Matching lupin cultivar to environment in Western Australia

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Abstract

The Western Australian lupin industry has predominantly been based on one or two cultivars at a time, covering much the same range of environments served by up to 11 wheat cultivars. Since the mid-1990s six narrow-leafed lupin cultivars have been released in WA, expanding the range of cultivars growers have to choose from. This raises the possibility that growers could exploit genotype ? environment (G?E) interactions by choosing different cultivars for different environmental niches. Eight lupin cultivars (including one yellow lupin cultivar) were tested at five locations in WA from 1998 to 2000 at four different sowing times. Among the narrow-leafed cultivars the total G?E variance was 1.9 times the cultivar variance. 13% of the G?E variance was explained by differences between cultivars in their linear response to sowing date. Most of the rest of the G?E variance was associated with differences between years. There was little opportunity to select lupin cultivars specifically for early or late sowing. The early flowering Belara was consistently high yielding in all environments but, surprisingly, it lost more yield with delayed sowing than other cultivars. This was due to its high yield potential since the penalty for delayed sowing was linearly related to yield potential. An important consequence of this is that early sowing is more crucial for profit maximisation in good seasons than in poor ones.

Introduction

Throughout most of its history the lupin industry in Western Australia has been based predominantly on one or two cultivars. For example, in 1995/96 Gungurru and Merrit were sown on 87% of the state's lupin area. By contrast, Cadoux and Spear together accounted for less than 30% of the wheat area, and the 11 most popular wheat varieties accounted for 86% of the state's crop (1).

Since 1995 six new narrow-leafed lupin (NLL) cultivars have been released in Western Australia. Several have special characteristics potentially valuable in specific environments. Myallie (1995) and Tallerack (1997) have improved brown spot tolerance. Tallerack is also restricted-branching. Tanjil (1998) has improved anthracnose tolerance. Belara (1997) is early flowering and matures rapidly whereas Kalya (1996) matures more slowly. Wodjil (1997), a yellow lupin, is very tolerant of brown spot and high soil Al.

Early sowing (April or May) is crucial to successful lupin culture in Western Australia (2), but this requirement limits the applicability of lupins in seasons breaking after late May, close to 50% of all growing seasons. Early maturity has always been a goal of lupin breeders in Western Australia to ensure adaptation to our short growing season. Early maturing cultivars would be expected to be less sensitive to delayed sowing. Their performance relative to other cultivars should therefore improve in late breaking seasons.

The aim of this work was to study the genotype by environment (G?E) interactions of modern lupin cultivars grown in important lupin producing environments in WA. Particular attention was given to the sowing time component of environment to see if earlier maturity reduces sensitivity to delayed sowing.

Methods

Merrit, Myallie, Kalya, Tallerack, Belara and Tanjil NLL, and Wodjil yellow lupin, were sown on four different dates in 1998 at Mingenew, Wongan Hills, Merredin, Newdegate and Gibson in Western Australia's grain belt. The earliest sowing date was as close as possible to the break of the season, and subsequent times followed at roughly two-weekly intervals. In 1999 and 2000 the same cultivars, with the addition of Quilinock NLL, were again compared at the same locations at four sowing dates.

As well as grain yield, flowering date (FD) and maturity date (MD) were recorded. FD was when 50% of plants had at least one open flower on the main stem, and MD was when pods lost their green tinge and seeds became hard.

Grain yield data were combined in a single data set, which was analysed by fitting linear mixed models using ASREML. Year, Location, Sowing Time and Species were considered fixed factors while Cultivar and its interactions were considered random. We also estimated spatial trends within each trial (3). Sowing time response was modelled as a separate linear function of sowing date for each Year-Location combination (Model 1). Model 2 elaborated this by allowing random variation among NLL cultivars in the regression coefficients on sowing date.

Results

There was considerable variation in grain yield between locations and years as well as between genotypes. The yield of Belara, for example, varied from 0.37 t/ha at Newdegate when sown in June 2000, to 4.78 t/ha at Mingenew when sown in May 1999. Grain yield declined when sowing was delayed, described well by a linear function of sowing date. Most of the yield variation between genotypes was in the contrast between yellow and narrow-leafed lupins. However, there was also significant variation between NLL cultivars (Table 1), and a significant G?E interaction variance which, in total, was 1.9 times the genetic (cultivar) variance.

Table 1. Variance components (?100) for genetic and G?E effects. Model 1 does not allow variation between cultivars in the linear rate of yield decline with delayed sowing, whereas Model 2 does. The asterisk (*) denotes estimates that do not exceed their standard error. The estimate for the Cultivar?Sowing time variance component in Model 1 is equal to its standard error.

	Model 1		**Model 2**	
	Variance	% Total G?E	Variance	% Total G?E
Genetic				
Cultivar	1.77		1.81	
G?E				
Cultivar?Year	1.19	35.7	1.12	38.5
Cultivar?Location	0.45	13.5	0.43	14.8
Cultivar?Sowing time	0.08*	2.4	0*	0

Cult?Year?Location	0.84	25.5	0.84	28.9
Cult?Year?Sowing time	0.20	6.0	0.16	5.5
Cult?Year?Loc?Sowing time	0.57	17.1	0.36	12.4
Total G?E	3.33		2.91	

About 60% of the G?E variance was associated with years and years within locations. Only about a quarter was associated with sowing time in Model 1 and, when the rate of yield decline was allowed to vary between cultivars for each Year-Location combination (Model 2), this was reduced to about 18%. Year and location is therefore much more important in discriminating between cultivars than sowing time. Total G?E variance in Model 2 was about 13% less than in Model 1.

Despite being the earliest flowering cultivar, Belara had the highest rate of yield loss with delayed sowing, varying from 7.4 kg/ha/day at Gibson in 2000 to 39.9 kg/ha/day at Gibson in 1998. These extremes were due, in part, to the 1998 trial at Gibson being affected by waterlogging, and the 2000 trial by bean root maggot. The waterlogging in 1998 affected later times of sowing more, increasing the apparent rate of yield loss; and the bean root maggot in 2000 only affected the two earlier times of sowing, reducing the apparent rate of yield loss. Wodjil yellow lupin was less sensitive to delayed sowing than NLL. Its rate of yield loss varied from less than 0 to 25.6 kg/ha/day, again at Gibson in 1998. The rate of yield loss with delayed sowing for a particular cultivar at a particular location in a particular year was linearly related to its yield potential (Figure 1). Note that the graphs for Gibson in 1998 and 2000 lie outside the range in which all other Year-Location combinations lie.

Delaying sowing delays flowering in lupins which, in turn, truncates the reproductive growth period. In this study we defined reproductive duration (RD) as the time elapsing from FD to MD. Figure 2 shows that RD was linearly dependent on FD, with each day's delay in FD consistently shortening RD by 0.7 days. However, the intercept of the line varies considerably between years and locations. Within a single genotype there is a strong positive relationship between RD and grain yield (Figure 2 shows data for Belara). Here, too, there is a different relationship in different years and locations, but if a few obvious outliers are ignored, a single consistent relationship begins to emerge.

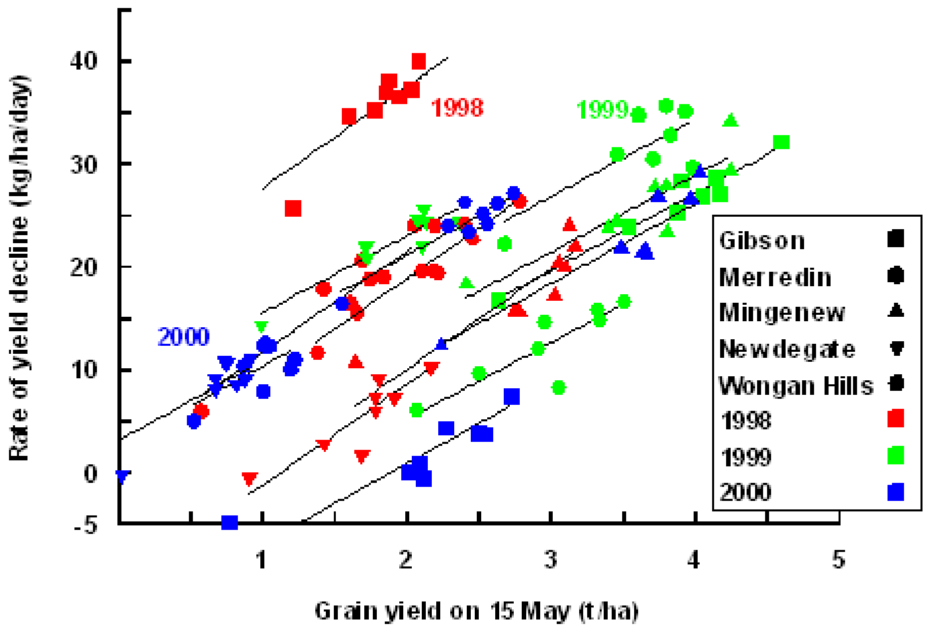

Figure 1. Dependence of rate of grain yield decline with delayed sowing on yield potential.

Discussion and conclusions

We detected considerable G?E interaction in lupins in WA, but Belara was consistently the highest, or almost highest, yielding cultivar so, if grain yield was the sole criterion for lupin variety choice, Belara would be universally applicable across the state. Of course, disease tolerance, particularly to anthracnose, is also important, and Tanjil will be chosen in some regions. Tanjil yielded relatively better in 1999 and at Wongan Hills and Mingenew.

Because sowing time did not change cultivar ranking, there is little prospect for improving lupin crop performance by choosing different cultivars to match sowing time from among the cultivars currently available. Belara, the earliest flowering cultivar in the study, surprisingly lost more yield with delayed sowing than other cultivars. Also, the penalty for delayed sowing in a particular environment was smaller, in general, when there was a low rather than a high yield potential. Both observations sprang from the relationship between the rate of yield decline with delayed sowing and yield potential. A consequence of this relationship is that profit maximisation will demand greater emphasis on getting the lupin crop in early in high than in low yield potential seasons. However, despite its sensitivity to delayed sowing, Belara is still better than other genotypes for late sowing because of its higher yield potential

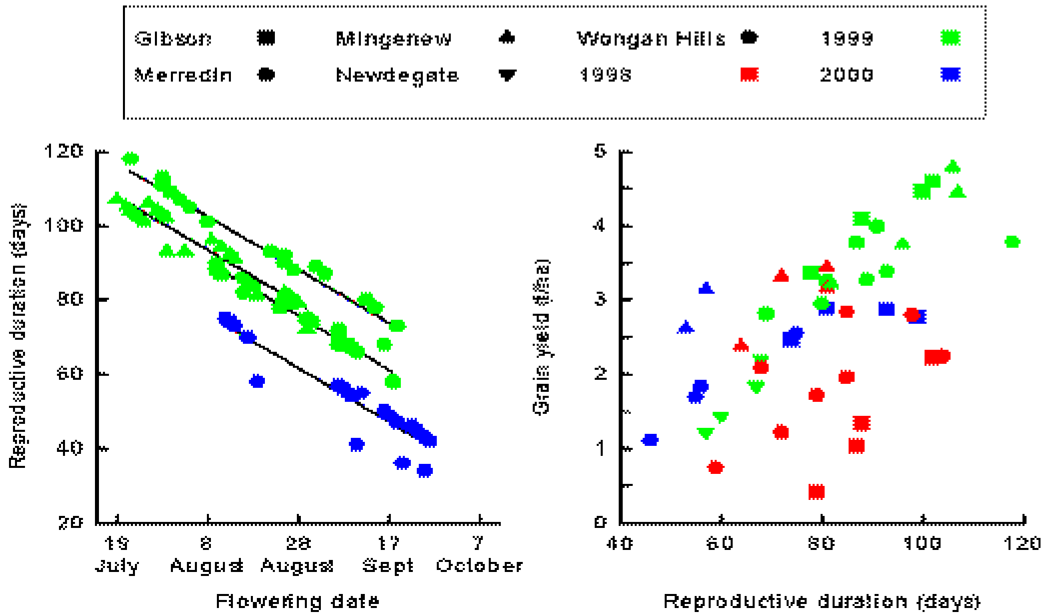

Figure 2. Dependence of reproductive duration on flowering date for lupins grown at Merredin and Mingenew in 1999, and at Wongan Hills in 1999 and 2000. Relationships between grain yield of Belara narrow-leafed lupin and reproductive duration.

We speculate that the unexpected sowing time response of Belara is due to its indeterminate reproductive pattern (4). Unlike the determinate cereals, lupins continue producing higher reproductive orders while resources for growth are still available. Fig. 2 shows that early flowering increases the time available to produce grain irrespective of sowing time. We show no data bearing on whether the efficiency of grain production during this time differs between genotypes, but the rate does not vary much within Belara. There is a suggestion in Fig. 2 that RD could be too long at Wongan Hills in 1999 and 2000.

References

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