YIELD AND NUTRIENT COMPOSITION OF SEVENTEEN LUPINUS MUTABILIS LINES

P.E. Horn and G.D. Hill
Department of Plant Science
Lincoln College
Canterbury
and
N.G. Porter
Applied Biochemistry Division
D.S.I.R., Lincoln
Canterbury

INTRODUCTION

Lupinus mutabilis is a large seeded lupin of South American origin from the Andean highlands. In preliminary evaluations in Canterbury (Porter *et al.*, 1976), Hill *et al.*, (1977) reported yields from 0.9 exceptionally high oil and protein content. Published yield figures are few, Blanco (1974), Masefield (1975, 1976), Hill *et al.*, (1977) reported yields from 0.9 tonnes hectare^{-1} to 6 tonnes hectare^{-1}.

The experiment reported here compares yield and composition of 17 introduced lines of *L. mutabilis* with *L. albus, L. angustifolius* and *L. luteus* in order to obtain information for a breeding programme using *L. mutabilis.*

METHODS

The lupin lines selected for test were *L. albus* cv. Ultra, *L. angustifolius* cv. Unicrop, *L. luteus* cv. Weiko III, *L. mutabilis* lines AZ 733, 736, 777, 785, 792, 880, 881, 882, 883, 884, 1011, 1012a (brown seeds), 1012b (speckled seeds), 1012c (roan seeds), 1012d (white seeds) and 1014. (N.B. line 1012 when grown last year produced 4 distinct seed colours, these were separated and grown as four lines to see if seed colour affected yield).

The experiment was sown on a Paparua soil on the Lincoln College Research farm (Henley) on 26 August 1977. A randomised block design of 4 replicates was used. Plots contained 5 rows 20 cm apart, and were 3.5 m long. All seed was inoculated with a commercial inoculum prior to sowing. Seed was hand sown to a depth of 4 cm at 10 cm spacings within the row (50 plants m^{-2}). Superphosphate was applied at sowing at a rate of 250 kg ha^{-1}. Thimet granules were applied at the end of September for control of aphids. No irrigation was applied.

The initial sowing of *L. albus* was eaten by hares immediately after germination and was resown in the last week of September.

A maturity 3 metres from the centre of the centre three rows of each plot were harvested (0.6 x 3.0m). Ten plants from each plot were taken at random from these rows to determine components of yield.

Threshed seed was sub-sampled for determination of oil, nitrogen and kernel.

Nitrogen was determined using a micro-Kjeldahl digestion and autoanalyser measurement of ammonia. Oil was determined gravimetrically by soxhlet extraction in petroleum ether. Testas were removed by the method of Edwards and Hill (1970).

For statistical analyses all percentages were arcsine transformed. Tables presented are based on untransformed data, but the Duncan letters refer to arcsine means.

RESULTS

Climate

The weather was wetter and cooler than normal in September. From October to the end of March it was warmer and drier than normal. In April it was warmer and wetter (Table 1).

General Observations

The results from the seventeen genotypes indicate that *L. mutabilis* is an extremely variable species. Seed colour was brown, roan, white, and numerous combinations of these colours. However, seed colour does not appear to effect yield as the four lines of AZ 1012 were not significantly different from each other in this respect.

Flower colour was of four basic types, white, pale blue, dark blue and a mixture of blue and yellow. The blue and yellow combination was the most frequent. The other colours appeared, apparently at random throughout all the lines. Plants which produced dark blue flowers also had a purple coloration in their stems and petioles.

Maturity of the plants was also variable, some plants from each line matured within five months of sowing. Many were still flowering seven months after sowing. Some lines (especially AZ 777 and 792) had a tendency to shatter and these may have been disadvantaged because early maturing plants shattered before harvest.

The heavy rain and relatively warm temperatures of April showed that the species was prone to sprouting in the pods. This feature was found in all *L. mutabilis* lines.

(L. albus and *L. angustifolius* plants which were unharvested at this time also showed some tendency to sprout).

Components of Yield

Nodes to flowering ranged from 8.32 in *L. luteus* to 15.85 in *L. mutabilis* (AZ 883), the lowest *L.*

mutabilis was 12.6 (AZ 785). The number of pods formed varied considerably ranging from 7.77 (*L. albus*) (lowest *L. mutabilis* 8.72 (AZ 1012c) 0 to 15.65 (AZ 777). Seed number plant^{-1} ranged from 16.05 (AZ 1012c) to 44.79 (AZ 736). There was a very highly significant negative correlation between seeds per pod and total pods per plant ($P \leqslant 0.001$). Seeds per pod ranged from 1.86 (AZ 1012c) to 3.26 *(L. luteus)*, (highest number in *L. mutabilis* was 2.61 (AZ 780)) (Table 2).

TABLE 1: Temperature, rainfall, evaporation and sunshine for September - April Lincoln College

°C	Temperature (Mean) Max.°C	Min. °C	Rainfall mm	Evaporation mm	Sunshine hours
1977					
Sept.	11.5 (-2.9)*	2.8 (-1.4)	103.7 (+57.7)	71.4	117.7 (-48.3)
Oct.	16.6 (-.5)	5.7 (-.5)	21.0 (-27)	142.4	192.5 (-5.5)
Nov.	18.4 (-.6)	6.6 (-1)	29.0 (-24)	181.8	220.2 (+11.2)
Dec.	21.1 (+.2)	8.4 (-1.2)	48.8 (-9.2)	215.1	191.9 (-23.1)
1978					
Jan.	22.8 (+.7)	12.5 (+1.8)	43.2 (-12.8)	238.2	205.2 (-16.8)
Feb.	23.2 (+1.3)	12.0 (+1.2)	19.9 (-36.1)	200.8	230.1 (+43.1)
Mar.	22.4 (+2.4)	10.5 (+1.2)	26.8 (-39.2)	180.4	198.8 (+22.8)
April	18.3 (+1)	11.1 (+4.3)	166.2 (+108.2)	65.1	85.9 (-57.1)

* Figures in parenthesis indicate the difference from the norm.

TABLE 2: Components of yield of *L. albus, L. angustifolius, L. luteus,* and 17 lines of *L. mutabilis*

Species	Nodes to flowering	Pods plant^{-1}	Seeds plant^{-1}	Seeds pod^{-1}
L. albus cv. Ultra	12.87 def	7.77 e	20.50 de	2.85 abc
L. angustifolius cv. Unicrop	15.65 ab	9.85 cde	30.72 bcd	3.20 ab
L. luteus cv. Weiko III	8.32 g	11.55 a-e	38.25 ab	3.26 a
L. mutabilis AZ733	13.32 def	13.67 a-d	26.57 b-e	1.94 e
AZ736	14.17 b-e	13.15 a-d	44.79 a	2.46 cde
AZ777	13.52 c-f	15.65 a	27.70 b-e	1.90 e
AZ780	11.98 f	10.12 b-e	31.01 bcd	2.61 bcd
AZ785	12.60 ef	15.37 ab	33.20 a-d	2.15 e
AZ792	13.70 c-f	9.22 cde	20.25 de	2.18 cde
AZ880	14.28 a-e	11.44 a-e	24.62 cde	2.16 cde
AZ881	12.73 def	13.88 a-d	30.08 bcd	2.20 cde
AZ882	13.35 def	14.58 abc	34.88 abc	2.30 cde
AZ883	15.85 a	11.70 a-e	23.18 cde	2.08 e
AZ884	14.21 a-e	11.07 a-e	21.55 cde	1.95 e
AZ1011	14.02 b-e	13.55 a-d	31.25 bcd	2.28 cde
AZ1012a	13.31 def	12.61 a-e	28.02 b-e	2.21 cde
AZ1012b	13.15 def	12.22 a-e	27.20 b-e	2.23 cde
AZ1012c	15.15 abc	8.72 de	16.05 e	1.86 e
AZ1012d	14.37 a-d	11.62 a-e	21.63 cde	2.10 e
AZ1014	13.50 c-f	11.22 a-e	25.87 b-e	2.31 cde

Harvest index was higher in *L. albus* (50.98%) and *L. angustifolius* (57.63%), than in any of the *L. mutabilis* lines in which it ranged from 22.98% (AZ 777) to 36.90% (AZ 1012c). Seed weight per plant varied from 1.74 (AZ 777) to 6.77 g. (*L. angustifolius*) (the highest *L. mutabilis* was 6.59 (AZ 785)). The mean seed weight of all *L. mutabilis* lines (62-216 mg) was less than that in *L. albus* (320 mg) or *L. angustifolius* (224 mg).

TABLE 3: Dry matter and seed weight per plant, harvest index and mean seed weight of 17 lines of *L. mutabilis.*

Species	Dry matter plant^{-1} g	Seed Plant^{-1} g	Harvest Index %	Mean Seed weight (mg)
L. albus cv. Ultra	12.90 b-e	6.60 ab	50.84 ab	320 a
L. angustifolius cv. Unicrop	12.02 b-e	6.77 a	57.63 a	224 b
L. luteus cv. Weiko III	14.48 a-e	6.43 ab	44.01 bc	170 bcd
L. mutabilis AZ733	14.95 a-d	3.98 a-f	26.36 efg	147 bcd
AZ736	14.35 a-e	5.45 a-d	27.55 d-g	120 de
AZ777	8.42 de	1.74 f	22.98 g	62 e
AZ780	10.68 cde	3.64 b-f	29.18 d-g	119 de
AZ785	17.05 abc	6.59 ab	35.36 c-f	205 bc
AZ792	7.60 e	2.40 ef	31.52 d-g	121 de
AZ880	14.42 a-e	3.73 b-f	27.48 d-g	149 bcd
AZ881	10.76 cde	3.42 c-f	33.08 d-g	115 de
AZ882	18.29 ab	4.79 a-e	27.50 d-g	139 cd
AZ883	9.63 de	2.80 def	30.87 d-g	124 de
AZ884	11.39 b-e	3.68 b-f	32.00 d-g	168 bcd
AZ1011	17.96 abc	6.00 abc	33.81 def	192 bcd
AZ1012a	20.91 a	5.33 a-e	23.28 fg	189 bcd
AZ1012b	17.39 abc	5.49 a-d	32.06 d-g	201 bc
AZ1012c	9.56 de	3.48 c-f	36.90 cd	216 bc
AZ1012d	12.62 b-e	4.44 a-f	36.38 cde	205 bc
AZ1014	12.25 b-e	4.29 a-f	35.02 c-f	165 bcd

Seed Composition

Seed of *L. mutabilis* lines AZ 1011, AZ 1012 a-d, and AZ 1014 contained more oil than the other lines grown (19-22%).

All lines of *L. mutabilis* had a higher seed nitrogen concentration than *L. albus* or *L. angustifolius. L. luteus* had a similar seed nitrogen concentration to *L. mutabilis.* The amount of kernel ranged from 77.97% *L. luteus* to 78.12% *L. angustifolius* to 83.32% *L. albus,* to 84.75% - 89.17% among the *L. mutabilis* genotypes.

TABLE 4: Concentration of seed nitrogen, oil and percent kernel in *L. albus, L. angustifolius, L. luteus* and 17 lines of *L. mutabilis*

Species	Whole Seed		
	N%	Oil %	Kernel %
L. albus cv. Ultra	6.14 cd	14.25 g	83.32 e
L. angustifolius cv. Unicrop	5.49 d	7.65 h	78.12 f
L. luteus cv. Weiko III	6.99 abc	5.46 i	77.97 f
L. mutabilis AZ733	7.34 ab	16.78 d-g	84.75 cde
AZ736	7.22 ab	17.31 c-g	87.55 a-d
AZ777	7.04 abc	15.75 g	86.55 a-e
AZ780	7.11 ab	16.47 efg	83.92 de
AZ785	7.54 a	16.52 efg	86.67 a-e
AZ792	6.51 bc	16.91 d-g	87.47 a-d
AZ880	6.65 abc	17.45 c-g	88.50 abc
AZ881	7.01 abc	16.19 fg	85.30 b-e
AZ882	7.21 ab	18.52 b-f	87.00 a-e
AZ883	7.09 ab	17.24 c-g	89.17 a
AZ884	7.53 a	16.68 efg	87.50 a-d
AZ1011	6.77 abc	19.12 b-e	88.85 ab
AZ1012a	6.54 bc	22.03 a	87.65 a-d
AZ1012b	7.34 ab	19.37 bcd	88.25 abc
AZ1012c	6.75 abc	20.35 ab	88.47 abc
AZ1012d	6.41 bc	20.63 ab	89.07 ab
AZ1014	6.58 bc	19.74 abc	88.35 abc

There was a significant correlation between amount of oil and kernel, and a significant negative relationship between seed oil and nitrogen concentration ($P \leqslant 0.05$). There was no relationship between nitrogen concentration and proportion of kernel.

The difference in seed yield between *L. albus* and *L. angustifolius*, 282.5 g m^{-2} and 248.4 g m^{-2} respectively, was not significant. Both these species produced significantly more seed than any of the *L. mutabilis* lines. The range of seed yield among the *L. mutabilis* genotypes was 26.3 g m^{-2} in AZ 792 to 119.3 g m^{-2} in AZ 733.

Because of its high seed yield *L. albus* also produced more oil, nitrogen and kernel per unit area than any *L. mutabilis* genotype.

TABLE 5: Yield per unit area of seed, nitrogen, oil and kernel in *L. albus, L. angustifolius, L. luteus* and 17 lines of *L. mutabilis*

Species	Seed g m^{-2}	Nitrogen g m^{-2}	Oil g m^{-2}	Kernel g m^{-2}
L. albus cv. Ultra	282.5 a	17.14 a	45.34 a	235.2 a
L. angustifolius cv. Unicrop	248.4 a	13.67 b	18.26 b-e	194.5 a
L. luteus cv. Weiko III	87.6 bcd	6.12 cd	4.76 g	84.7 bcd
L. mutabilis AZ733	119.3 b	8.55 c	20.63 bcd	102.2 b
AZ736	66.2 b-e	4.85 cde	10.77 d-g	57.5 b-e
AZ777	44.9 de	3.15 de	7.04 fg	38.9 de
AZ780	60.1 b-e	4.27 de	9.62 efg	50.5 b-e
AZ785	49.9 cde	3.73 de	8.28 efg	43.3 cde
AZ792	26.3 e	1.77 e	4.24 g	23.0 e
AZ880	73.9 b-e	4.92 cde	12.49 c-g	65.5 b-e
AZ881	74.2 b-e	5.19 cde	11.99 d-g	62.6 b-e
AZ882	94.9 bcd	6.87 cd	16.71 b-f	76.5 bcd
AZ883	74.5 b-e	5.28 cde	12.85 c-g	66.3 b-e
AZ884	81.5 b-e	6.11 cd	13.53 b-g	71.4 b-e
AZ1011	74.4 b-e	4.54 de	14.03 b-g	66.2 b-e
AZ1012a	94.9 bcd	6.27 cd	23.89 b	82.9 bcd
AZ1012b	94.4 bcd	6.93 cd	18.24 b-e	83.5 bcd
AZ1012c	85.8 b-e	5.79 cd	17.41 b-f	75.8 bcd
AZ1012d	109.1 bc	6.08 cd	22.96 bc	97.5 b
AZ1014	106.3 bc	7.08 cd	20.94 bcd	93.7 bc

DISCUSSION

Although the *L. mutabilis* genotypes were introduced as distinct lines (apart from 1012 a-d) it appears that they have undergone little of no selection. Until 1971 little scientific work had been done on this species. The University of Cuzco (Peru) in that year started to create a germplasm bank, their collections were based on geographical regions and not botanical characteristics (Blanco 1974). While the lines used here did not come directly from Peru it would seem that they also were unselected 'botanically'.

The fact that this species does have a high percentage of oil, nitrogen and kernel in seed could make it a valuable crop plant. However, before it can become an economic crop there will need to be an extensive breeding programme.

Initial work should include selection for:

1. flower colour
2. early maturity
3. low alkaloid content

(It has already been reported by Blanco (1974) that the white seed colour is a recessive character).

The highly significant correlation between oil and mean seed weight, and between oil and harvest index (Table 6) suggests that selection for oil could be started by taking large seeded lines with a harvest index of 35 percent or more. These suppositions are, however, based on simple correlations.

TABLE 6: Correlations between nitrogen, oil, kernel mean seed weight and harvest index among 17 lines of *L. mutabilis*

	Oil %	Nitrogen %	Kernel %	Mean Seed Weight
Nitrogen %	-0.327*			
Kernel %	0.327*	0.153		
Mean Seed Weight	0.435**	-0.049	0.198	
Harvest Index %	0.401**	-0.047	-0.060	0.266

The significant negative correlation between percent oil and nitrogen would suggest that selection for oil and nitrogen would need to be made independently.

Although *L. mutabilis* oil has been reported to be of high nutritional quality (Hudson *et al.*, 1976), analysis of a wide range of genotypes for oil quality does not appear to have been reported. The oil extracted from the lines grown in this trial will be analysed to determine fatty acid composition.

CONCLUSIONS

From the results of this experiment it appears that *L. mutabilis* is a plant with potential for both oil and protein production. If it is to compete successfully with other grain legumes it will have to be improved considerably. To this end further lines of this species have been introduced and it is planned to grow and evaluate these during the coming season.

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