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Raingrown and irrigated lupins in the Callide Valley, Queensland

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Summary

Genotypes of the three *Lupinus* spp. *L. albus*, *L. angustifolius* and *L. cosentinii* were tested for seed yield and other agronomic characters in raingrown and irrigated trials in an alluvial cracking clay over three years in the Callide Valley, central Queensland.

Raingrown production ranged from 267 kg/ha in a dry year to 3188 kg/ha in a wet year. Low yields in the two dry years were attributed to an interaction between low rainfall and high temperatures after commencement of flowering in August. As this is the normal climatic pattern for the Callide Valley. Raingrown production is not recommended.

L. albus genotypes were the most successful under irrigation with the better ones producing yields averaging in excess of 3000 kg/ha. No genotype outyielded ($P < 0.05$) either Ultra or Kiev Mutant both of which have been released commercially; these two cultivars were also amongst the highest producers of seed protein.

INTRODUCTION

Since the early 1970s, lupins of the *L. angustifolius* and *L. albus* species have been grown successfully as a raingrown, winter, grain legume in southern New South Wales (Corbin 1978), Victoria (Reeves 1974), Tasmania (Garside 1977), South Australia (Coleman *et al.* 1974) and southern Western Australia (Gladstones 1980). In Queensland, the crop has demonstrated potential under raingrown conditions in the South Burnett (Hodge 1978), but with variable success on the Darling Downs (B.D. Hall, pers. comm. 1984). Irrigated trials in Queensland have been successful on the Darling Downs (Hall 1978), in the Callide Valley (Jackson *et al.* 1980) and on the Atherton Tableland (D. Younger, pers. comm. 1984).

The performance of lupins in irrigated trials, their benefits in rotations (Boundy 1978) and their on farm use in pig and poultry rations have maintained interest in this crop. Since irrigation supplies are limited to certain areas of the Callide Valley region and information on raingrown lupins was unavailable in the area, this study was undertaken to evaluate a number of genotypes under raingrown and irrigated conditions in this region.

MATERIALS AND METHODS

Experimental design

Adjacent irrigated and raingrown trials each having three replicates in a randomised block design were planted at Biloela Research Station(24° 24′S, 15°30′E, 173 m above sea level) in the Callide Valley, central Queensland in 1978, 1979 and 1980 on a highly fertile alluvial cracking clay (Ug 5.15, Northcote 1971). Climatic data for the trial periods in these years are given in Table 1. Eight row plots 8 m long and 0.18 m between rows were hand thinned to 25 plants/m^2 (irrigated trials) and 10 plants/m^2 (raingrown trials) two weeks after emergence.

Genotypes and cultural methods

Trials were planted at a similar time in each of the three years (Table 1) using genotypes of *L. albus*, *L. angustifolius* and *L. cosentinii* (Table 2). The same genotypes were grown in raingrown and irrigated trials but not necessarily across years. Two *L. albus* genotypes in the 1978 trials were discontinued because of high akaloid levels (CPI 31620) or duplication (Kiev). The latter genotype was confirmed as being the same as that received as Kiev Mutant (R. Oram, pers. comm. 1984). Additional genotypes were added in 1979 and 1980 as they became available for testing.

Table 1. Climatic data at Biloela Research Station and sowing and harvest dates for the experimental period

Month	Years											
	Mean daily max temp (°C)				Mean daily min temp (°C)				Total rainfall (mm)			
	1978	1979	1980	LTA*	1978	1979	1980	LTA	1978	1979	1980	LTA
May	24.0	25.1	27.1	25.2	10.9	8.8	12.6	9.4	64.2	11.6	44.8	37.9
June	20.4	24.2	23.5	22.1	6.7	7.7	6.5	6.3	65.6	24.8	3.7	37.2
July	21.1	23.0	22.5	21.8	6.0	4.8	3.7	4.9	106.6	1.4	19.0	30.7
August	21.3	24.8	23.0	23.3	7.4	4.9	6.2	5.2	48.6	12.0	6.0	21.2
September	24.2	28.2	30.4	26.9	9.8	10.3	7.6	8.4	69.4	0.4	0.0	23.0
October	27.0	30.6	31.7	29.7	11.2	14.2	15.7	13.1	6.2	10.4	34.4	51.7
November	28.9	32.3	33.6	31.7	16.4	18.1	16.6	16.3	239.9	95.0	16.3	81.0
Sowing date	29 May 78				1 Jun 79				5 Jun 80			
Harvest date	13 Nov 78				31 Oct 79				5 Nov 80			

* Long term average – 56 years.

Table 2. Species, names and origin of genotypes evaluated at Biloela Research Station during the period 1979–80

Species	Name	Origin
Lupinus albus	CPI 31620	Bulgaria
	CPI 47643	Ukraine
	CPI 56600*	Ukraine
	CPI 57216 S†	Ukraine
	Kiev Mutant‡	Ukraine
	Kiev Skorospely*	Ukraine
	Ultra‡	W. Germany
	Ultra S1§	QDPI
	Ultra S6§	QDPI
	C77¶	CSIRO, ACT
	CW77¶	CSIRO, ACT
	W77¶	CSIRO, ACT
	(3×4)5S¶	CSIRO, ACT
	(2×8)5S¶	CSIRO, ACT
	(12×1)2S¶	CSIRO, ACT
	(2×8)5¶	CSIRO, ACT
	(12×8)1¶	CSIRO, ACT
Lupinus angustifolius	Unicrop‡	WADA
	Illyarrie‡	WADA
	72 A14-4	WADA
	P21255	WADA
	P22612	WADA
Lupinus cosentinii	CB 48	WADA

* 56600 and Kiev Skorospely originally the same line but outcrossing within Australia has resulted in their being treated as two different lines in this study.

†57216 S is a CSIRO selection within 57216.

‡Cultivar registered in Australia by Western Australia Department of Agriculture (WADA).

§Queensland Department of Primary Industries early selection from Ultra.

¶CSIRO crossbred selection.

Plots were sown with a cone planter. All seed was inoculated with commercial peat inoculum (*Rhizobium* strain WU425). Seed of CB48 was acid treated to remove hardseededness (Horn and Hill 1974). No herbicides or fertilisers were applied.

Irrigation and moisture usage

One irrigation was applied at commencement of flowering in 1978. In 1979, the first irrigation (50 mm) was 8 weeks after planting (bud visible on main stem of Ultra) and 5 weeks after planting in the 1980 trial. Further irrigations were in 1979 and 1980 when a water deficit of 50 mm had been accummulated (summation of 0.8 daily pan evaporation minus rainfall). Irrigation applications were continued until the end of flowering in Ultra. All irrigations were as sprays. Gravimetric soil moistures were measured to 180 cm at emergence, 50% flowering of main stem racemes and maturity in each plot of Ultra in the irrigated and raingrown trials.

Phenology and plant height

The periods between emergence, flowering and maturity, and duration of flowering were recorded for all genotypes in all years. Flowering was measured from the appearance of a flower on the main stem of 50% of plants to 95% completion of flowering on all plants. Maturity was determined as fawn colouration of 95% of pods. The heights of 3 plants per plot were measured at maturity.

Seed yield, weight and protein

Seed was harvested from a 6 m length of each plot with a Seedmaster experimental plot harvester and weighed. Individual seed weights were determined by weighing two, 200 seed samples per plot. Nitrogen determinations were carried out by the Kjeldahl method on a bulked sample of three replicates in each trial and converted to protein percentage by multiplying by 6.25.

Lodging and shattering characteristics

Plants angled at 45° or more from the upright position at harvest were considered to be lodged. Lodging was rated on a scale 0 to 3 with 0=nil, 1=0 to 10%, 2=10 to 20% and 3=20 to 30%. Shattering was recorded as either present (+) or absent (−).

Statistical analysis

Data were analysed separately for raingrown and irrigated experiments. The analysis of variance technique was used to test for differences among genotypes for individual experiments and for experiments with data combined over years. The protected least significant difference procedure was used to compare means at the (P = 0.05) level of significance. In the combined analysis of variance model, the pooled error mean square was used as the denominator for the F-tests of the fixed effect of years and of varieties (McIntosh 1983).

Plant height data of the nine genotypes common to each of the irrigated and rainfed trial series was pooled for a combined analysis of variance. The analysis was rejected on the basis of Bartlett's test of homogeneity of error variances. Data for seed weight of the nine common genotypes in each of the 3 years in the irrigated trials and for seed yield and seed weight in the raingrown trials could not be pooled over years, either on the basis of Bartlett's test or because of significant ($P < 0.05$) genotype × year interactions.

RESULTS

Phenology and plant height

The growth cycles of CB 48 (*L. cosentinii*), Unicrop (*L. angustifolius*) and Ultra (*L. albus*) were selected as representatives of the three species. Because of the similarity in the growth cycles of individual genotypes in the 1979 and 1980 seasons, phenology data for 1979 only is contrasted with the 1978 data for raingrown and irrigated trials in Figure 1. The main feature observed was the longer flowering period of the *L. albus* and *L.*

angustifolius genotypes in 1978. The effect was not so marked for *L. cosentinii.* Irrigation had little effect on duration of flowering in either season.

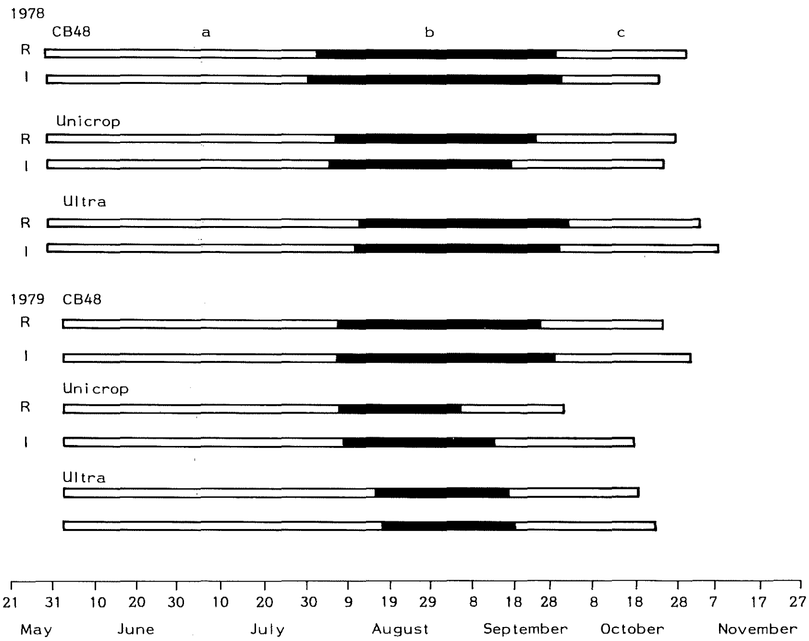

Figure 1. Duration of the periods: a, sowing to flowering; b, flowering and c, flowering to maturity in raingrown (R) and irrigated (I) trials for genotypes CB48 (*L. cosentinii*), Unicorp (*L. angustifolius*) and Ultra (*L. albus*) in 1978 and 1979 at Biloela Research Station.

Height differences ($P < 0.05$) among *L. albus* and *L. angustifolius* genotypes were measured in the irrigated trials (Table 3) and raingrown trials (Table 4). The height differences among species in the irrigated trials were not as evident in the raingrown trials.

Seed yield, weight and protein

Individual trial data for these characters are presented in Table 3 (irrigated) and Table 4 (raingrown). In the irrigated trials *L. albus* genotypes consistently outyielded ($P < 0.05$) those of the other two species.

Yield differences ($P < 0.05$) among species were not consistent in the raingrown trials. *L. albus* produced highest yields in those years when rainfall during the growing season was above average (1978) and average (1980). In 1979 when growing season rainfall was below average, *L. angustifolius* produced highest yields.

Weight of seed was associated primarily with species, *L. albus* having the largest seeds followed by *L. cosentinii* and *L. angustifolius.* In the irrigated trials seed weight was generally less in 1978 and 1980 than in 1979 while in the raingrown trials the reverse occurred. Differences ($P < 0.05$) were apparent among *L. albus* and *L. angustifolius* genotypes in the irrigated and the raingrown trials.

Protein contents were highest in *L. albus* with *L. angustifolius* having similar values to *L. cosentinii* except in one raingrown trial where the latter was noticeably lower. Generally, higher protein contents were recorded in the raingrown trials than in the irrigated trials for *L. albus* and *L. angustifolius.* The protein levels were similar in the *L. cosentinii* genotype for all trials.

Table 3. Yield, protein content, seed weight (expressed as 12% moisture content) plant height and lodging rating of irrigated lupin genotypes grown at Biloela Research Station 1978–80

Species/ genotype	Lodging rating*			Height (cm)			Seed wt (mg/seed)			Protein content (%)			Seed yld (kg/ha)			
	1978	1979	1980	1978	1979	1980	1978	1979	1980	1978	1979	1980	1978	1979	1980	Mean
L. albus																
CPI47463	2	0	3	92	81	124	332	362	340	31.4	31.2	31.5	4732	2793	2979	3501
CPI56600	3	1	2	98	74	113	319	352	337	32.6	31.6	32.7	4278	2238	2798	3104
Ultra	2	1	2	99	85	120	327	347	348	33.0	32.2	32.3	4237	2750	3102	3363
(2×8)5	2	1	2	106	85	119	348	373	328	33.0	30.6	30.5	4129	2602	3292	3342
CPI31620	3	–	–	105	–	–	297	–	–	34.7	–	–	4061	–	–	–
(12×8)1	2	1	2	102	90	130	362	379	347	33.0	31.5	31.4	4048	2757	3325	3377
Kiev Mutant	2	0	2	91	68	106	310	382	342	31.2	32.2	34.8	4034	2710	2732	3159
Kiev	2	–	–	96	–	–	305	–	–	33.2	–	–	3909	–	–	
Kiev Skorospely	2	1	3	93	91	117	305	355	326	34.4	31.5	31.9	3660	2890	3216	3255
Ultra Selection 1	–1†	3	–	83	112	–	344	316	–	31.7	31.9	–	3148	2555	–	–
(3×4)5S	–	2	3	–	94	122	–	296	268	–	31.3	34.1	–	2356	2386	–
CPI57216S	–	1	3	–	103	126	–	344	310	–	30.9	32.0	–	2345	2655	–
(2×8)5S	–	2	2	–	93	124	–	313	300	–	32.0	34.7	–	2337	2963	–
W77	–	1	3	–	89	120	–	319	287	–	32.2	31.5	–	2327	2943	–
(12×1)2S	–	1	2	–	96	131	–	351	312	–	31.7	30.3	–	2304	2983	–
C77	–	2	2	–	104	124	–	316	278	–	32.0	35.9	–	2219	2854	–
CW77	–	0	3	–	86	119	–	312	282	–	32.5	31.5	–	1965	2835	–
Ultra Selection 6	–	–	3	–	–	113	–	–	318	–	–	31.8	–	–	2630	–
L. angustifolius																
P22612	–	0	2	–	64	82	–	171	163	–	27.3	30.1	–	2235	2243	–
72A14-4	–	0	2	–	69	82	–	161	146	–	27.9	27.5	–	2198	1943	–
Unicrop	2	0	2	94	61	88	166	172	151	29.2	27.0	29.5	2919	2126	1815	2287
Illyarrie	–	0	2	–	58	82	–	166	145	–	28.7	30.8	–	1740	1708	–
P21255	–	0	2	–	76	93	–	171	134	–	27.7	28.9	–	1446	1575	–
L. cosentini																
CB48	1	0	1	61	52	88	214	226	245	29.2	28.0	29.9	2914	1311	1805	2010
Mean	2.09	0.71	2.32	94	81	111	298.6	295.7	273.8	32.2	30.5	31.6	3902	2324	2606	3044
l.s.d (P=0.05)	n.a.	n.a.	n.a.	17	15	9	21	22	26	n.a.	n.a.	n.a.	674	525	541	357

* Lodging rating 0=nil 1=0–10% 2=10–20% 3=20–30% †not included ‡not available

Lodging and shattering

Lodging only occurred in the irrigated trials being particularly extensive in the 1978 and 1980 trials (Table 4). *L. albus* genotypes were most susceptible and all received either a 2 or 3 rating in these two years.

Pod shattering was only recorded in the 1979 irrigated trials and occurred in Illyarrie and P22612, when 10 to 20% shattering was observed in both genotypes.

Seasonal effects

Well above average winter rainfall, lower mean daily maximum temperatures and higher mean daily minimum temperatures distinguished the 1978 season from the 1979 and 1980 seasons (Table 1). Temperatures and rainfall in the 1979 and 1980 seasons were typical of the long term climatic pattern in which the winter and spring rainfall are unreliable. Consequently, plant development and yield results recorded in the latter two seasons would be more representative of the long term performance of lupins in this environment.

Water use efficiency

Water use efficiencies were calculated for seed yield in cv. Ultra in the raingrown and irrigated trials in 1979 and 1980 (Table 5), but not in other trials because of excessive flooding.

In the irrigated trials water extraction was evident to a depth of 160 cm and in the raingrown trials to 130 cm.

Table 4. Yield, protein content, seed weight (expressed at 12% moisture content) and plant height of raingrown lupin genotypes grown at Biloela Research Station 1978–80

Species/ genotype	Height (cm)			Seed wt (mg/seed)			Protein content (%)			Seed yld (kg/ha)		
	1978	1979	1980	1978	1979	1980	1978	1979	1980	1978	1979	1980
L. albus												
CPI56600	86.3	43.0	57.0	302	246	270	33.4	34.1	37.6	3984	328	1057
Kiev Mutant	74.8	43.7	57.0	298	254	265	33.7	34.5	35.4	3886	287	1182
Ultra	77.3	38.3	53.0	295	250	248	33.2	35.3	36.7	3709	258	812
Kiev	77.6	–	–	296	–	–	33.5	–	–	3651	–	–
CPI47463	76.5	42.3	51.0	284	251	273	34.5	34.5	36.7	3416	236	883
(12×8)1	88.1	41.3	54.7	334	248	308	33.9	32.9	38.4	3310	211	1001
Kiev Skorospely	74.5	43.7	53.3	294	241	275	33.7	36.7	36.0	3283	271	1085
CPI31620	82.4	–	–	266	–	–	33.6	–	–	3194	–	–
(2×8)5	86.1	42.3	57.3	298	249	276	33.7	33.7	33.3	2609	278	1224
(2×8)5S	–*	43.7	55.3	–	220	245	–	33.9	36.3	–	285	983
(3×4)5S	–	42.0	56.3	–	225	236	–	35.7	38.8	–	226	963
CPI57216S	–	42.7	56.7	–	236	269	–	31.3	34.7	–	216	889
CW77	–	42.7	58.3	–	229	249	–	34.3	35.1	–	203	989
(12×1)2S	–	38.0	61.7	–	245	284	–	32.7	37.0	–	197	913
Ultra Selection 1	–	38.3	52.0	–	239	258	–	36.5	36.7	–	192	850
W77	–	35.7	52.7	–	218	263	–	34.6	38.1	–	161	665
C77	–	40.6	57.3	–	218	256	–	35.8	36.7	–	128	782
Ultra Selection 6	–	–	53.0	–	–	260	–	–	38.4	–	–	784
L. angustifolius												
P22612	–	41.3	44.7	–	118	126	–	31.6	37.8	–	465	395
Unicrop	43.0	47.7	30.0	147	116	117	26.9	34.0	-	2370	462	488
Illyarrie	–	46.0	55.3	–	117	123	–	32.1	32.1	–	453	869
72A14-4	–	45.7	51.3	–	114	117	–	32.6	32.7	–	402	599
P21255	–	40.0	47.0	–	117	97	–	32.6	34.5	–	72	126
L. cosentini												
CB48	49.4	40.0	52.0	210	244	225	28.4	27.4	29.8	1659	299	879
Mean	78.0	42.0	54.0	274.9	209.3	229.1	32.9	33.3	35.8	3188	267	833
l.s.d. (P=0.05)	13.7	4.9	8.0	12.5	18.5	40	n.a.†	n.a.	n.a.	623	102	359

* Not included † Not available

Table 5. Water use efficiency values for raingrown and irrigated lupins (cv. Ultra) grown at Biloela Research Station

Year	Water use efficiency (kg/mm/ha)	
	Raingrown	Irrigated
1979	1.97	7.83
1980	6.06	7.33

DISCUSSION

In the Callide Valley severe frosts (screen temperatures below −3.0°C) can occur in July and early August. These temperatures have caused heavy damage in *L. albus* and *L. angustifolius* when they occur during pod set and pod filling (Jackson and Berthelsen 1984). To minimise frost damage to young reproductive growth, sowings should be made so that flowering does not commence until at least the beginning of August. This means, however, that most flowering and pod filling occurs in late August and September during a period over which daily maximum temperatures usually rise rapidly and the probability of rainfall is at its lowest.

The importance of moisture availability from flowering onwards has been demonstrated in *L. angustifolius* by Stoker (1975) and in *L. albus* by Withers (1979). High temperatures also accelerate soil moisture deficits and appear to be important in their own right. In *L. angustifolius* high temperatures (generally above 25°C) at flowering reduce pod set (Downes and Gladstones 1984*a*) and after flowering further reduce seed yield (Downes and Gladstones 1984*b*). In 1978 the above average rainfall and below average maximum temperatures in spring resembled the growing season in southern Australia and successful raingrown production was achieved. Lower yields in raingrown trials in 1979 and 1980 were attributed to the interaction between low rainfall and high maximum spring temperatures (Table 1). Since the latter conditions are more typical of late winter and early spring in the Callide Valley, raingrown production can not be recommended.

Irrigated production was successful in each of the three years. Yield differences between the raingrown and irrigated trials are mainly attributed to the difference in water availability at flowering and pod filling. *L. albus* had the highest seed yields and also the highest protein levels. Yields of the two released cultivars Ultra (Anon. 1977) and Kiev Mutant (Anon. 1982) were not exceeded ($P < 0.05$) in any of the irrigated trials. Both produced high levels of protein. CPI 47463 and the CSIRO crossbreds (2 × 8)5 and (12 × 8)1 also demonstrated high yielding ability.

Water use efficiency figures for irrigated and raingrown seed yield of Ultra (Table 5) are similar to the average figure (6.5 kg/mm/ha) measured for raingrown Unicrop in south-west Western Australia by Anderson (1980). The exception is the low water use efficiency of 1.9 kg/mm/ha in the 1979 raingrown trial when high temperatures and moisture stress probably caused a high level of pod abortion. In comparison the average water use efficiency for wheat (1971 to 1973 inclusive) was 9.1 kg/mm/ha in the Callide Valley under raingrown conditions (Thomas and Ladewig 1983).

In the raingrown trials, differences in seed weight and plant weights from year to year were largely a reflection of the amount and timing of rainfall. Rainfall prior to flowering increased plant height and rainfall during flowering increased seed weight. Higher protein levels in the 1980 raingrown trial may have resulted from higher available nitrogen at the particular trial site.

Reduced seed weight on taller plants in the 1980 irrigated trial was attributed to irrigation timing. The first irrigation was early in the vegetative stage and caused rapid elongation of the plants. The final irrigation was applied during pod filling, causing lodging particularly in *L. albus*. Stem damage resulting from severe lodging may have been responsible for the reduction in seed weight.

Stoker (1975) demonstrated in New Zealand that no benefit was obtained by irrigating *L. angustifolius* prior to flowering. In contrast Whithers and Forde (1979) using cv. Ultra in controlled environment studies found water stress during various growth stages from floral initiation to the end of second order lateral flowering, reduced seed yield by between 43% and 72% compared with non-stressed plants. Further research is warranted to determine optimum irrigation scheduling in *L. albus*. Methods of irrigation application should also be investigated to reduce the chance of lodging.

Overall these trials have demonstrated that *L. albus* is superior to *L. angustifolius* in this region. *L. albus* is more adapted to the heavier clay loam soils and the higher temperatures as suggested by Gladstones (1970). Although only one genotype of *L. cosentinii* was tested, its inherent hard-seededness and comparatively low yield suggest that this species, though adapted to drier and warmer climates (Gladstones, 1970) requires further improvement before it could be considered for the environment in question.

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