Potential for improvements in lupin yield on sandy alkaline soils

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Summary. Grain legume production on extensive areas of alkaline sandy soils in southern Australia is restricted due to the poor agronomic characteristics of many species and low yields achieved with current production systems. Experiments were conducted on the adaptation of lupin species to these soils and to develop techniques to increase grain production from the most extensively grown species, *Lupinus angustifolius.* No rhizobia strains were found to be superior to WU425 on alkaline soils. It was found that cultivars of *L. pilosus* and *L. atlanticus* yielded more than the narrow leaf lupin varieties when grown on alkaline soils. High numbers of *Bradyrhizobium lupini (>1000/g* soil) were found in all 19 soils sown only once with inoculated lupins 1-17 years previously. The addition of iron to these soils increased lupin dry matter production but not grain yield.

Introduction

Alkaline soils of light texture predominate in the Victorian and South Australian Malice and are widely distributed throughout the wheatbelt in New South Wales (1). A further 6 million hectares of alkaline soils are located in the extensive cropping areas of Western Australia (2). These soils are poorly suited to the production of narrow leaf lupins *(L. angustifolius)* as grain yield declines when soil pH increases (3). This is attributed to pH induced iron deficiency in the lupin (4).

Alternative grain legume crops, such as field peas, have good adaptation to alkaline soils but are agronomically unsuited to sands (2). Because lupins are the most effective crop for increasing the nitrogen status of the sandy soils with neutral to low pH (5) interest has been shown in developing a lupin variety/species that will produce the same benefits when grown on alkaline sandy soils (6). Consequently the potential yield of a range of *Lupinus* species on alkaline soils was determined. Because the productivity of *L. angustifolius* may be improved with a more effective strain of *B. lupini,* 3 strains of *B. lupini* were evaluated on *L. angustifolius* cv. Merrit. In addition, supplementation of nutrients rendered less available by high soil pH was evaluated.

Methods

The experiments were located at the Malice Research Station, Walpeup on sand - sandy loam soils with a surface pH exceeding 8.0 (H20) and an alkaline trend. Crop husbandry followed recommended practices for growing lupins in low rainfall areas (7). Plot size for the fertiliser and rhizobia experiments was 1.4 m (8 rows) x 17.5 m long. Treatments were arranged in a randomised complete block design with four replications. To minimise edge effects, sampling and harvest was confined to the central 6 rows. Seven weeks post-sowing and at mid-anthesis, 6 x 1.0 m lengths of row were sampled for crop density and dry matter production. At maturity grain yield was obtained with a plot harvester and grain weight measured from a sub-sample of the harvested grain. The following methods were specific to each of the four experiments described:

Experiment 1.

In 1992, on a calcareous soil (pH 8.7 at surface), two formulations of iron fertiliser (EDDHA chelate and sulphate) were sown at four rates (nil, 0.25, 0.50 and 1.00 kg Fe/ha), as a deep band under *L. angustifolius* (cv. Merrit). In order to ensure that deficiencies of other nutrients did not limit iron uptake, these treatments were applied with and without the addition of potassium (12 kg K/ha), sulphur (8.0 kg S/ha) and zinc (2.0 kg Zn/ha). In addition phosphorus (18 kg P/ha) and sulphur (8.5 kg S/ha) were applied to all plots.

Experiment 2.

The productivity of six lupin species (Table I) was evaluated, over 3 seasons, on an alkaline sandy loam soil. Plot size was 0.53 m (3 rows) x 5 m long in 1990 and 1991 and 3 rows x 10 m in 1992. The plots were arranged in a randomised complete block design with two replications in 1991 and 1992. In 1990 replication was not possible due to seed limitations. The grain was hand harvested and included assessments of shattering losses in 1990 and 1991. The shattering loss was the amount of grain collected from the ground compared to that remaining on the plant. The seed was harvested when mature (before shattering occurred) in 1992 and dried to a standard moisture content (12%) before the yield was recorded.

Experiment 3.

The lupin cultivar Merrit was either inoculated with one of three *Bradyrhizobium* strains (WU425, 606A and 6068) or uninoculated and sown in a alkaline sandy loam soil. The soil had no previous history of inoculum application or lupin production and was shown, using dilution series (8), to have very low numbers of naturally-occurring *B. lupini.* A lupin nodulation score was determined, at 8 weeks and at late anthesis, from 10 plants selected at random from each plot. Dry matter production was measured at late anthesis.

Experiment 4.

Rhizobial persistence in alkaline sandy soils was assessed in a glasshouse experiment. Three lupin plants (cv. Merrit) were grown in each 15 cm diameter pot with fertiliser added to supply all macro-nutrients except nitrogen. Soil used in the pots was collected from 19 field sites where *B. lupini* (strain WU425) had been applied once to the only *L. angustifolius* crop grown within the range of one to seventeen years prior to the experiment. The soil from each site was placed into 8 pots. 4 of which received no added inoculum while strain WU425 was added to the other four. Each pot was one replication of the completely randomised experiment. The *Bradyrhizobium* strains present in the soil and their abundance when collected for the experiment were determined using a dilution series (8). At late anthesis the lupin plants were scored for nodule formation on the roots and an isolation made for identification of the infective strain. Lupin dry matter production at late anthesis was also measured, by oven drying plant shoots at 105? for 48 hours.

Results

Experiment 1.

Plant density six weeks post-sowing and at anthesis was unaffected by the rate or form of iron applied. Lupin plant density for all treatments at 7 weeks averaged 34.7 plants/m^2 and ranged from 31.0 - 41.9, (l.s.d. (P = 0.05) = 8.3). Dry matter production at anthesis (Fig. l) was greatest when 0.25 kg/ha of iron was applied as the chelate form. This rate of iron chelate, in combination with additional potassium, sulphur and zinc had the greatest dry matter production (2600 kg/ha) compared with no additional nutrients (2160 Kg/ha). All other treatments produced less than 2060 kg/ha of lupin dry matter at anthesis, which was significantly less (P=0.05) than 2600 kg/ha.

The fertiliser treatments had no significant effect on grain yield (range of 1.89 - 2.22 t/ha; I.s.d. P(0.05)=0.35) although plots fertilised with ferric sulphate consistently yielded more than those treated with iron chelate or no iron.

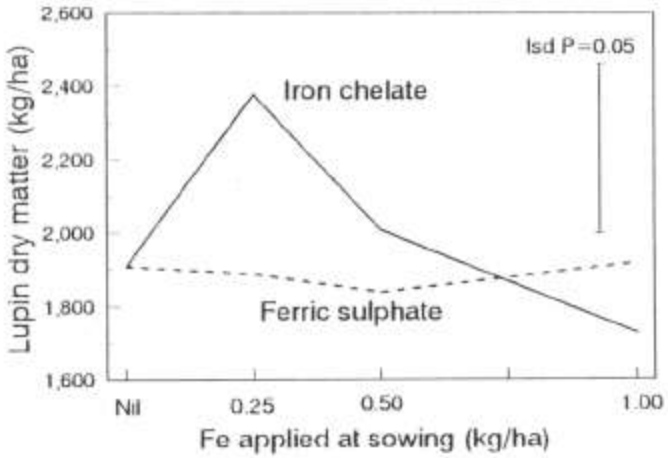

Figure 1. Lupin dry matter production at anthesis

Experiment 2.

The grain yield of some lines of the six lupin species evaluated is presented in Table I. Many of these lines are rough seeded wild types which had pods that shatter when allowed to ripen on the plants. None of the *L. atlanticus* cultivars tested had shattering losses of <40%. Some *L. pilosus* lines had losses below 22% in both years and the *L. angustifolius* and *L. luteus* cultivars lost less than 10% of seed due to shattering. Grain weights of many species exceeded that of *L. angustifolius.* The largest grain weight was 0.8 g/seed, for a line of *L. pilosus,* not included in Table I.

Table I. Grain yield. grain weights and shattering losses of lines of six lupin species grown in three seasons on alkaline soils at Walpeup.

Species	Line	Yield 1990 (t/ha)	Yield 1991 (t/ha)	Yield 1992 (t/ha)	Yield ave. 91-92 (%)	Grain wt. 1992 (g)	Shatter loss 90-91 (%)
L. angustifolius	Gungurru	-	0.67	1.52	100	0.11	<5
L. atlanticus	P22918	2.47	0.73	0.87	97	0.33	82
	P22927	-	0.72	1.52		0.56	
	AM-318	2.13	0.72	1.22	95	0.22	63
L. pilosus	P23030	1.77	0.59	1.72	93	0.40	80
	P23340	3.08	0.93	1.57	126	0.55	18
	P23342	-	1.03	1.05		0.56	
L. albus	Kiev mut.	-	-	3.24		0.25	
L. cosentinii	Erregulla	0.61	0.26	0.93	42	0.14	24
L. luteus	Motiv369	2.47	-	1.09		0.13	
	R-1171	1.28	-	0.94		0.11	
l.s.d. (P=0.05)		N.A.	0.27	0.68		11.2	

Experiment 3.

The recommended commercial lupin inoculum (strain WU425) and strain 60613 resulted in better early nodule development and grain yield than either strain 606A or the uninoculated control (Table 2).

Table 2. The nodule development. dry matter production and grain yield response of *L. angustifolius* when four inoculation treatments were applied to the seed.

Rhizobium strain	Nodulation, 8 weeks (score 0-5)	Nodulation, anthesis (score 0-5)	Dry matter anthesis (g/plant)	Grain yield (t/ha)	Grain weight (g/100)
WU425	1.49	1.98	11.4	2.54	14.3
606A	0.43	2.14	9.52	2.16	14.6
606B	1.06	2.06	9.74	2.62	14.7
nil	0.17	1.10	9.80	2.22	14.1
l.s.d. (P=0.05)	0.55	0.61	n.s.	0.30	n.s.

Experiment 4.

The population of *B. lupini* exceeded 1000/g in all soils examined and there was no correlation between the population size and time since lupins were grown at the location. At anthesis lupin dry matter production from pots in which the soil was inoculated at sowing was 113 - 83% of that of plants from uninoculated pots. Inoculation did not increase nodulation. The identity of the strains of rhizobia present in the soil is currently under examination.

Discussion

Rainfall during the May - November growing season at Walpeup in 1992 was 50% (110 mm) above the long term average. Although the addition of iron chelate increased dry matter measured at anthesis, it did not result in higher yield. Increased iron mobility in the soil, as a consequence of the very wet spring, may have supplied sufficient nutrient to the plant during grain filling. Lines of *L. pilosus* and *L. allamicus* that outyielded *L. angustifolius,* when grown on alkaline soils, were identified and warrant further investigation. The *Bradyrhizobium* strain currently used with *L. angustifolius* is not the cause of poor production on alkaline sands. The need to inoculate each lupin crop sown will be negated if current work confirms that WU425 is the strain persisting on these soils. Its suitability for other lupin species remains to be determined.

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