A role for wide rows in lupin cultivation in Western Australia

R.J. French[1] **and Martin Harries[2]**

[1]Department of Agriculture and Food, Western Australia, Dryland Research Institute, PO Box 432, Merredin, WA 6415 and Centre for Legumes in Mediterranean Agriculture, University of Western Australia, Crawley, WA 6009 Email bfrench@agric.wa.gov.au [2]Department of Agriculture and Food, Western Australia, PO Box 110, Geraldton WA 6530 Email mharries@agric.wa.gov.au

Abstract

19 field trials comparing lupin growth in rows spaced from 18 to 100 cm apart were conducted between 2002 and 2005. We show that lupins in wide rows intercept less solar radiation than in narrow rows so often produce less biomass but because they defer water use until later in grain filling, they experience less severe water deficits, and can have higher harvest index. We analyse the dependence of the row spacing responses observed in these trials to meteorological and developmental variables using partial least squares regression, and explain 63.5% of the variation in the wide/narrow yield ratio with two composite variables. These show that wide rows yield relatively better than narrow rows under warm and dry conditions, and that conditions both before and after the crop flowers are important. We assessed a number of important lupin production environments in WA using these relationships and conclude that lupins will yield close to the same in 25 and 50 cm rows when sown at the normal time (early May) under average seasonal conditions. This should give confidence to growers wishing to grow lupins in wide rows in order to improve stubble handling or to permit interrow spraying with non-selective herbicides. However, we emphasise that this assumes average seasonal conditions, and that a more sophisticated analysis taking account of season-to-season variation is necessary.

Key words

Crop growth, environmental influences, radiation interception, soil water, partial least squares regression

Introduction

There has been considerable interest in growing lupins in wide rows in Western Australia. In the early 1990s this was driven by the frequent need to handle large amounts of stubble when planting lupins (Jarvis 1992). More recently the promise of more stable yields in low rainfall environments (Crabtree *et al.* 2002) and being able to control troublesome weeds by interrow spraying (Hashem *et al.* 2005) has been important. Key to the adoption of wide rows is how grain yield is affected. Based on 23 trials Jarvis (1992) reported that yield increased by 3% on average when row spacing increased from 18 to 36 cm, but recent interest has focused on rows at least 50 cm apart. Crabtree *et al.* (2002) derived a relationship between row spacing response and yield potential implying that doubling row spacing (usually from 25 to 50 cm in their context) would boost yield when yield potential was below 1.78 t/ha, and by as much as 50% when yield potential was about 0.4 t/ha. They argued that lupins in wide rows deferred use of soil water between rows until later in grain filling, were less stressed, and therefore filled more grain. The same argument has been used for growing wheat in wide rows on shallow soils in WA's northern wheatbelt (Blackwell *et al.* 2006). However, the relationship of Crabtree *et al.* (2002) showed considerable variation, and our own results have shown similar variation in row spacing response (French 2004). This paper describes an attempt to understand how environment influences lupin yield response to row spacing so that we can predict whether lupins are likely to yield better in wide or narrow rows for various production areas.

Methods

19 field trials comparing lupins at different row spacings were conducted from 2002 to 2005 across the lupin production areas of WA. All trials included a narrow spacing between 18 and 25 cm and a wide spacing of 50 or 60 cm; some also included 75 and 100 cm spacings. Trials were factorial designs with

row spacing as one factor; other factors, not necessarily tested in each trial, were pre-seeding irrigation, cultivar, sowing time, stubble retention, and crop density. Plots were 20 or 30 m long and from 2 to 4.5 m wide. In all cases the outside rows were left unharvested to avoid edge effects.

Machine-harvested grain yield and the dates of 50% flowering and maturity (when pods turn brown) were recorded in each trial. Mature biomass production and harvest index were measured in most trials and biomass production at earlier stages in some. In one trial soil water was monitored in some treatments by neutron moisture meter, and solar radiation interception with tube solarimeters (Delta-T Devices, Cambridge, UK) placed above and below the crop canopy. Weather data was obtained from the Department of Agriculture's network of automatic weather stations, located within 1 km of all but one trial. In this case weather data was obtained from the patched-point data set maintained by the Queensland Department of Natural Resources and Mines. To compare responses between sites we calculated a wide/narrow ratio as the ratio of yield in 50 (or 60) cm rows to the yield in the 18 (or 25) cm rows. We used row spacing means averaged across factors that did not interact significantly with row spacing. Different responses were calculated for sowing time and pre-seeding irrigation treatments. In crop density trials only data from 40 plants/m? treatments were used (in most other trials density was in the range 50-60 plants/m?). Partial least squares (PLS) regression (Helland 1988) was used to investigate the relationship between wide/narrow ratio and the following variates: pre-sowing rain, sowing-flowering (vegetative) rain, average vegetative temperature, thermal time to flowering, vegetative duration, flowering-harvest (grain filling) rain, grain filling duration and average temperature and vapour pressure deficit during grain filling. PLS calculations were done with GENSTAT 8.2.

Results

Figure 1 *a* shows that lupins in wide rows yielded relatively better when yield potential was low, similar to Crabtree *et al.* (2002), but were at a significant disadvantage in very high yielding situations. However, there was a great deal of variation about the fitted line, and only two sites with yields above 2.5 t/ha. Figure 1 *b* shows examples of two very different responses drawn from this dataset.

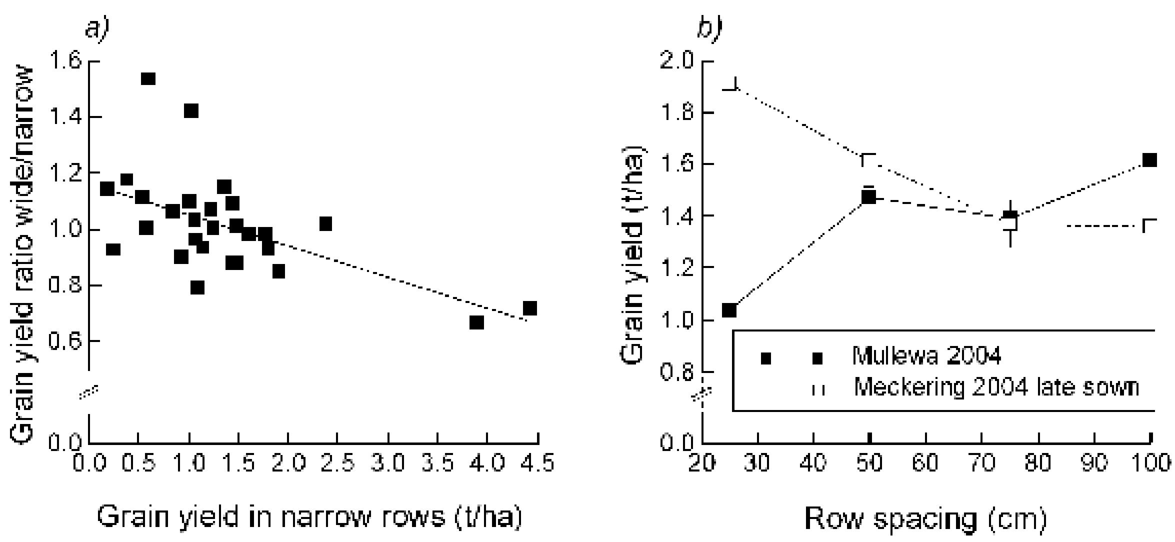

Figure 1. ***a)*** **The ratio of lupin grain yield grown in 50 or 60 cm rows to that in 18 – 25 cm rows as a function of grain yield in narrow rows.** ***b)*** **Two different lupin grain yield responses to row spacing at different locations in WA in 2004.**

Table 2 shows that total biomass production was nearly always greatest in narrow rows, although there was often little difference between 25 and 50 cm treatments. However, harvest index was often higher in wide rows, particularly in 2004, indicating less water stress during grain filling.

Table 1. Effects of row spacing on lupin biomass production and harvest index at a range of sites in WA. Quadrat samples were taken at crop maturity. Figures marked with an asterisk are significantly different (P=0.05) from the corresponding value for 25 cm.

Location	Year		Biomass at maturity (g/m?)			Harvest index		
			25 cm	50 cm	100 cm	25 cm	50 cm	100 cm
Merredin	2002	watered	203	221	199	0.40	0.42	0.43
	2003	late sown	472	398	306*	0.28	0.29	0.27
	2004		384	361	330*	0.25	0.31*	0.35*
	2005		595	449*		0.40	0.39	
Wongan Hills	2003	early sown	578	512	416*	0.34	0.36	0.36
	2004		551	522	446*	0.35	0.37	0.39*
Mullewa	2002		204	219	184	0.18	0.22	0.33*
	2003	early sown	761	749	586*	0.23	0.22	0.23
	2004		468	541	464	0.25	0.31*	0.35*
	2005		776	562*		0.43	0.42	
Newdegate	2003		582	448*	371*	0.36	0.35	0.33*
	2005		654	578		0.43	0.43	
Meckering	2004		745	633*	558*	0.28	0.29	0.26

The smaller biomass production in wide rows was due to reduced radiation interception (Figure 2 *a*) since radiation use efficiency (RUE) did not initially differ with row spacing (Figure 2 *b*). However, in the experiment shown, RUE began to decline earlier in narrow rows. This happened at about the same time as proportional interception began to decline sharply: about mid-September in 25 and 50 cm spacings, and late September/early October in 75 and 100 cm spacings. Delayed development of water stress, evident from observations of leaf wilting and patterns of leaf drop (data not shown), was responsible for this. This was, in turn, related to maintenance of higher soil moisture contents under wide row canopies, in particular in the interrow (Figure 3). During grain filling, lupins in 25 cm rows extracted water about 10 days earlier than in 75 or 100 cm rows.

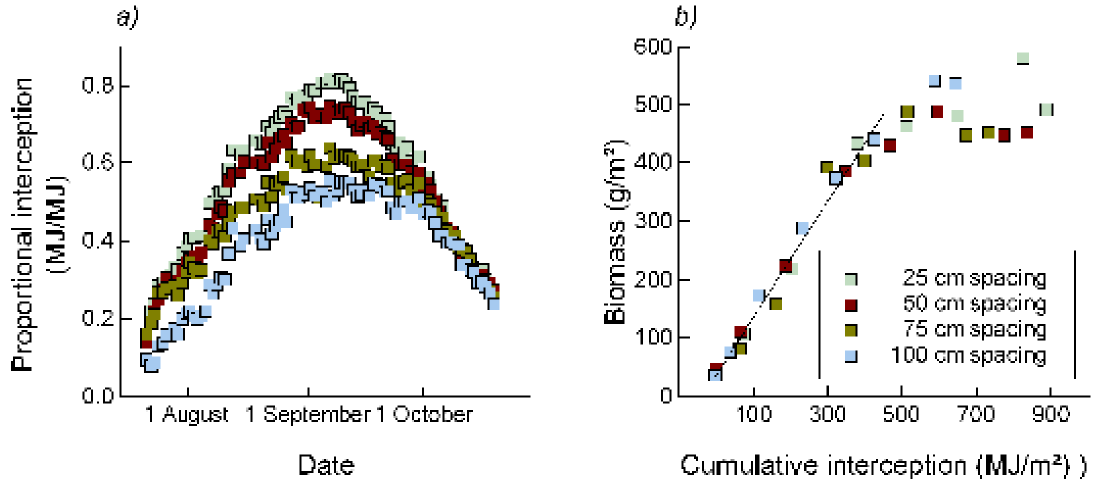

Figure 2. ***a)*** **How proportional radiation interception by lupin canopies with different row spacing changed with time at Merredin, WA, in 2004.** ***b)*** **Relationship between cumulative radiation interception after 22 July and biomass production in the same experiment.**

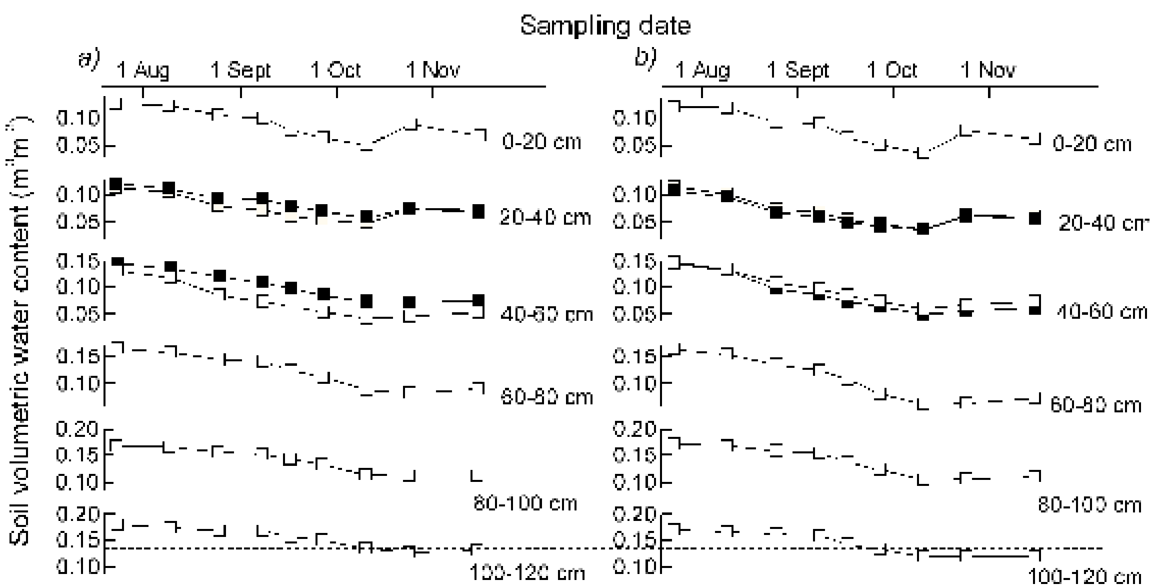

Figure 3. Change in soil volumetric water content under lupins grown in 100 cm rows (*a*) and 25 cm rows (*b*) at Merredin, WA, in 2004. At 20 - 40 cm and 40 - 60 cm depths water content is shown both for soil directly underneath the row (open symbols) and halfway between the row (closed symbols), but at other depths only means of both positions are shown.

This suggests environments where water availability limits grain filling and canopies develop rapidly (i.e. with warm winters and hot dry springs) should favour wide relative to narrow rows. Partial least squares regression revealed that two components explained 44.8 and 18.7% of the variation in the wide/narrow yield ratio. The first component was related to conditions during vegetative growth, and had high loadings for rain before flowering, temperature during the vegetative stage and vegetative duration. The second component was related to conditions during grain filling, and had high loadings for the duration of grain filling and rain, temperature and vapour pressure deficit during grain filling. Figure 4 shows that wide rows did well relative to narrow rows when conditions were warm and dry during both the vegetative and reproductive stages of crop growth, consistent with our hypothesis. We calculated average values for the two PLS components, based on assumed flowering and maturity dates and average weather data from 1957 to 2005, for lupins sown on 10 May or 1 June at Mingenew, Mullewa, Wongan Hills and Merredin in WA. These are the triangular symbols in Figure 4, and we would expect from their positions that most of these “environments” would have wide/narrow ratios between 0.9 and 1.1. We would expect only the June sowing at Merredin to be higher, and only the June sowings at Wongan Hills and Mingenew to be lower.

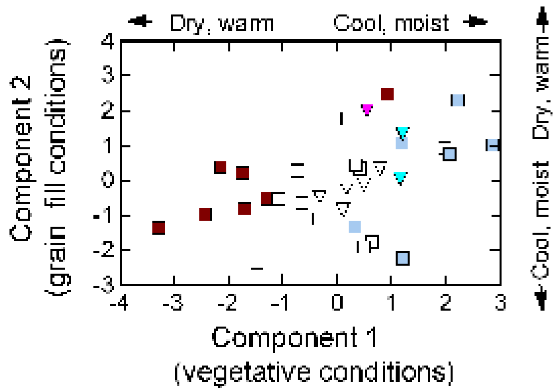

Figure 4. Plot of the first two PLS components for each row spacing response described in this paper (squares). Brown squares have wide/narrow ratio > 1.1 and pale blue < 0.9. Triangles represent other environments in WA, the pink triangle is expected to have a high ratio and the blue triangles low ratios.

Conclusions

There are two opposing influences of row spacing on lupin grain yield. Firstly, lupins in wide rows intercept less solar radiation and so grow more slowly under stress-free conditions, producing less biomass than lupins in narrow rows. But wide rows extract soil water more slowly, so under dry and warm conditions they suffer less stress during grain filling, and thus convert biomass into grain more efficiently. The predominant influence depends on seasonal conditions, and in the important lupin production areas of WA lupins sown at the normal time in early May will yield about the same in 25 and 50 cm rows under average seasonal conditions. This suggests that wide rows can be safely adopted for agronomic reasons other than yield, but it should be borne in mind that at any location wide rows can yield more grain than narrow rows, particularly in dry and warm seasons, and less in cool and moist seasons. Further analysis will be necessary to fully understand the implications of season-to-season variability for row spacing response and how it will vary across regions.

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