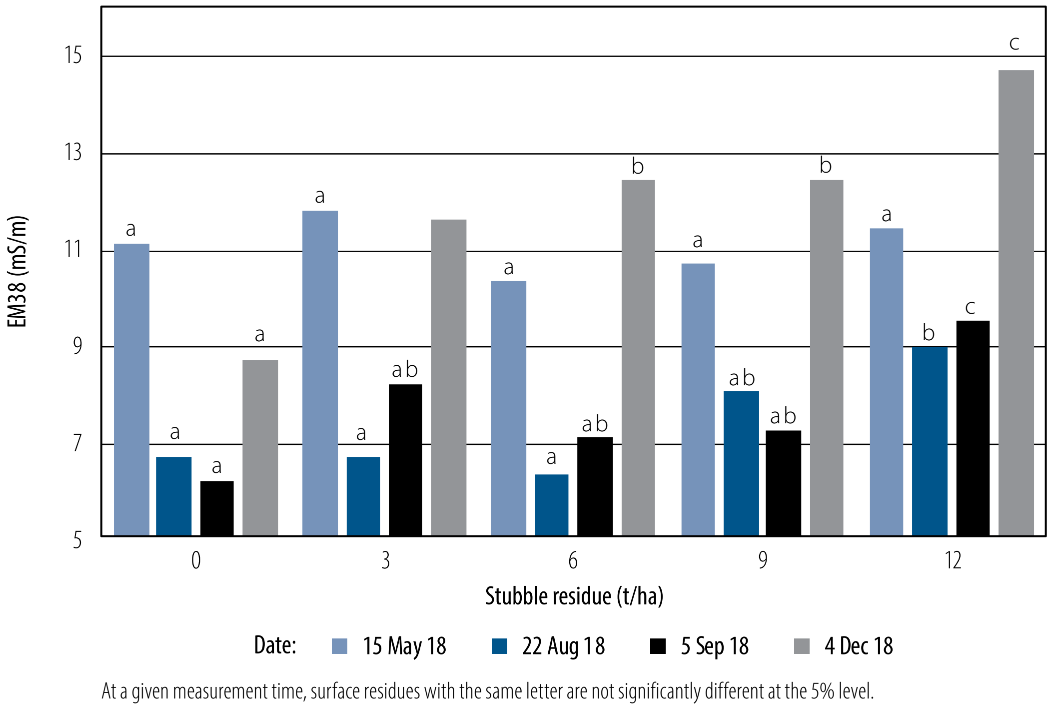

Figure 1 EM38 values in millisiemens per metre (mS/m) collected over four dates and five surface residue amounts (0–12 t/ha).

Effect of surface residue on temperature

The number of frost days (days with a temperature below 0 °C) were recorded in both chickpea and lentil plots (Figure 2). Frost days were mostly recorded during the vegetative growth phase and decreased in frequency throughout flowering and podding. There was a linear response with increasing amounts of surface residue.

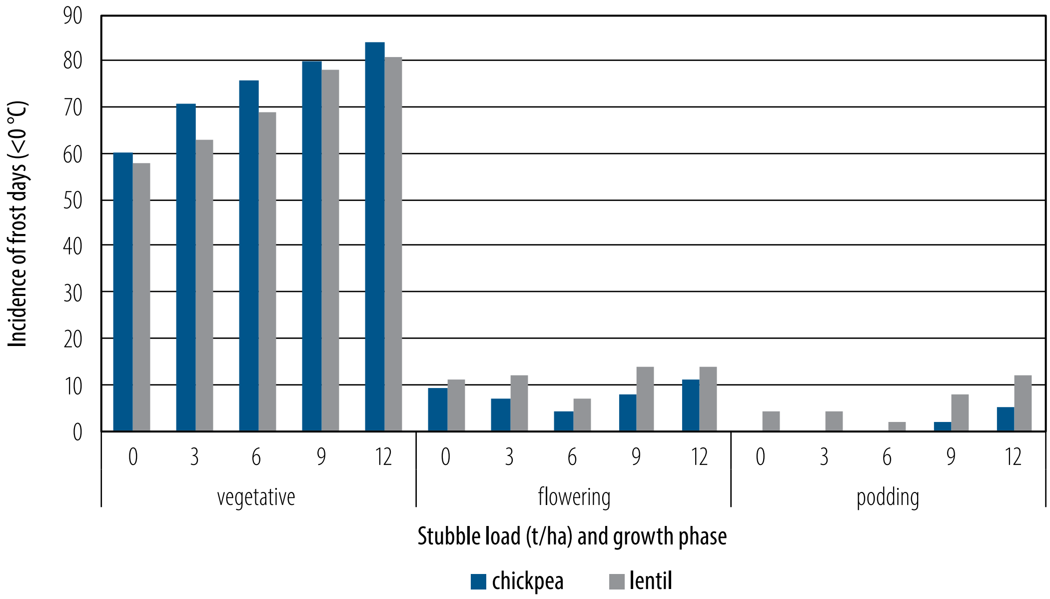

Figure 2 Number of frost days (days with a temperature <0 °C) recorded on stubble surface at each growth phase (vegetative, flowering and podding) for chickpea and lentil at Wagga Wagga in 2018.

Low temperatures at flowering and podding causes flower and pod abortion and is a major factor in unstable yields. As the amount of surface residue increased, during flowering, the cumulative number of hours below 0 °C increased for chickpea (PBA HatTrick⁽ᵈ⁾) and for lentil (PBA Ace⁽ᵈ⁾), and the absolute minimum temperature decreased (Table 1).

For chickpea, averaged across three replicates, the lowest absolute minimum temperature on the residue surface was –7.8 °C at 12 t/ha (with up to 11.1 hours of below 0 °C on one day) and –4.6 °C (with up to 8.3 hours of below 0 °C) at 0 t/ha on 17 September. For lentil, at 9 t/ha and 12 t/ha up to 11.8 hours of below 0 °C was experienced compared with 8.5 hours at 0 t/ha. The lowest absolute minimum temperature for lentil was –8.1 °C at 12 t/ha and –4.0 °C at 0 t/ha on 17 September.

Table 1 Lowest daily minimum temperature, daily hours below 0 °C and cumulative hours when surface temperature was below 0 °C during chickpea and lentil flowering period.

Flowering period	Surface residue	Lowest daily minimum (°C)	Maximum daily hours less than 0 °C	Cumulative hours less than 0 °C
Chickpea				
17 Sep–12 Oct	0 t/ha	–4.6	8.3	32.7
17 Sep–12 Oct	3 t/ha	–5.7	9.4	53.1
17 Sep–12 Oct	6 t/ha	–5.7	9.6	59.2
17 Sep–12 Oct	9 t/ha	–6.8	10.4	74.2
17 Sep–12 Oct	12 t/ha	–7.8	11.1	87.8
Lentil				
12 Sep–19 Oct	0 t/ha	–4.0	8.5	35.5
12 Sep–19 Oct	3 t/ha	–5.4	8.5	56.8
12 Sep–19 Oct	6 t/ha	–5.0	8.5	56.0
12 Sep–19 Oct	9 t/ha	–8.1	11.8	123.8
12 Sep–19 Oct	12 t/ha	–8.1	11.8	125.5

Chickpea phenology

The duration of the vegetative, flowering and podding phases differed between treatments and varieties (data not shown). For all three varieties the vegetative phase was significantly shorter at 0 t/ha due to higher surface temperatures. In PBA Slasher⁽ᵈ⁾ and PBA HatTrick⁽ᵈ⁾, the vegetative phase was significantly shorter at 3 t/ha than the 6 t/ha, 9 t/ha and 12 t/ha treatments. For all three varieties, 0 t/ha had the longest flowering duration and there was a significant variety × surface residue interaction. Podding duration showed no varietal difference, but was longer at higher surface residue (12 t/ha). Plants took longer to reach physiological maturity at 12 t/ha than at 0 t/ha.

Lentil phenology

The duration of the vegetative, flowering and podding phases differed between residue treatments and varieties, but there was no interaction (data not shown). At all surface residue treatments, PBA Jumbo2⁽ᵈ⁾ flowered earlier than PBA Ace⁽ᵈ⁾. Increasing amounts of surface residue extended the vegetative phase duration.

The vegetative phase duration increased from 113 days for PBA Jumbo2⁽ᵈ⁾ and 116 days for PBA Ace⁽ᵈ⁾ on bare soil (0 t/ha) to 129 days for PBA Jumbo2⁽ᵈ⁾ and 131 days for PBA Ace⁽ᵈ⁾ with high (12 t/ha) residue loads.

Surface residue, in addition to delaying flowering, also reduced flowering duration compared with bare soil, possibly due to flowering starting when temperatures were higher and hence accelerating plant development. Generally, there was a trend towards delayed physiological maturity as surface residue increased. There was a significant increase in days to physiological maturity from 0 t/ha to 12 t/ha surface residue, but with no varietal differences.

Chickpea biomass, grain yield and yield components

Plant establishment decreased with increasing surface residue (Table 2). However, no varietal responses or interactions between variety and surface residue were found. This was due to the increased difficulty for emerging seed to push through the higher surface residue treatments.

Harvest biomass and grain yield were significantly lower at 12 t/ha than all other surface residue treatments (Table 2). Varietal differences were found, but had no interaction with surface residue treatment; PBA HatTrick$^{\phi}$ had the largest biomass, followed by CICA1521 and PBA Slasher$^{\phi}$ with the lowest biomass.

Grain yield ranged from a low of 0.85 t/ha for PBA Slasher$^{\phi}$ at 12 t/ha up to 1.5 t/ha in CICA1521 at 0 t/ha (Table 2). At all surface residue treatments, CICA1521 was highest yielding and PBA Slasher$^{\phi}$ lowest yielding. There were differences in yield components and harvest index (Table 2). CICA1521 had the largest 100 grain weight (21.01 g) at 0 t/ha surface residue (bare soil) and PBA Slasher$^{\phi}$ had the smallest grain weight (15.17 g) at 12 t/ha surface residue. Pod number per plant ranged from 14 for CICA1521 (13 filled) at 0 t/ha surface residue, to 31 for PBA HatTrick$^{\phi}$ (25 filled) grown at 9 t/ha surface residue. Seeds per plant ranged from 20 at 0 t/ha to 30 at 12 t/ha surface residue and there were no varietal differences. Harvest index ranged from 0.41 for PBA HatTrick$^{\phi}$ grown at 9 t/ha surface residue to 0.51 for CICA1521 at 0 t/ha surface residue.

Lentil biomass, grain yield and yield components

For plant establishment there were no varietal differences for surface residue load or interactions between variety and surface residue (Table 3).

There were differences due to variety and surface residue treatment on harvest biomass, but there was no interaction between variety and surface residue treatment (Table 3). Across all surface residues, PBA Ace$^{\phi}$ had higher biomass than PBA Jumbo2$^{\phi}$.

There were no varietal differences in grain yield, but surface residue had an effect, with a significant decrease in grain yield as surface residue increased above 3 t/ha (Table 3). The 12 t/ha treatment was the lowest yielding at 0.96 t/ha, while the 3 t/ha surface residue treatment was the highest yielding with a grain yield of 1.47 t/ha. The differences in yield mirrored the differences in 100 grain weight where 12 t/ha surface residue resulted in low grain weight. There were no significant effects for variety, surface residue and interaction on total, filled and unfilled pod number, and on harvest index.

Conclusion

The 2018 growing season at Wagga Wagga was one of the most difficult on record with a high level of frost incidence and below average growing season rainfall of 162 mm April–October, compared with the long-term average of 330 mm. We found that as surface residue amounts increased, in-crop surface minimum temperatures declined, and lethal frost frequency and the duration of radiant frost increased. As a result, the observed delay in flowering for both chickpea and lentil with high surface residue is likely due to lower temperatures and a greater number of frost days (less than 0 °C) delaying floral initiation and overall plant growth. The longer growth duration, especially in chickpea, in the 12 t/ha surface residue treatment, was due to the significant vegetative frost damage and subsequent regrowth observed in this treatment. The subsequent regrowth was insufficient to compensate for the severe vegetative frost damage.

For chickpea, there was a linear decline in grain yield with increasing surface residue. The higher pod number (filled and unfilled) and seed number did not compensate for the lower grain weight at 12 t/ha and hence the 12 t/ha was significantly lower yielding than all other surface residue treatments.

Table 2 Chickpea establishment, biomass, yield and yield components at harvest for different surface residues at Wagga Wagga in 2018.

Variety	Surface residue (t/ha)	Establishment (plants/m^2)	Biomass (t/ha)	100 grain weight (g)	Pod no./ plant	Filled pod no./plant	Unfilled pod no./ plant	Yield (t/ha)	Harvest index
CICA1521	0	42.3	2.90	21.01	14	13	1	1.48	0.51
	3	38.7	3.03	20.29	15	14	1	1.47	0.49
	6	40.3	2.95	19.15	20	17	3	1.39	0.47
	9	32.3	2.94	18.64	24	21	3	1.35	0.46
	12	28.7	2.01	17.79	21	19	2	1.01	0.50
	Mean	37.1	2.87	18.06	26	21	5	1.24	0.43
PBA HatTrick	0	39.7	3.00	19.69	21	17	4	1.38	0.46
	3	41.0	3.13	18.97	22	18	4	1.37	0.44
	6	37.7	3.05	17.83	27	21	6	1.29	0.42
	9	33.7	3.04	17.32	31	25	6	1.24	0.41
	12	33.7	2.11	16.47	28	23	5	0.91	0.43
	Mean	37.1	2.87	18.06	26	21	5	1.24	0.43
PBA Slasher	0	42.3	2.65	18.40	17	15	2	1.32	0.50
	3	38.7	2.78	17.68	19	16	2	1.31	0.47
	6	37.7	2.70	16.54	23	19	4	1.23	0.46
	9	37.0	2.69	16.02	27	23	4	1.18	0.44
	12	30.0	1.76	15.17	24	21	3	0.85	0.48
	Mean	37.1	2.52	16.76	22	19	3	1.18	0.47
Mean of all varieties	0	41.4	2.85	19.70	17	15	2	1.39	0.49
	3	39.4	2.98	18.98	19	16	2	1.38	0.47
	6	38.6	2.90	17.84	23	19	4	1.30	0.45
	9	34.3	2.89	17.33	27	23	4	1.26	0.44
	12	30.8	1.96	16.48	24	21	3	0.92	0.47
l.s.d. (P<0.05)									
Surface residue		7.93	0.34	0.87	5.15	4.3	1.34	0.14	0.01
Variety		n.s	0.2	0.37	3.55	2.96	0.92	0.10	0.01
Interaction (surface residue × variety)		n.s	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.03

n.s., not significant.

Table 3 Lentil biomass, yield and yield components at harvest for different surface residues at Wagga Wagga in 2018.

Variety	Surface residue (t/ha)	Establishment (m^2)	Biomass (t/ha)	100 grain weight (g)	Seeds/ plant	Pod no./ plant	Filled pod no./plant	Unfilled pod no./ plant	Grain yield (t/ha)	Harvest index
PBA Ace	0	131.0	2.98	4.72	25.0	22.0	19	3	1.33	0.44
	3	124.0	3.36	4.63	30.0	23.0	20	2	1.54	0.46
	6	118.0	3.17	4.62	24.0	19.0	17	2	1.35	0.43
	9	114.0	2.79	4.33	33.0	23.0	22	1	1.14	0.41
	12	102.0	2.66	4.19	25.0	25.0	21	4	1.02	0.38
	Mean	117.8	2.99	4.50	27.4	22.4	20	2	1.27	0.42
PBA Jumbo2	0	117.0	2.94	5.46	23.0	23.0	20	3	1.37	0.46
	3	124.0	2.85	5.38	20.0	18.0	16	2	1.40	0.49
	6	120.0	2.68	5.37	18.0	17.0	14	2	1.19	0.44
	9	106.0	2.85	5.08	24.0	20.0	19	1	1.16	0.41
	12	115.0	2.29	4.94	22.0	26.0	20	4	0.91	0.39
	Mean	116.4	2.72	5.25	21.4	20.8	18	2	1.20	0.44
Mean of all varieties	0	124.0	2.96	5.09	24.0	22.5	20	3	1.35	0.45
	3	124.0	3.10	5.01	25.0	20.5	18	2	1.47	0.48
	6	119.0	2.93	5.00	21.0	18.0	16	2	1.27	0.44
	9	110.0	2.82	4.71	28.5	21.5	21	1	1.15	0.41
	12	108.5	2.47	4.57	23.5	25.5	21	4	0.96	0.39
l.s.d. ($P<0.05$)										
Surface residue		n.s	0.35	0.16	n.s.	n.s.	n.s.	n.s.	0.15	n.s.
Variety		n.s	0.18	0.07	0.1	n.s.	n.s.	n.s.	0.09	n.s.
Interaction (surface residue × variety)		n.s	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s	n.s.

n.s., not significant.

Similarly, for lentil the lower temperatures at 12 t/ha surface residue resulted in decreased biomass accumulation, lower grain weight and yield. Conversely, the 3 t/ha surface residue treatment had the highest yield, thus indicating that lower surface residue quantities can make a beneficial contribution.

The results of this experiment highlight the need for improved understanding of the interaction between variable surface residue and abiotic stressors across pulse species and the implications of high stubble loads/residues in stubble retention and disc seeding systems. While there is generally a low probability of seeding into high surface residue loads greater than 9 t/ha in the dryland cereal growing areas of southern NSW, this experiment highlights the potential risk to pulse production.

Reference

Verrell A, 2016. Stubble and its impact on temperature in chickpea crops. *GRDC Update paper*, Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/07/stubble-and-its-impact-on-temperature-in-chickpea-crops. Viewed on 20 April 2020.

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