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Sowing time and tillage practice affect chickpea yield and nitrogen fixation
1. Dry matter accumulation and grain yield

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Summary. Mean protein concentrations in wheat (*Triticum aestivum*) on the Darling Downs of southern Queensland have fallen below 10% in recent years, preventing farmers from obtaining 'Prime Hard' status (13.0%) for their wheat crop. Two management options, for improving this situation are applications of nitrogenous fertiliser in a wheat monoculture or inclusion of a legume in rotation with wheat. Long-term trials at Warra, on the western Darling Downs, resulted in the selection of chickpea (*Cicer arietinum*) as a useful grain legume cash crop with potential for improvement of its nitrogen (N) fixing ability through management. This 2-year study examined the effect of sowing time and tillage practice on dry matter yield, grain yield, N accumulation and N_2 fixation in chickpea and the subsequent soil N balance. There were 3 sowing times during autumn and winter of each year using conventional tillage (CT). Zero tillage (ZT) was introduced after the first crop for all sowing times.

Greater total dry matter yield and grain yield (4.18–5.95 and 1.63–2.25 t/ha, respectively) resulted from sowing in autumn or early winter than from sowing in late winter (3.39–3.86 and 0.97–1.22 kg/ha, respectively). The effects of tillage practice were variable, depending on growth stage. At harvest, ZT plots produced greater total dry matter yield (4.20 t/ha) and grain yield (1.94 t/ha) than CT plots (3.01 and 1.29 t/ha, respectvely), whereas at the time of maximum dry matter, yield was higher under CT for autumn sowings, and under ZT for winter sowings.

Introduction

Continuous cultivation and cropping in the major cereal growing areas of southern Queensland has depleted soil organic carbon and nitrogen (N) and decreased crop yields and grain protein content (Dalal *et al.* 1991). Dalal *et al.* (1991) estimated that 1.2 million hectares of the total cereal and oilseed cropping area of 1.5 million hectares in southern Queensland are affected by a decline in soil fertility, with the resulting loss in production to the grain industry estimated at $A324 million per year. This has resulted in increased use of nitrogenous fertilisers and stimulated interest in rotation cropping systems using legumes as a source of N. Cropping systems with legumes have been used successfully in southern Australia (Donald 1965), where they form the basis of the cropping–pasture rotation system (Perry 1989). Application of such rotation systems in southern Queensland has been limited, except for the pasture legume lucerne (*Medicago sativa*) (Littler and Whitehouse 1987), and the grain legume chickpea (*Cicer arietinum*) (Doughton 1988).

Chickpea has been widely used in cereal rotations in southern Queensland, but limited studies have been conducted on the influence of pre-sowing soil N levels on dry matter accumulation and distribution, and on N_2 fixation (Doughton *et al.* 1993). Early planting of chickpea may result in greater biomass (Siddique and Sedgley 1986) and N accumulation. The effect of tillage practice on chickpea production appears not to have been studied, but dry matter yields and N_2 fixation in soybean were found to be greater under zero tillage (ZT) than under conventional tillage (CT) (Herridge and Bergersen 1988).

Previous studies (Siddique and Sedgley 1986; Beech and Leach 1989) have reported that autumn sowing results in greater dry matter yield than winter or spring sowing. Similarly, water-use efficiency declines from autumn sowing to winter or spring sowing (Siddique and Sedgley 1986; Beech and Leach 1989). Trials in south-east Queensland by Brinsmead (1992) suggest an optimum sowing period from 10 May to 20 July. Our study aims, in part, to confirm the autumn sowing period for the lower rainfall areas of the western Darling Downs.

The overall aim of the study was to determine the effects of sowing time and tillage practice on dry matter yield, grain yield, N accumulation and N_2 fixation in chickpea, and the soil N balance of a Vertisol. We report here the effects of sowing time and tillage practice on maximum dry matter accumulation, grain yield and water-use efficiency. The effects on N accumulation, N_2 fixation and N balance are presented in Horn *et al.* (1996).

Materials and methods

Experimental site

This study was conducted in conjunction with a long-term soil fertility restoration project (Dalal *et al.* 1995) at Warra, in the Chinchilla district of southern Queensland (26°47'S, 150°53'E). Mean annual maximum and minimum temperatures at the site are 27 and 12°C, respectively. Rainfall is generally summer-dominant (63% falling from November to April) with an annual average rainfall of 685 mm. Monthly rainfall from January 1992 to December 1993 is shown in Figure 1. In-crop weather data for the 2 years of the study is shown in Table 1.

The soil (Ug5.24; Northcote 1979) is a deep, uniformly textured, dark greyish brown to dark brown cracking clay Vertisol (Thermic, montmorillonitic, Typic Chromustert; Soil Survey Staff 1975). It had been cropped continually for 57 years, principally for cereal [wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), sorghum (*Sorghum bicolor*)] but also for sunflower (*Helianthus annuus*) production. Soil organic carbon and total N contents are 0.74 and 0.072%, respectively, and clay content is 58% in the 0–10 cm depth (Dalal *et al.* 1991). Soil pH is 8.6 to 10 cm depth, becoming strongly acid (pH 5.0) below about 100 cm (Dalal *et al.* 1995).

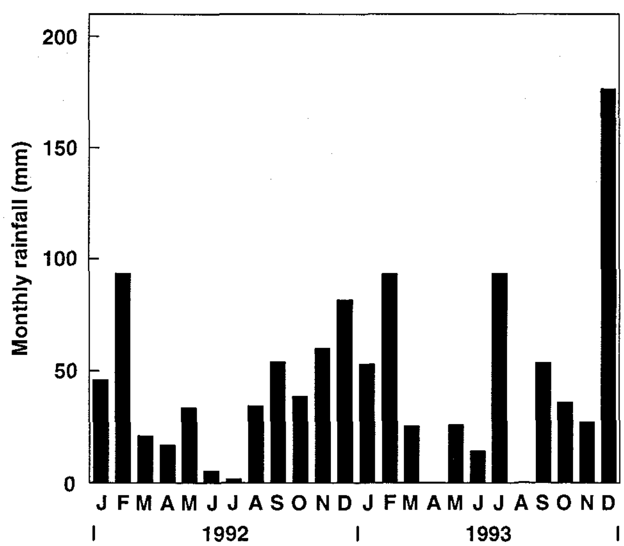

Figure 1. Monthly rainfall at the study site from January 1992 to December 1993.

Table 1. Growing season in-crop rainfall, degree-days, and frosts for 1992 and 1993

Sowing date	In-crop rainfall (mm)	Degree-days[A]	Damaging frosts[B]
	1992		
1 May	166	2794	10
27 May	133	2202	1
7 August	151	1982	0
	1993		
28 April	187	2133	0
8 June	161	1644	0
21 July	173	1724	0

[A] Cummulative daily mean air temperatures from sowing to physiological maturity of chickpea crop.
[B] Frosts affecting flowering or pod-set, based on guidelines by Foley (1945).

Experimental design

The field experiment was established in May 1992, following a cultivated fallow since May 1991, when sorghum was harvested. The design was a randomised complete block, with individual plot dimensions of 22.5 by 6.25 m. The initial treatments were CT (3 cultivations with chisel plough and scarifier) and 3 sowing dates of chickpea with 8 replicates. Eight replicates of wheat were also sown in preparation for the next season's chickpea plots. Zero tillage treatments (using glyphosate at 1.4 L/ha, 3 times during the fallow period to control weeds) were commenced after the harvest of the chickpea and wheat plots in November 1992. In 1993, the treatments were 3 sowing dates of chickpea and 2 tillage treatments (CT as in 1992 and ZT) with 4 replicates of each. In addition, continuous wheat was grown under CT and ZT as control treatments, giving a total of 14 plots per replicate (56 plots in all).

Cultural practice

Desi type chickpea (cv. Barwon) was sown at 65 kg/ha (about 350 000 seeds/ha) on 1 May, 27 May and 7 August 1992. The 7 August 1992 sowing was substituted for the planned sowing date in early July because of inadequate rainfall. Chickpea was sown into a relatively dry seed bed and irrigated with 30 mm of water on 15 August to ensure adequate germination and plant establishment. Chickpea seed was inoculated with appropriate rhizobium in a peat carrier at the rate of 5 g peat/kg. Seed was also treated with Apron (a.i. metalaxyl, at 1.5 g/kg seed), a fungicide to control phytophthora root rot, and then planted with 222 kg/ha of granulated single superphosphate with copper (Cu) and zinc (Zn), to supply 18 kg phosphorus/ha, 2 kg Cu/ha and 2 kg Zn/ha. Wheat (var. Hartog) was sown on 27 May at 35 kg/ha with the same application of superphosphate.

For the following autumn and winter seasons, chickpea (cv. Barwon) was sown at 65 kg/ha on 28 April, 8 June and 21 July 1993, and wheat on 22 July 1993, with the same cultural practices as in 1992, and harvested in November–December.

Sampling and analyses

Soils were sampled before sowing and after harvest in 1992 and 1993. Two cores were taken per plot to 150 cm depth, segmented at 10-cm intervals to 30 cm and at 30-cm intervals to 150 cm. Cores were then bulked to 1 sample per plot per depth. Soil was oven-dried to 105°C and moisture content determined.

Samples of chickpea were taken at intervals during the growing season, from flowering to harvest, to establish the time of maximum dry matter yield and grain yield. Above-ground plant samples were collected from 2 m of row in each plot. Flowering was defined as 50% of plants having commenced flowering. Plant samples were dried at 65°C and total dry matter yield and grain yield were determined.

Water-use efficiency

Water-use efficiency (WUE) of the chickpea grain yield at harvest was calculated from:

WUE (kg/ha.mm) = grain yield (kg/ha)/water utilised (mm)

where water used by the chickpea crop is the soil water before sowing minus soil water at harvest (0–120 cm) plus in-crop rainfall.

Statistical analysis

Significant differences between treatments were established using ANOVA (Research Experiment Management System, Queensland Department of Primary Industries).

Results

Dry matter yield

The greatest dry matter yields were achieved from the 1 May 1992 and 8 June 1993 sowings (Table 2). The smallest dry matter yields resulted from the late sowings in both years.

No significant difference in dry matter yield was found between the early and mid sowing time in either year, but there was a significant difference in dry matter yield between the early and mid sowings and the late sowing in both years (Table 2). Dry matter yield through the growing season was generally higher under ZT, though this trend was reversed at the time of maximum dry matter yield (Table 3). Significant sowing time x tillage interactions were evident at flowering in the 8 June sowing and at harvest in the 28 April sowing (Table 3).

Grain yield

Trends were similar to dry matter yield, with significant grain yield differences occurring only between the late and early–mid sowings in both years (Table 2). Mean grain yield from ZT (1.94 t/ha) for all sowing times was almost 50% higher than CT (1.29 t/ha) (Table 3). The sowing time x tillage interaction was significant only in the 28 April sowing with higher grain yield from ZT (2.28 t/ha) than from CT (0.99 t/ha) (Table 3).

Vegetative yield

Vegetative yield (dry matter excluding grain) increased during flowering and pod fill in both years, but declined before or at the time of maximum dry matter yield. Vegetative dry matter loss occurred due to

Table 2. Effect of sowing time on maximum dry matter (DM) yield and grain yield of chickpea in 1992 and 1993 (conventional cultivation)

Sowing date	DM (t/ha)	Grain yield (t/ha)
	1992	
1 May	5.15	2.14
27 May	4.18	2.10
7 August	3.86	1.22
l.s.d. ($P = 0.05$)	1.15	0.58
	1993	
28 April	5.93	1.63
8 June	6.11	2.25
21 July	2.48	0.97
l.s.d. ($P = 0.05$)	1.62	0.69

Table 3. Effect of sowing time and tillage practice on total dry matter (DM), grain and vegetative yield (t/ha) of chickpea in 1993

CT, conventional tillage; ZT, zero tillage

Sowing date	Flowering CT	Flowering ZT	Max. DM stage CT	Max. DM stage ZT	Harvest CT	Harvest ZT
			Total DM yield			
28 April	1.55	2.39	5.93	4.68	2.30	4.86
8 June	1.17	2.40	6.11	5.78	4.28	4.89
21 July	2.48	2.09	2.48	3.38	2.45	3.02
l.s.d. ($P = 0.05$)						
Sowing time x tillage	1.06		n.s.		1.85	
			Grain yield			
28 April	—	—	—	—	0.99	2.28
8 June	—	—	—	—	2.13	2.36
21 July	—	—	—	—	0.76	1.18
l.s.d. ($P = 0.05$)						
Sowing time x tillage					0.98	
			Vegetative yield			
28 April	1.55	2.39	3.74	2.94	1.31	2.59
8 June	1.17	2.40	3.74	3.52	2.15	2.53
21 July	2.48	2.09	2.61	2.49	1.69	1.83
l.s.d. ($P = 0.05$)						
Sowing time x tillage	1.06		n.s.		0.96	

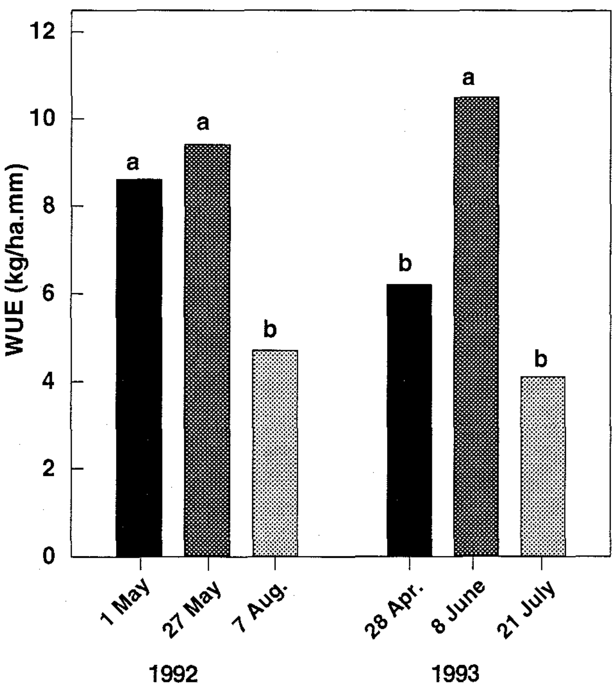

Figure 2. Effect of sowing time on water-use efficiency (WUE) of chickpea in 1992 and 1993. Within each year, means marked with the same letter are not significantly different at $P = 0.05$.

translocation to grain and leaf fall, during the time from maximum dry matter yield to harvest (Table 3). Vegetative yields were similar from ZT and CT except at harvest, when the mean vegetative yield from ZT (2.32 t/ha) was significantly greater than from CT (1.72 t/ha) (Table 3). However, the vegetative yield increase from ZT treatments (35%) was less than the grain yield increase (50%). Sowing time x tillage interactions were significant at flowering and harvest, similar to those of maximum dry matter yields (Table 3).

Water-use efficiency

Water-use efficiency varied from 4.1 kg/ha.mm for the 21 July 1993 sowing to 10.5 kg/ha.mm for the 8 June 1993 sowing (Fig. 2). In both years, the late winter sowings had the lowest WUE. Tillage practice did not significantly affect WUE.

Discussion

Dry matter yield

Sowing from late April to early June produced greater maximum dry matter yields in both years than sowing in July or August. Brinsmead (1992) found that for 6 sites in southern Queensland, the period from 10 May to 20 July was the optimum sowing time for chickpea to achieve dry matter yields within 10% of the maximum recorded for those sites. In the present study, the greatest dry matter yields were 5.15 and 6.11 t/ha from the 1 May 1992 and 8 June 1993 sowings, respectively (Table 2). The dry matter yield of 2.48 t/ha from the 21 July 1993 sowing (Table 2) suggests that the 20 July date recorded by Brinsmead is probably not an optimum period for chickpea sowing in southern Queensland. Similar dry matter yields from chickpea in autumn-sown trials have been recorded by other workers, 5.06 t/ha (Beech and Leech 1989), and 4.95 and 6.76 t/ha (Siddique and Sedgley 1986). The chickpea grain yields reported by Siddique and Sedgley (1986) from late June to mid July sowings, were 3.84 and 3.23 t/ha, respectively. The present study confirms that sowing in July or later adversely affects chickpea dry matter yield.

The smaller yield for the 27 May 1992 sowing can partly be explained by a late frost (−0.7°C on 14 September) during a phase of rapid dry matter accumulation and pod-set. Although 10 potentially damaging frosts occurred during the growing season of the 1 May 1992 sowing, they occurred after the maximum dry matter yield was attained. Temperatures in 1993 were not low enough to affect dry matter yield or pod-set. Savithri *et al.* (1980) reported that no fruit set occurred in chickpea below 15°C. No mention was made of how low the temperature can fall and fruit set still occur when it rises again, though it appears that temperatures below 0°C (Ellis *et al.* 1986) cause irreparable damage to the ability of chickpea to set fruit.

Mean dry matter yield at harvest was greater in ZT (4.26 t/ha) than in CT (3.01 t/ha) treatments (Table 3). Total available soil water in the root zone (0–120 cm) at sowing was similar in both tillage treatments, but ZT plots contained more water in the 60–90 cm soil layer than CT plots (data not shown). This water was possibly utilised by chickpea after flowering to achieve greater dry matter yield in the ZT treatment.

Grain yield

Grain yields were 1.63–2.25 t/ha for autumn and early winter sowings, compared with 0.97–1.22 t/ha for late winter sowings in 1992 and 1993 (Table 2). These yields are substantially lower than reported for similar soils in southern Queensland by Brinsmead (1992), with a range from 5.68 to 6.12 t/ha for autumn sowings and 2.34 to 3.60 t/ha for late winter–spring sowings. In the study by Brinsmead (1992), moisture stress was minimised by supplementary irrigation. The importance of soil water is highlighted in a 2-year study by Beech and Leach (1988) on a Vertisol at Dalby. In May sowings with above-average in-crop rainfall (488 mm during April–November 1979), grain yield was 5.06 t/ha. With below-average rainfall (246 mm during April–November 1980) grain yield was only 1.99 t/ha. In the present study, rainfall during the growing season from April to November was 244 mm in 1992 and 251 mm in 1993 (with average in-crop rainfall of 150 mm in 1992 and 174 mm in 1993, Table 1), and it was a major factor contributing to the lower yields. The amount and distribution of rainfall in relation to sowing date therefore appears to be a critical factor in below-average rainfall seasons.

As with total dry matter yield at harvest, grain yield was higher in ZT (1.94 t/ha) than CT (1.29 t/ha). There are few studies of the effects of tillage practice on chickpea. However, Aujila and Cheema (1983) reported chickpea grain yield of 0.84 t/ha from the control treatment (similar to ZT) and 1.02 t/ha from 2 cultivations (similar to CT). The inconsistency between these results and the current study suggests that tillage practice may have no significant effect on chickpea yield in an average- to above-average rainfall season. However, in dry seasons, when conservation of soil moisture becomes critical, ZT appears to be a useful practice.

The only significant interaction between sowing time and tillage practice was in the 28 April 1993 sowing, which resulted in greater grain yield from ZT than CT (Table 3). However, a large part of the 2 m of row sampled in 1 CT plot was frost-affected and yield was reduced, thus the interaction needs to be confirmed in further studies.

Early sowing ensures more favourable growing conditions for chickpea, resulting in increased dry matter and grain yields. Sowing from 28 April to 8 June produced an 85% greater grain yield than sowing from 21 July to 7 August, and confirms the work of Brinsmead (1992). It also suggests an optimum sowing period from early May to mid June, rather than mid July, as suggested by Brinsmead. Almost 50% more grain was produced from ZT compared with CT treatments. Low in-crop rainfall of 133–187 mm (1992 and 1993) prevented optimum crop growth, resulting in smaller dry matter and grain yields than reported by Brinsmead (1992), and Beech and Leach (1988). Similarly, WUE by chickpea (Fig. 2) confirms that early May to mid June sowings in both years provided much higher WUE than either the early autumn (28 April) or late winter sowings (21 July and 7 August). This suppports earlier findings (Siddique and Sedgley 1987; Leach and Beech 1988) that sowing at an optimum time encourages chickpea canopy development, reducing soil water evaporation in winter and crop transpiration in spring.

Climatic influences, such as amount and distribution of rainfall, extremes of temperature and frost during flowering and pod-set make it difficult to suggest an optimum range of sowing dates based on only 2 season's data. However, it seems that early May to mid June sowings ensure favourable growing conditions for chickpea, resulting in increased dry matter and grain yield. Addition of ZT as a cultural practice further enhances sowing time effects through increased water available to the crop.

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References

Aujila, T. S., and Cheema, S. S. (1983). Modifying profile water storage through tillage, herbicide, chemical evaporation retardant and straw mulch and its effect on rainfed chickpea (*Cicer arietinum* L.). *Soil and Tillage Research* **3**, 159–70.

Beech, D. F., and Leach, G. J. (1988). Response of chickpea accessions to row spacing and plant density on a Vertisol on the Darling Downs, south-east Queensland. 1. Dry matter production and seed yield. *Australian Journal of Experimental Agriculture* **28**, 367–76.

Beech, D. F., and Leach, G. J. (1989). Effect of plant density and row spacing on the yield of chickpea (cv. Tyson) grown on the Darling Downs, south east Queensland. *Australian Journal of Experimental Agriculture* **29**, 241–6.

Brinsmead, R. B. (1992). Chickpea cultivar by planting time studies in Queensland. *In* 'Proceedings of the 6th Australian Society of Agronomy Conference'. (Eds K. J. Hutchinson and P. J. Vickery.) pp. 244–6. (University of New England: Armidale.)

Dalal, R. C., Strong, W. M., Weston, E. J., Cooper, J. E., Lehane, K. J., King, A. J., and Chicken, C. J. (1995). Sustaining productivity of a Vertisol at Warra, Queensland, with fertilisers, no-tillage, or legumes. 1. Organic matter status. *Australian Journal of Experimental Agriculture* **35**, 903–13.

Dalal, R. C., Strong, W. M., Weston, E. J., and Gaffney, J. (1991). Sustaining multiple production systems. 2. Soil fertility decline and restoration of cropping lands in sub-tropical Queensland. *Tropical Grasslands* **25**, 173–80.

Donald, C. M. (1965). The progress of Australian agriculture and the role of pastures in environmental change. *Australian Journal of Science* **27**, 187–97.

Doughton, J. A. (1988). Grain legumes and nitrogen in Queensland cropping systems. *In* 'Proceedings of the Queensland Crop Production Conference'. (Eds J. P. Thompson and J. A. Doughton.) pp. 46–54. (Queensland Department of Primary Industies: Brisbane.)

Doughton, J. A., Vallis, I., and Saffigna, P. G. (1993). Nitrogen fixation in chickpea. 1. Influence of prior cropping or fallow, nitrogen fertilizer and tillage. *Australian Journal of Agricultural Res*earch **44**, 1403–13.

Ellis, R. H., Covell, S., Roberts, E. H., and Summerfield, R. J. (1986). The influence of temperature on seed germination rate in grain legumes. 2. Intraspecific variation in chickpea (*Cicer arietinum* L.) at constant temperatures. *Journal of Experimental Botany* **37**, 1503–51.

Foley, J. C. (1945). Frost in the Australian region. Bulletin No. 32, Commonwealth Meteorological Bureau of Australia, Melbourne.

Herridge, D. F., and Bergersen, F. J. (1988). Symbiotic nitrogen fixation. *In* 'Advances in Nitrogen Cycling in Agricultural Ecosystems'. (Ed. J. R. Wilson.) pp. 46–65. (CAB International: Wallingford.)

Horn, C. P., Dalal, R. C., Birch, C. J., and Doughton, J. A. (1996). Sowing time and tillage practice affect chickpea yield and nitrogen fixation. 2. Nitrogen accumulation, nitrogen fixation and soil nitrogen balance. *Australian Journal of Experimental Agriculture* **36**, 701–6.

Littler, J. W., and Whitehouse, M. J. (1987). Effects of pasture on subsequent wheat crops on a black earth soil of the Darling Downs. III. Comparison of nitrogen from pasture and fertilizer sources. *Queensland Journal of Agriculture and Animal Science* **44**, 1–8.

Northcote, K. H. (1979). 'A Factual Key for the Recognition of Australian Soils.' 4th Edn. (Rellim Technical Publications: Glenside, S. Aust.)

Perry, M. W. 1989. Farming systems of southern Australia. *In* 'Proceedings of the 5th Australian Society of Agronomy Conference'. (Ed. G. P. Ayling.) pp. 167–80. (University of Western Australia: Perth.)

Savithri, K. S., Ganapathy, P. S., and Sinha, S. K. (1980). Sensitivity to low temperature in pollen germination and fruit set in *Cicer arietinum* L. *Journal of Experimental Botany* **31**, 475–81.

Siddique, K. H. M., and Sedgley, R. H. (1986). Chickpea (*Cicer arietinum* L.), a potential grain legume for south Western Australia: seasonal growth and yield. *Australian Journal of Agricultural Research* **37**, 245–61.

Soil Survey Staff (1975). 'Soil Taxonomy—a Basic System for Making and Interpreting Soil Surveys.' United States Department of Agriculture Handbook No. 436. (USDA: Washington, DC.)

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