MANAGEMENT OPTIONS TO INCREASE GRAIN PROTEIN CONTENT OF AUSTRALIAN SWEET WHITE LUPIN (*L. ANGUSTIFOLIUS*) IN WESTERN AUSTRALIA

Bob French[1], Pierre Fiévez[2] and Martin Harries[3]

[1]Department of Agriculture and Food, Western Australia, Dryland Research Institute, PO BOX 432, Merredin WA 6415; Australia and Centre for Legumes in Mediterranean Agriculture, University of Western Australia, Crawley WA 6009, Australia
[2]Pierre Fiévez and Associates, PO Box 3262, Broadway, Nedlands WA 6009, Australia
[3]Department of Agriculture and Food, Western Australia, Marine Terrace, Geraldton WA 6530, Australia

Corresponding author's email: bfrench@agric.wa.gov.au

ABSTRACT

It is desirable to raise the protein content of lupins produced in Western Australia because their value on the world market depends on their use as a protein source. We investigated the role the following aspects of lupin management could play in raising the production of lupin protein in Western Australia: sowing time, planting arrangement, weed competition, and crop nutrition. We do not explicitly address cultivar choice in this paper. Delaying sowing consistently led to increased grain protein concentration in lupin production environments in Western Australia and this did not vary among narrow-leafed lupin cultivars. However, it also led to even more consistent yield penalties so that delaying sowing reduced total protein yield per hectare. Increasing crop row spacing can lead to reduced protein, although it also often has no effect. As increased row spacing can give more stable grain yields in some environments it does not necessarily reduce total protein production per hectare.

High crop density sometimes has no effect on grain protein, but when it does have an effect it increases it. As high density also usually leads to high grain yields it also increases total protein production per hectare.

No effects of K, S or trace element nutrition were observed on grain protein. P application increased grain protein, but this was in a situation where yield was also very responsive so there is no evidence that supra-optimal rates of P increase protein production. Improving N nutrition during reproductive growth increased grain protein reasonably consistently, but when applied as a foliar spray it often reduced grain yield as well, so it rarely increased total protein yield. Applying extra N to the soil in such a way as its uptake by the crop was delayed also increased grain protein in a number of cases and also led to some increases in total protein production, but it is doubtful if any of these responses were economic.

We conclude that in order to maximise lupin protein production growers should manage their crops for maximum yield.

KEYWORDS

Lupinus angustifolius, grain protein, crop management, Western Australia

INTRODUCTION

Lupins exported from Western Australia are predominantly used as a source of protein in the manufacture of feed for livestock (Edwards and van Barneveld, 1998). In 2001 the Grain Pool of Western Australia began offering growers a premium for lupins with more than 32% protein as an incentive to produce higher protein grain. The ultimate objective was to raise the value of the state's lupin crop thereby improving returns to growers. In order to respond rationally to this incentive growers need to know how various environmental and management factors influence lupin grain protein. In this paper we ask what lupin growers can do to raise grain protein content.

Appropriate management to achieve high grain protein in wheat and other cereals is well understood. The 'high protein package' for wheat in Western Australia consists of appropriate selection of soils, rotation, cultivar, and sowing time as well as appropriate weed control and fertiliser management. These aspects of crop management are all potentially important in determining protein content in lupins but, because lupins are a leguminous crop, it is likely that their grain protein will respond differently to that of cereals.

There are significant and consistent differences between lupin cultivars in grain protein (Cowling and Tarr, 2004) but existing reports on the effects of other management variables on grain protein are inconsistent. For example, Jackson *et al.* (1986) found that delayed sowing increased grain protein in Queensland, Farrington (1974) found no effect in Western Australia,

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while Payne *et al.* (2004) found that it reduced lupin grain protein in Oregon, North America. This emphasises the need to conduct trials in the environment of interest before making recommendations to growers.

Appropriate use of fertiliser N is essential to the management of grain protein in wheat (e.g. Anderson *et al.* 1995). However, fertiliser N can stimulate grain yield at the expense of grain protein and it is not obvious that it will increase total N uptake by lupins, which derive as much as 97% of their requirements from symbiotic N_2 fixation (Unkovich *et al.* 1997), a process often suppressed by mineral N (Evans *et al.* 1987). Grain protein in wheat is more likely to respond positively to N fertiliser the later it is applied because when tillering and ear formation are complete the crop has limited capacity to respond by increasing yield (Fischer *et al.* 1993). In grain legumes N_2 fixation rates usually decline following flowering and are low during grain filling (Unkovich *et al.* 1994) when grain protein is being accumulated, so N applied at this stage would be less likely to suppress N_2 fixation and thus more likely to raise grain protein content.

Other mineral nutrients, because they affect lupin crop growth, could also potentially affect grain protein content. In particular, we thought S, Mo, and Co nutrition were likely to be important because S is an important component of lupin seed storage proteins and Mo and Co are essential for N_2 fixation.

In this paper we present the results of trials designed to test the effects of sowing time, crop density, row spacing and fertiliser management on lupin grain protein.

MATERIALS AND METHODS

FIELD TRIALS

We report the results from 35 field trials conducted in Western Australia from 2000 to 2006 covering agronomy and nutrition, summarised in Tables 1 and 2. All trials were conducted in cone seeder plots, and managed according to industry best practice, except where variation from normal management was part of the experimental treatment. Further details of treatments are given in the Results and Discussion.

MEASUREMENTS

All plots were harvested by self-propelled plot harvester to estimate grain yield. Sub samples of the harvested grain was retained for analysis. Seed protein was estimated either by NIR spectrometry or by multiplying seed N estimated by LECO combustion by 6.25. Protein content was adjusted to a 10% seed moisture basis for statistical analysis. Total protein yield was calculated from grain yield and seed protein.

STATISTICAL TREATMENT OF DATA

GENSTAT was used to statistically analyse the data. The analysis of variance model used for each trial had an appropriate error structure for the design of that particular trial. Pooled data sets were further explored using linear regression analysis. The significance of individual terms was assessed by comparing changes in sums of squares accounted for with the residual mean square in the model. Significance was assessed at the 5% probability level.

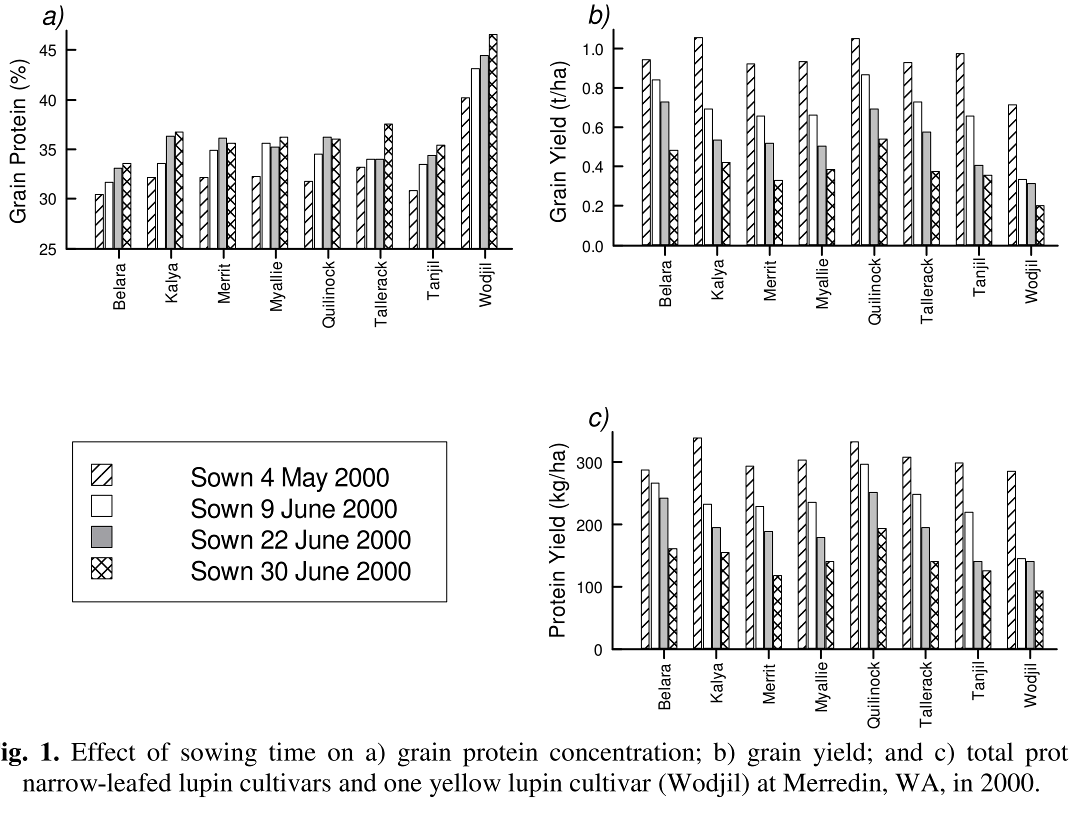

Fig. 1. Effect of sowing time on a) grain protein concentration; b) grain yield; and c) total protein yield of six narrow-leafed lupin cultivars and one yellow lupin cultivar (Wodjil) at Merredin, WA, in 2000.

RESULTS AND DISCUSSION

SOWING TIME

Delaying sowing produced higher grain protein in all but three trials where sowing time was a treatment. Typical responses, from Merredin in 2000, are shown in Figure 1. There were no significant cultivar × sowing time interactions in grain protein in any of the trials reported here. Differences between experimental sites show that there was considerable environmental variation in grain protein response to sowing time (Fig. 2). The average rate of grain protein gain as sowing was delayed was 0.057 %/day, but this varied from -0.001 %/day to 0.109 %/day.

Delaying sowing reduced grain yields (Fig. 1). The average rate of yield decline was 11.8 kg/ha/day, but this rate varied from 53.4 kg/ha/day to a yield gain of 17.2 kg/ha/day. Total protein production in kg/ha declined with delayed sowing at all sites except West Buntine in 2003 (Fig. 1 shows the response at Merredin in 2000).

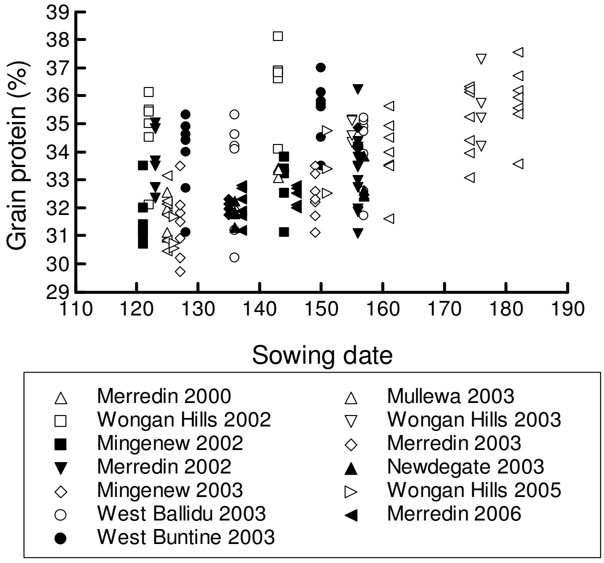

Fig. 2. Effect of sowing time on grain protein concentration in 13 Western Australian agronomy trials between 2000 and 2006. Within each trial there may be several cultivars or other agronomic treatments apart from sowing time; these are not distinguished in this figure.

CROP DENSITY AND ROW SPACING

Lupin grain protein responded to row spacing in 7 out of 16 trials. In all but one trial grain protein declined as spacing became wider. There were interactions between row spacing and sowing time or crop density in some experiments. At Wongan Hills and Newdegate in 2003 grain protein was higher in 50 cm than in 25 cm rows, but declined at wider spacing. There was no obvious pattern between protein and yield responses to row spacing. Some of these responses are shown in Figure 3.

Crop density had no effect on grain protein in trials in 2002 or 2003, when density ranged from 13 to 79 plants/m². In 2005 and 2006 density significantly affected grain protein in five out of six trials, with higher grain protein in denser crops (Fig. 4). At Merredin in 2006 grain protein was more responsive to crop density in 23 cm rows than in 50 cm rows, and at Wongan Hills grain protein was only responsive to density in the absence of competition from wild radish. The response of grain protein to crop density is potentially useful to growers because it almost never decreases with increasing density and yield usually increases (although grain protein does not consistently increase with increasing density). When site effects were removed each 1% increase in grain protein produced an extra 34.9 kg protein/ha on average. Grain yield was still the most important determinant of protein yield, though.

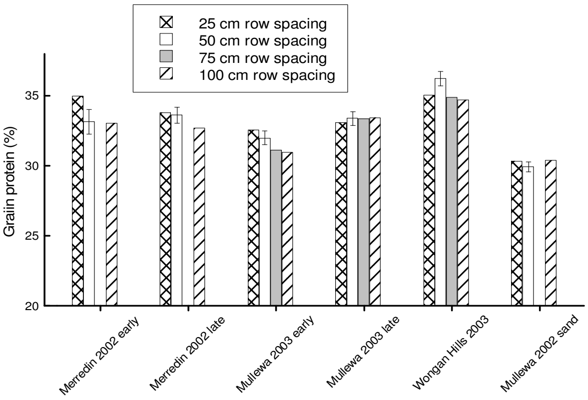

Fig. 3. Effect of row spacing on lupin grain protein concentration in 4 Western Australian agronomy trials in 2002 and 2003, showing examples of responsive and non-responsive sites. Vertical bars represent LSD at P = 0.05.

CROP NUTRITION: NUTRIENTS OTHER THAN N

There was no significant positive response of grain protein to the application of up to 120 kg/ha muriate of potash or up to 20 kg/ha S as superphosphate or gypsum. This was despite significant grain yield responses to K in about half of the trials and the S trial sites having been chosen for there low soil S status.

The trials at Mingenew, West Ballidu, and West Buntine in 2003 tested responses to 15 kg/ha P either drilled with the seed or deep banded 5-7 cm below the seed. Grain protein was greater in the P treatments at West Buntine and West Ballidu, but only responded to deep banding at West Buntine. However, grain yield also responded to P at each of these sites, and to deep banding. The five macro and micronutrient trials in 2002 and 2003 had Mo, Co, B, and Mn treatments singly and in various combinations. There were no significant grain protein or grain yield responses to any of these treatments.

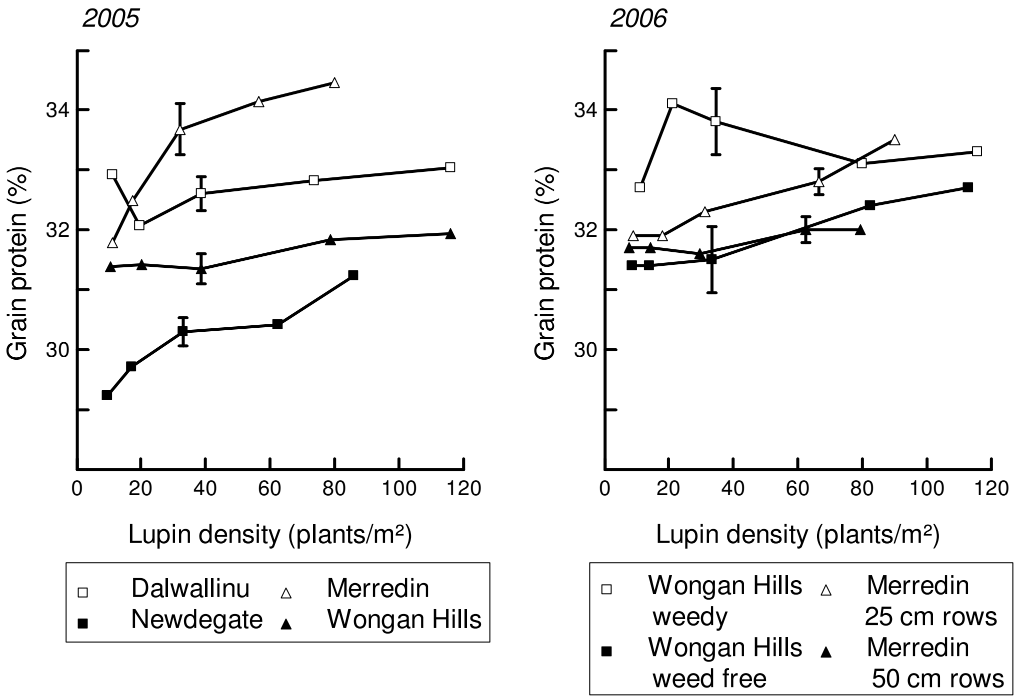

Fig. 4. Effect of crop density on lupin grain protein concentration in 6 Western Australian agronomy trials in 2005 and 2006. Vertical bars represent LSD at P = 0.05.

Crop nutrition: N

Our studies on N nutrition concentrated on N application during reproductive growth when grain protein is being laid down. Foliar N was applied at various stages from main stem flowering through to leaf drop. Applying N as Flexi-N, a concentrated solution of urea and ammonium nitrate, at rates of up to 50 kg N/ha raised grain protein concentration significantly in four of nine trials and had no effect in the other five. It depressed grain yield significantly in three out of nine trials and had no effect in the other six.

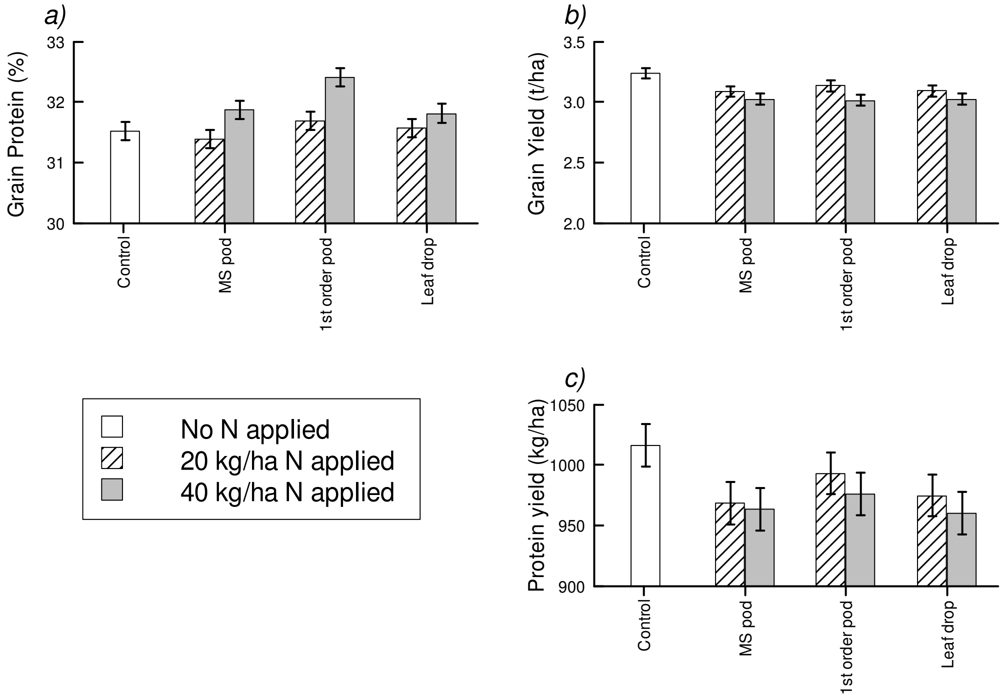

Fig. 5. Effect of foliar application of nitrogen to lupins on grain protein concentration, grain yield and protein yield at Mingenew in 2001. Figures are means of three cultivars: Belara, Kalya, and Tanjil. Vertical bars represent LSD at P = 0.05.

Figure 5 shows data from the most responsive site, at Mingenew in 2001. Here, foliar application of 40 kg N/ha increased grain protein by up to 0.9%, with the largest effect when applied during podding on 1st order branches. However, foliar N application also significantly reduced grain yield with the net effect that protein yield was reduced by N application. Foliar N application reduced total protein production in two out of six trials (total protein production was not calculated in the micro and macro nutrient trials for 2002), and had no effect in a further three. At Wongan Hills in 2001 application of 20 kg N/ha at main stem podding increased total protein production from 1116 to 1199 kg/ha.

We were not confident that foliar applied N was always absorbed efficiently, and it sometimes caused leaf burn that was probably responsible for the negative yield responses. In 2003 we investigated alternative means of supplying N to lupins during reproductive growth. We applied N as urea drilled between crop rows at sowing so that its uptake was delayed until crop roots reached it in the soil, as urea drilled between crop rows at flowering, or as a plastic-coated slow release formulation of urea drilled with the seed, below the seed, or between crop rows. The only treatment that significantly affected grain protein concentration was drilling 100 kg/ha urea halfway between 50 cm rows at seeding, which raised it from 35.2% to 37.0% at Merredin. However, this treatment did not significantly affect protein yield. 105 kg/ha (equivalent to 100 kg/ha urea) plastic-coated urea drilled halfway between crop rows, on the other hand, raised total protein yield from 374 to 435 kg/ha, due to enhanced grain yield. At Mingenew drilling plastic-coated urea between crop rows at sowing and drilling ordinary urea between crop rows at flowering both raised grain protein concentration from 32.9% to 33.9 and 33.8% respectively, but neither treatment had any significant effect on protein yield per hectare.

CONCLUSIONS

Grain protein in lupins responds to crop management but the responses are often unpredictable, small, and coupled with negative yield responses. The most consistent agronomic effect on grain protein is that of delayed sowing. Unfortunately the associated yield penalty more than offsets any protein advantage and total protein yield, which is what the grower is paid for, is reduced as sowing is delayed. Greater competition within the crop often leads to higher protein concentration. When this competition comes from other crop plants, as in dense crops, this is usually associated with higher yield and, in this case, it is worth managing to increase protein concentration.

Protein responses to nutrients other than nitrogen were small or non-existent. There is no scope to improve the protein content of the WA crop by changing the management of K, S, P or trace elements. We observed quite a few responses to N applied in such a way that it was taken up by the crop during reproductive growth. However, foliar application was often associated with a yield penalty and only one positive response was observed in total protein yield. Delaying uptake of soil applied N led to some positive responses but these didn’t usually translate into protein yield responses.

We recommend that WA growers continue to manage lupin crops for maximum yield in order to maximise total protein production per hectare. This includes sowing early at a high seed rate, controlling weeds, and ensuring good crop nutrition.

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Table 1. Summary of agronomy trials reported in this paper.

Year	Location	Treatments	Mean grain yield (t/ha)
2000	Merredin	4 sowing times × 8 cultivars	0.64
	Esperance	4 sowing times × 8 cultivars	2.46
2002	Wongan Hills	2 sowing times × 3 seed rates × 6 cultivars	0.42
	Mingenew	2 sowing times × 3 seed rates × 6 cultivars	2.78
	Merredin: clay loam	3 row spacings × 2 pre-season irrigations × 2 cultivars	0.19
	Merredin: sandy loam	3 row spacings × 2 pre-season irrigations × 2 cultivars	0.25
	Merredin: gravelly sand	3 row spacings × 2 pre-season irrigations × 2 cultivars × 2 sowing times	0.69
	Merredin: acid sand	3 row spacings × 2 pre-season irrigations × 2 cultivars	0.31
	Mullewa: loamy soil	3 row spacings × 2 pre-season irrigations × 2 cultivars	0.63
	Mullewa: sandy soil	3 row spacings × 2 pre-season irrigations × 2 cultivars	1.10
2003	Mingenew	2 sowing times × 2 seed rates × 7 cultivars	2.76
	West Ballidu	2 sowing times × 2 seed rates × 7 cultivars	2.27
	West Buntine	2 sowing times × 2 seed rates × 7 cultivars	1.25
	Mullewa	4 row spacings × 2 sowing times	1.25
	Wongan Hills	4 row spacings × 2 sowing times	1.06
	Merredin	4 row spacings × 2 sowing times	1.14
	Newdegate	4 row spacings × 2 sowing times	1.04
2005	Dalwallinu	2 row spacings × 5 crop densities	0.55
	Wongan Hills	2 row spacings × 5 crop densities	3.53
	Merredin	2 row spacings × 5 crop densities	1.03
	Newdegate	2 row spacings × 5 crop densities	1.74
	Wongan Hills	2 sowing dates × 4 wild radish densities × 3 cultivars	1.55
	Merredin	2 sowing dates × 4 wild radish densities × 3 cultivars	0.23
2006	Wongan Hills	2 wild radish densities × 3 row spacings × 5 crop densities	0.68
	Merredin	3 row spacings × 5 crop densities	1.02
	Merredin	2 sowing times × 2 annual ryegrass densities × 3 cultivars	1.10

Table 2. Summary of nutrition trials reported in this paper.

Year	Location	Treatments	Mean grain yield (t/ha)
2000	Merredin	3 application times × 2 rates of foliar N	0.42
2001	Mingenew	3 application times × 3 rates of foliar N × 3 cultivars	3.08
	Wongan Hills	3 application times × 3 rates of foliar N × 3 cultivars	3.73
	Merredin	3 application times × 3 rates of foliar N × 3 cultivars	2.15
	Kellerberrin	3 K rates × 7 cultivars	0.85
	Wongan Hills	3 K rates × 7 cultivars	1.90
	Eneabba site with no K history	3 K rates × 7 cultivars	1.90
	Eneabba site with previous K application	3 K rates × 7 cultivars	1.48
2002	Dandaragan	2 S rates × 8 cultivars	1.75
	Wongan Hills	19 macro and micronutrient treatments	0.53
	Mingenew	19 macro and micronutrient treatments	3.49
	Miling	19 macro and micronutrient treatments	0.50
2003	Dandaragan site with poor fertility	4 S rates × 4 cultivars	1.89
	Dandaragan site with good fertility	4 S rates × 4 cultivars	2.11
	Mingenew	9 macro and micronutrient treatments	
	West Ballidu	9 macro and micronutrient treatments	
	West Buntine	9 macro and micronutrient treatments	
	Mingenew	12 N application treatments with varying rates, forms and application times	1.97
	Merredin	12 N application treatments with varying rates, forms and application times	1.00