The impact of row spacing on the growth and yield of lentil cultivars in southern Australia.

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Abstract

No-till cultivation, wider row spacing, inter-row sowing and residue retention have been widely adopted in south-eastern Australia but we have little understanding of their impacts on the growth and grain yield in lentil nor implications for cultivar development. Four field experiments were conducted 2007-2009 in the southern Mallee and Wimmera of Victoria on a range of lentil cultivars differing in physiological characteristics (flowering time, height, resistance to lodging) and growth habit (erect, spreading/sprawling). The impacts of row spacing (19 cf. 30 cm), residue retention (standing residue cf. slashed residue) and sowing date were investigated. At maturity, measurements of canopy and pod height, and grain yield were recorded. Grain yields in plots on 30 cm row spacings with standing residue were significantly higher than plots sown on 19 cm row spacings with slashed residue. Canopy and pod height were also increased in the wider row spacing across all trials. Varietal differences in response to changes in row spacing occurred with grain yield improvements in the standing residue, 30 cm row space treatment ranging from -4% - +31%, compared with the 19 cm row space slashed residue treatment. Lentils can thus be successfully grown in row spacings up to 30 cm and inter-row into standing residue, with improved harvestability through increased pod height, and higher grain yields. In addition, there appears to be an opportunity the develop cultivars better suited to these practices. For example, the cultivar most susceptible to lodging, Aldinga, showed the greatest response to wider row sowing. Sprawling cultivars, more susceptible to lodging, are likely to benefit in wide rows and standing stubble, which provides a trellis to improve harvestability.

Key Words

Lentil, row spacing, tillage, crop residue, genetic variation, no till.

Introduction

In 2009, 104,000 ha of lentils were sown in the cropping zone of southern Australia, producing 143,000 t of grain (ABARE 2010). In parts of this zone they are a very profitable component of the farming system, and rotationally, lentils can provide a ‘disease break’, opportunities for improved weed control and improved nutrition through contribution of symbiotically fixed nitrogen (Mayfield et al 1996). Lentil can be highly profitable with returns from a 1 t/ha crop in 2009 in excess of $700/ha.

Farming systems are constantly evolving and offer new challenges for cultivar improvement. In south-eastern Australia cultivation practices that minimise soil compaction and maximise residue retention have been widely adopted over the last 10 years. These practices include all or a combination of wider row spacings (i.e. >30 cm c.f. traditional 15-20 cm), inter-row sowing into standing residue, controlled traffic and earlier sowing. Research elsewhere indicates that the biomass and grain yield of lentil sown with these practices is either increased or similar to traditional practices with narrower row spacings, stubble slashed or removed (Cutworth 2002; Chen 2006). However, no studies compare a wide range of physiologically different cultivars. This rapid change in farming systems often means that we do not develop an understanding of the impacts of current practices on growth and grain yield of lentil cultivars.

In wider-row cropping systems with standing stubble it could be hypothesised that varieties with traits related to increased canopy width, biomass, height and vigour may benefit. This study investigated the impact of row spacing, residue and sowing date on crop and pod height and grain yield of lentil cultivars displaying diverse physiological characteristics in the southern Mallee and Wimmera of Victoria.

Methods

Experimental design

Four field experiments were conducted from 2007 to 2009 (Table 1) on a range of lentil varieties differing in physiological characteristics and growth habits (Table 2). At Dimboola in 2007, eight cultivars (Table 2) were compared across 3 row spacings and residue treatments (Table 1). The experiment was replicated 3 times in a randomised split-plot design with row spacing and residue treatment as the main block and cultivar in plots. In all other experiments 16 cultivars (Table 2) were compared across 2 sowing dates and 2 or 3 row spacing and residue treatments (Table 1). Experiments were replicated 3 times in a randomised split-split-plot design with sowing date as the main block, row spacing and residue treatment as sub blocks and cultivar in plots. In all trials all cultivars were sown to achieve a targeted plant density of 120 plants/m^2. All seed was inoculated with rhizobium prior to sowing. Plots (8m long) were sown with 80 kg/ha of ‘grain legume super + 2.5% Zn’ (0:15:7) at Wimmera sites and 60 kg/ha at the southern Mallee sites. In all experiments, weeds, insects and fungal diseases were controlled by the application of suitable pesticides and fungicides at relevant stages of crop growth. To replicate the cropping system, the 30 cm row spacing plots were sown with narrow lucerne points, press wheels and chemicals applied pre-sowing. The 19 cm row spacing plots were sown with narrow lucerne points, harrows and chemicals applied post-sowing, pre-emergent.

Table 1. Site and soil types of field experiment sites in the Wimmera (Dimboola, Horsham and Minyip) and southern Mallee (Curyo) of Victoria, and experimental details of treatments applied (sowing dates, row spacing and residue).

Site	Soil type	Sowing date	Row Spacings and Residue
Dimboola 2007 36°25’S, 142°00’E	Alkaline black cracking clay (pH[1] 8.6)	June 15	30 cm row spacing[2], standing stubble[3]: ST, 0.30 30 cm row spacing, slashed stubble: sl, 0.30 19 cm row spacing, slashed stubble: sl, 0.19
Horsham 2008 36°43’S, 141°51’E	Alkaline black cracking clay (pH 8.7)	May 28 June 26	ST, 0.30; sl, 0.30; sl, 0.19
Curyo 2009 35°47’S, 142°48’E	Alkaline sandy loam (pH 8.6)	May 5 June 10	ST, 0.30; sl, 0.19

Minyip 2009 36^{o}27'S, 142^{o}28'E	Alkaline black cracking clay (pH[1] 8.6)	May 12 June 16	ST, 0.30; sl, 0.30; sl, 0.19

[1]pH (0-10cm) - 1:5 water; [2]Sown inter-row between stubble rows of previous cereal crop; [3]Stubble height = 10-15 cm at all sites except Minyip 2009 where it was approximately 20 cm.

Measurements and analysis

Weather conditions (rainfall, air temperature, soil temperature and humidity) were recorded daily by automatic weather stations. At maturity, measurements of height at the top of the canopy and pod height (i.e. height of the lowest pods in the canopy measured from the ground surface) were recorded at maturity. Only results from pod heights are presented in this paper as canopy and pod height were significantly correlated (r = 0.8). All experiments were machine harvested and grain yields recorded. To compare all data across trials REML was used (Genstat 12.1). The varieties CIPAL804 (tested in only 1 experiment) and 99-088L (tested in 2 experiments, but in only 1 comparison that compared the 3 row space/residue treatments) were omitted. As the primary interest of this study was a row space/residue comparison and preliminary analyses of variance (ANOVAs) for each trial showed interactions between times of sowing and some of the other factors, it was decided to treat each sowing time as an independent "experiment". This is reasonable, given the different climatic conditions faced by the plots sown at different times. Therefore, for the combined REML analyses there was a total of 7 "experiments". Other measurements were taken including: detailed soil physical and chemical properties, seedling emergence, date of flowering and maturity, above ground dry matter at maturity and seed size; but are not presented in this paper.

Results

Climate

In 2007 at Dimboola, growing-season rainfall (GSR: May to October), was well below the long-term average (127 mm c.f. 281 mm) after high rainfall in January and April (approximately 150% above the long-term average). Maximum temperatures were generally slightly above average and minimum temperatures below average (data not shown). In 2008 at Horsham GSR was well below average (186 mm c.f. 281 mm). It was particularly notable that rainfall for September and October, a critical period for lentils was significantly below the long term averages (21 mm c.f. 46 mm in September and 5 mm c.f. 44 mm in October). Maximum temperatures were generally above average during September and October, with several days above 30^{o}C in the later part of October. Minimum temperatures were below average July-October, after being warmer than average in June (data not shown). In 2009, GSR at Curyo was equivalent to the long-term average (220 mm cf. 228 mm), while GSR at Minyip was above the long-term average (333 mm cf. 281 mm). There was a relatively dry period through October until mid/late November. Maximum temperatures were generally above average throughout the year except for November 7-20, when a heat wave was experienced with most days above 35^{o}C. This heatwave coincided with the dry conditions described above.

Table 2. Agronomic characteristics of lentil cultivars and trials in which they were sown.

Name	Vigour[1]	Lodging Resistance[1]	Flowering Time[1]	Maturity[1]	Growth Habit Comments	D08[2]	H08[2]	C09[2]	M09[2]
Aldinga	Mod	S	Mid	Mid	tall, primary branches?	X	X	X	X

Northfield	Poor/Mod	MS	Mid/Late	Mid	short	X	X	X	X
Nugget	Mod	MS/MR	Mid	Mid/Late	semi-erect-branching	X	X	X	X
Nipper	Poor/Mod	MR	Mid/Late	Mid	short/erect	X	X	X	X
Boomer	Good	MS	Mid	Late	tall/bulky	X	X	X	X
PBAFlash	Mod	MR	Mid	Early/Mid	erect/high pods	X	X	X	X
PBABounty	Mod	MS	Mid/Late	Mid	prostrate/many branches	X	X	X	X
CIPAL501	Mod	MS	Mid	Mid/Late	semi-erect-branching		X	X	X
PBAJumbo	Mod	MS	Mid	Mid	tall, primary branches?		X	X	X
CIPAL607	Poor/Mod	MS	Mid/Late	Mid/Late		X	X	X	X
PBABlitz	Mod/Good	MR	Early/Mid	Early			X	X	X
CIPAL611	Mod	MR	Mid/Late	Mid			X	X	X
CIPAL801	Mod	R	Mid	Mid	erect/tall		X	X	X
CIPAL802	Mod	R	Mid	Mid	erect/tall		X	X	X
CIPAL803	Mod	MR	Mid	Mid	prostrate/bulky/branching		X	X	X
CIPAL804	Mod/Good	MS	Mid	Mid/Late	tall/bulky				X
99-088L	Mod	R	Mid/Earl	Mid	tall		X	X	

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R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible; [1]Ratings relative to Nugget, mod = moderate.

Pod height and grain yield

The pod height of all cultivars sown in the standing residue, 30 cm row space treatment (ST, 0.30) was about 27% higher, than the slashed residue treatments at both 30 cm and 19 cm row space (sl, 0.30 and sl, 0.19; Table 3). There was no significant interaction with cultivar, however some varieties appeared to show a much greater increase in pod height than others in the ST, 0.3 compared with sl, 0.19 treatment. For example, Aldinga and CIPAL803 showed a 39% increase in pod height, while PBAJumbo, PBAFlash and Nipper showed an increase of <20% (Table 3). Average pod height of CIPAL802, CIPAL801, CIPAL611 and PBAFlash were greater than 10 cm, PBABounty was 6.7 cm (Table 3). Height to the lowest pod of early sown treatments was always higher than later sown treatments (data not shown).

The grain yield of cultivars in the ST, 0.30 treatment averaged about 9% higher than the sl, 0.19 treatment (Table 4). However, there was no significant difference to the sl, 0.3 treatment. No significant interaction with cultivar and stubble treatment was seen, however similar to pod height, some varieties appeared to show a much greater increase in grain yield than others in the ST, 0.3 compared with sl, 0.19 treatment. For example, Aldinga and PBABounty showed a 31% and 20% increase in grain yield, respectively, while CIPAL611, CIPAL803 and CIPAL501 showed no increase or a slight decrease in grain yield (Table 4). There were significant differences in the average grain yield of cultivars with a range from PBAFlash at 0.63 t/ha to Northfield at 0.33 t/ha (Table 4). Grain yields of early sown treatments averaged 20% more than later sown treatments (data not shown).

Conclusion

Grain yields of the lentil cultivars were generally lower than expected from long term averages (approximately 1.2-1.5 t/ha; Materne, pers. comm.) due to either low growing season rainfall (2007 and 2008) or high temperature stress (2009). In these lower yielding seasons the grain yield of lentils was improved when grown in wider row spacings (i.e. 30 cm) compared with a more traditional spacing of 19 cm, particularly when residue from the previous season's cereal crop is left standing. In addition, pod height, which is critical for ease of harvest, was significantly increased when cultivars were grown in standing stubble. This increase in pod height is probably a result of a shading effect from the stubble, resulting in plants that have greater stem elongation because they grow upwards towards the sunlight. The standing residue then provides a 'trellis', ensuring that lodging is minimised at maturity. This is particularly evident in the sl, 0.3 treatment, which had lower pods heights than ST, 0.3 because of significant lodging.

Development of cultivars adapted to current farming systems is essential to ensure the long term profitability and viability of the lentil industry in southern Australia. This research showed that the new, higher yielding more erect cultivars, such as PBAFlash and CIPAL801 tend to rank relatively higher in any row space/residue treatment (Tables 3 and 4). However, the relative change from the more traditional sl, 0.19 treatment to the ST, 0.3 treatment was variable among cultivars. This could mean that a variety such as Aldinga, which is susceptible to lodging, can have relatively low grain yields in the sl, 0.19 treatment and relatively high grain yield in the ST, 0.3. If cultivar selection continued under traditional practices it is probable that a cultivar like Aldinga, which performs well in modern systems, would be overlooked. No specific traits for improved adaptation to wider rows and standing residue can be identified from this research currently.

Table 3. Predicted mean pod height[1] (cm) of lentil cultivars grown in three row space/residue treatments across 4 sites from 2007-09. Numbers in brackets indicate percentage increase or decrease in the ST, 0.3 treatment compared with the Sl, 0.19 treatment.

Row Space/ Residue	Northfield	CIPAL501	CIPAL607	Nipper	Boomer	Nugget	CIPAL803	CIPAL611
sl, 0.19	7.7	8.3	7.3	8.9	8.4	8.1	8.0	9.8
sl, 0.3	7.5	8.5	8.0	9.1	9.6	8.6	8.1	9.0
ST, 0.3	10.0 (31)	11.2 (35)	9.2 (26)	10.3 (15)	11.0 (32)	10.9 (34)	11.1 (39)	13.1 (39)
Average	*8.4*	*9.3*	*8.1*	*9.4*	*9.7*	*9.2*	*9.1*	*10.6*

Row Space/ Residue	PBABounty	PBABlitz	Aldinga	PBAJumbo	CIPAL802	CIPAL801	PBAFlash	*Average*
sl, 0.19	5.7	7.4	7.4	7.8	9.8	9.2	9.9	*8.2*
sl, 0.3	6.1	8.3	8.0	7.4	9.9	9.4	9.9	*8.5*
ST, 0.3	8.2 (33)	9.9 (29)	10.5 (39)	9.4 (18)	12.0 (23)	11.8 (31)	11.4 (19)	*10.7 (27)*
Average	*6.7*	*8.5*	*8.7*	*8.2*	*10.6*	*10.1*	*10.4*	*?*

lsd($P<0.05$)cultivarxrow space/residue = ns; cultivar = 1.1; row space/residue = 0.5.[1]height of lowest pods from ground

Table 4. Predicted mean grain yield (t/ha) of lentil cultivars grown in three row space/residue treatments across 4 sites from 2007-09. Numbers in brackets indicate percentage increase or decrease in the ST, 0.3 treatment compared with the Sl, 0.19 treatment.

Row Space/ Residue	Northfield	CIPAL501	CIPAL607	Nipper	Boomer	Nugget	CIPAL803	CIPAL611
sl, 0.19	0.31	0.47	0.39	0.40	0.40	0.44	0.50	0.51
sl, 0.3	0.36	0.40	0.44	0.55	0.45	0.46	0.41	0.52
ST, 0.3	0.32 (2)	0.45 (-4)	0.45 (17)	0.46 (15)	0.47 (17)	0.49 (12)	0.49 (-3)	0.51 (0)

Average	*0.33*	*0.44*	*0.43*	*0.47*	*0.44*	*0.46*	*0.47*	*0.52*

Row Space/ Residue	PBABounty	PBABlitz	Aldinga	PBAJumbo	CIPAL802	CIPAL801	PBAFlash	*Average*
sl, 0.19	0.47	0.53	0.42	0.52	0.55	0.56	0.59	*0.47*
sl, 0.3	0.44	0.56	0.56	0.47	0.61	0.64	0.65	*0.50*
ST, 0.3	0.54 (20)	0.55 (6)	0.56 (31)	0.57 (8)	0.61 (13)	0.64 (18)	0.66 (17)	*0.52 (9)*
Average	*0.48*	*0.55*	*0.51*	*0.52*	*0.59*	*0.61*	*0.63*	*?*

lsd(P<0.05)cultivar x row space/residue = ns; cultivar = 0.08; row space/residue = 0.04

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