A COMPARISON OF SEED AND NUTRIENT YIELD OF SPRING-SOWN GRAIN LEGUMES

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ABSTRACT

Eight grain legumes **Glycine max., Lupinus albus, L. angustifolius, L. mutabalis (2), Phaseolus vulgaris, Pisum sativum,** and **Vicia faba** were sown at Lincoln in spring 1976.

Yield of dry seed ranged from 41 g m^{-2} in **G. max.** to 340 g m^{-2} in **P. sativum,** nitrogen content from 3.52 per cent in **P. vulgaris** to 6.60 per cent in **L. mutabilis** 1011, acid detergent fibre was highest in **L. angustifolius** (17.0%) and lowest in **P. sativum** (4.5%).

The only varieties to contain significant amounts of seed oil were **L. albus** (10.8%) **L. mutabalis** (12.1 and 13.4%) and **G. max.** (16.3%).

On the basis of seed protein production both **L. albus** (120 g m^{-2}) and **L. angustifolius** (87 g m^{-2}) produced more than peas at (76 g m^{-2}). **L. albus** also produced the most oil (35 g m^{-2}) and from quality considerations would probably be the most suitable grain legume for the spring sowing in Canterbury.

INTRODUCTION

The traditional grain legume in Canterbury has been the field pea. Farm yields ranged from 1.5 to 2.9 tonnes $hectare^{-1}$. The older shattering varieties of lupins were also grown and lupin seed yields were seldom more than 1.6 tonnes $hectare^{-1}$ (Claridge, 1972).

The breeding and selection of new non-shattering lupin varieties by Gladstones (1970) has changed the potential of this crop and high experimental seed yields of **Lupinus angustifolius** have been reported (Stoker, 1975; Lucas *et al.,* 1976). In a preliminary evaluation of new lupin genotypes, **Lupinus mutabilis** lines of South American origin were found to have exceptionally high seed protein and oil content, and a low proportion of testa compared with other lupin species (Porter *et al.,* 1976). The only published yield figures for this species appear to be those of Masefield (1975, 1976), who claimed yields of up to 6 tonnes $hectare^{-1}$.

Goulden (1976) obtained seed yields of 6.2 tonnes $hectare^{-1}$, from spring-sown irrigated **Phaseolus vulgaris** at Lincoln. Although there appear to be no published trial results, yields of 3 to 4 tonnes $hectare^{-1}$ on Canterbury farms have been common for **Vicia faba** (field beans).

Soya bean trials in Canterbury by Dougherty (1969) gave poor yields (1.3 tonnes $hectare^{-1}$). The new Swedish variety Fiskeby V which is reputed to be cold tolerant (Holmberg, 1973) might, however, be more suited to the Canterbury environment.

Most grain legumes however are grown not as seed crops but for the protein and/or oil content of their seed. There appear to have been no comparative trials of grain legume species in Canterbury which have measured seed yield. Trials on individual legume species have generally ignored seed composition. However, Hill and Horn (1975) did speculate on comparative protein production from common grain legumes.

The experiment reported here compares the yield and composition of eight spring-sown non-irrigated grain legumes selected from seven legume species in the Canterbury environment.

METHODS

The legume species and varieties selected for test were **Glycine max** cv Fiskeby V, **Lupinus albus** cv Ultra, **L. angustifolius** cv Unicrop, **L. mutabilis** 1011 (1) (a white coated large seeded introduction obtained via DSIR Otara) **L. mutabilis** AZ 792 (2) (a white coated small seeded line selected from lines evaluated in 1975/76 on the basis of composition and seed production) **Phaseolus vulgaris** cv Canadian Wonder, **Pisum sativum** cv White Prolific, and **Vicia faba** cv Maris Bead.

The experiment was sown on a Wakanui silt loam on the Lincoln College Research Farm on 6 October 1976. A randomised block design with four replicates was used. Plots contained 10 rows of plants 15 cm apart and were 3 m long (1.5 x 3m). Seed of all legumes except peas and common beans were inoculated prior to sowing with commercial inoculum and hand sown at a depth of 4 cm at 10 cm spacings within the row (66 plant m^{-2}).

Previous experiments on the same paddock nearby had shown no response to the application of phosphate (Hill, unpublished) so no fertilizer was applied at sowing. Thimet granules were applied at sowing for control of aphids.

Following the storms of 12-14 November 1976 all **Phaseolus vulgaris** seedlings were killed and these were replanted the following week.

No irrigation was applied and plants were dependent on natural rainfall.

At maturity two rows from each side of the plots were discarded. Ten plants were pulled at random from the central six rows of each plot for the determination of the components of yield. The remainder of the plot was then harvested for seed yield determination (0.9 x 3.0 m).

After threshing seed from each plot was subsampled for determination of percent kernel, nitrogen, oil and fibre.

Testas were removed using the method of Edwards and Hill (1970). Nitrogen in whole seeds and kernels was determined using a micro-Kjeldahl digestion and Autoanalyser measurement of ammonia. Oil was determined gravimetrically by Soxhlet extraction in petroleum ether. Acid detergent fibre was determined using the method of Bailey and Ulyatt (1970).

For statistical analyses all percentage values were arcsine transformed.

RESULTS

Climate

The season was cooler than average until December, and considerably wetter than average during December and January. The month of March when most of the plots were ripening had an extremely low rainfall (Table 1).

TABLE 1: Rainfall and mean temperature, Lincoln College October 1976 to April 1977

Month		Rainfall mm	Mean Temperature °C
1976	October	51 (+ 3)*	8.8 (-2.1)
	November	48 (- 4)	10.9 (-1.9)
	December	99 (+ 41)	14.8 (0)
1977	January	75 (+ 19)	14.7 (-1.3)
	February	50 (+ 3)	16.1 (+0.3)
	March	5 (- 52)	14.6 (+0.5)
	April	30 (- 23)	10.8 (+3.8)

* Figures in parenthesis indicate deviation from long term average.

Components of Yield

Soya, common and field beans flowered at the lowest node while Unicrop and peas flowered at the highest. The number of pods formed per plant ranged from 5.1 in field beans to 11.5 in soya beans. There were wide differences in the number of seeds per plant; common bean set only 7.1 while peas produced 40.7. These figures are reflected in the number of seeds in each pod. In spite of their high pod number soya beans set only 1.46 seeds per pod, while Unicrop and peas set 3.60 and 3.92 respectively (Table 2).

TABLE 2: Components of yield of eight spring-sown grain legumes

Species	Nodes to Flowering	Pods $Plant^{-1}$	Seeds $Plant^{-1}$	Seeds Pod^{-1}
G. max	4.77 d	11.5 a	17.1 cd	1.46 e
L. albus	12.62 c	7.6 abc	20.7 bcd	2.81 c
L. angustifolius	19.52 a	9.4 abc	33.8 ab	3.60 ab
L. mutabalis (1)	14.90 b	7.9 abc	24.4 bc	3.09 bc
L. mutabalis (2)	16.30 abc	10.8 ab	26.5 bc	2.45 cd
P. vulgaris	6.52 d	5.8 bc	7.1 d	1.74 de
P. sativum	16.10 ab	10.2 abc	40.7 a	3.92 a
V. faba	7.95 d	5.1 c	12.1 cd	2.33 cd

The highest amount of total dry matter per plant at 24.2g, was from **Lupinus mutabilis** (2) with soya beans the least at 5.2 g $plant^{-1}$. However, in terms of seed per plant, peas produced the most (9.2 g) and soya beans the least (1.9 g). Harvest index appeared to be related to the length of time the plant had been under improvement, and ranged from 24 per cent in **L. mutabilis** (1) to 54 per cent in the peas. Mean seed weight among the lines ranged from 110 mg in Fiskeby V to 418 mg in **L. albus** (Table 3).

TABLE 3: Dry matter and seed weight per plant, harvest index and mean seed weight of eight spring-sown grain legumes

Species	Dry Matter $Plant^{-1}$g	Seed $Plant^{-1}$ g	Harvest Index %	Mean seed Weight mg
G. max	5.17 e	1.87 c	36 c	110 C
L. albus	20.76 ab	8.60 a	41 bc	418 A
L. angustifolius	14.72 c	6.38 ab	43 bc	187 BC
L. mutabalis (1)	12.77 cd	3.00 c	24 d	123 C
L. mutabalis (2)	24.18 a	6.18 ab	25 d	233 B
P. vulgaris	6.76 e	2.74 c	44 bc	405 A
P. sativum	16.93 bc	9.17 a	54 a	230 B
V. faba	8.41 de	4.29 bc	51 ab	377 A

Seed Composition

The seed of common beans, peas, and soya beans all contained more than 90 per cent kernel. Lupin species except **L. mutabilis** contained less kernel especially **L. angustifolius** in which the seed was 23.1 per cent testa. Seed fibre content of the lupins highlighted this high proportion of testa, and only **L. mutabilis** (2) contained less than 10 per cent fibre. Peas, common bean and field beans contained only 4-6 per cent fibre. The only lines to contain more than 1 per cent oil were the soya beans and the lupins (Table 4).

The three lupin species and the soya beans had a much higher whole seed nitrogen concentration than the other three species. Removal of the testa in the lupins concentrated seed nitrogen which in **L. albus** and **L. mutabilis** rose to more than 7 per cent of the total kernel. Kernel nitrogen concentration of **L.**

TABLE 4: Seed composition of eight spring-sown grain legumes

Species	Kernel %	Fibre %	Oil %	Whole Seed N %	Kernel N %
G. max	90.8 B	10.2 c	16.28 A	5.60 B	6.15 B
L. albus	83.0 E	14.1 b	10.80 C	5.86 B	7.21 A
L. angustifolius	76.9 F	17.0 a	4.65 D	5.05 C	6.43 B
L. mutabilis (1)	86.6 D	13.4 b	13.38 B	6.46 A	7.43 A
L. mutabilis (2)	88.8 C	8.3 d	12.06 BC	6.60 A	7.64 A
P. vulgaris	92.4 A	4.9 f	0.96 E	3.52 E	3.56 D
P. sativum	91.3 B	4.5 f	0.97 E	3.60 DE	3.71 D
V. faba	86.9 D	6.3 e	1.18 E	3.98 D	4.63 C

TABLE 5: Yield of seed, kernel, protein, oil, and fibre from, eight spring-sown grain legumes on a dry matter basis

Species	Seed $g\ m^{-2}$	Kernel $g\ m^{-2}$	Protein $g\ m^{-2}$	Oil $g\ m^{-2}$	Fibre $g\ m^{-2}$
G. max	41 d	39 d	14.5 f	6.8 c	4.2 d
L. albus	328 ab	273 a	120.3 a	35.4 a	46.4 a
L. angustifolius	277 b	213 b	87.4 b	13.0 b	46.9 a
L. mutabalis (1)	115 c	99 c	46.5 cd	15.4 b	15.2 b
L. mutabalis (2)	128 c	114 c	53.1 c	15.3 b	10.4 bc
P. vulgaris	136 c	125 c	30.0 e	1.3 d	6.6 cd
P. sativum	340 a	310 a	76.4 b	3.2 cd	15.4 b
V. faba	142 c	124 c	35.6 de	1.6 d	9.0 c

angustifolius was not different from that of soya beans. Common beans, field beans and peas had considerably less testa, and kernel nitrogen concentrations were only slightly higher than in whole seed (Table 4).

Yield and Nutrient Production

There was no difference in seed yield between **L. albus** at 328 and peas at 340 g m^{-2}. Soya beans yielded the least (41 g). Kernel produced per unit area among lines was in the same order, and ranged from 39 in soya beans to 310 g m^{-2} in peas. When lines were compared on the basis of seed protein production peas yielded the same as Unicrop but less than Ultra. The production of significant amounts of oil particularly in **L. albus**, probably meant that the energy value of the lupin seed per unit area was above that of the pea seed. The lupin seed from the two high yielding cultivars also produced more fibre per unit area than any of the other legumes (Table 5).

DISCUSSION

For three of the legumes evaluated this experiment may not have provided a fair comparison. Higher seed yields of field beans have been obtained from autumn sowing (Newton and Hill, 1977). Notwithstanding the cold tolerance of Fiskeby V (Holmberg, 1973) the 1976/77 growing season in Canterbury did not appear to suit the soya beans. Dougherty (1969) obtained considerably higher yields from early December-sown, later-maturing, cultivars. Similarly the yield of common beans was only a quarter of that obtained by Goulden (1976) when sown at the same time and with irrigation.

Although high yields of **L. angustifolius** seed have been obtained from October sowings in a favourable season (Lucas *et al.*, 1976), the lupins evaluated may also have had their yield reduced by the October sowing. Withers *et al.*, (1974) found that there was a linear decline in seed production of **L. angustifolius** as sowing date went from April to October. There is no published information on optimum sowing date for **L. albus** or **L. mutabilis** under New Zealand conditions. However, it is probable that similar factors operate to those in **L. angustifolius.**

With regard to seed yield there was little to choose among the two **L. mutabilis** genotypes, the field or common beans. Protein production from both **L. mutabilis** lines was superior to **P. vu garis** and 1011 was also superior to the field bea is. The protein produced by **L. angustifolius** was below the estimate of Hill and Horn (1975) but almost exactly equal to the suggested figure of Withers *et al.*, (1975). The protein production of **L. albus** was between the estimated values of Hill and Horn (1975) and Withers *et al.*, (1975). **Lupinus albus** produced 40 g m^{-2} more protein than peas.

Only lupins produced a significant amount of oil on a unit area basis. Lupin seed oil in **L. angustifolius, L. albus** and **L. mutabilis** is considered to be of high quality (Hansen and Czochanska, 1974; Hudson *et al.*, 1976). The major fatty acid in oil of the lupin species evaluated is oleic (18:1), although up to 30 per cent of the oil may be linoleic (18:2). Apart from **L. albus** (8.5 per cent) lupin seed oil generally contains less than 5 per cent linolenic acid (18:3) (Gross and von Baer, 1975; Hansen, 1976; Hudson *et al.*, 1976).

Production of higher amounts of protein does not necessarily mean that seed will be superior for non-ruminant feeding. Therefore seed from this experiment is to be evaluated for protein quality in rat feeding trials by the Protein Group of the Applied Biochemistry Division, D.S.I.R. Further chemical tests are to be carried out to measure trypsin inhibitors, haemagglutinants, alkaloids and gross energy value.

CONCLUSIONS

From the results of this experiment sweet genotypes of **L. albus** appear to be the most suitable grain legume for spring legume seed protein production in the Canterbury environment. This species lacks a suitable genetic market to indicate when outcrossing has occurred. Problems have therefore been caused by alkaloids in a supposedly sweet line used in pig feeding trials (Pearson and Carr, 1977). Seed was subsequently found to contain significant amounts of residual alkaloid (Ruiz *et al.*, 1977). The discovery by Hill and Horn (unpublished) of a pink flowered mutant opens the possibility of marking this species in the same way as the "Uni" series in **L. angustifolius** (Gladstones, 1970).

The yield of **L. mutabilis** was considerably less than that from Ultra, Unicrop or the peas. As yet there are no alkaloid free genotypes in this species. However, the seed composition, and the yield obtained indicate that this species has considerable potential. Further work is therefore planned to screen for alkaloid free genotypes and evaluate yield among the introduced genotypes.

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