EFFECT OF TIME OF SOWING AND ROW SPACING ON YIELD AND SEED COMPOSITION OF GLYCINE MAX cv. FISKEBY V AND LUPINUS ANGUSTIFOLIUS cv. UNICROP

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ABSTRACT

The cold tolerant soya bean Fiskeby V, and Unicrop lupins were sown at Lincoln in early and late December 1977 in rows 20 and 40 cm apart.

At both times of sowing the soya beans produced 288 g m^{-2} of seed when sown in rows 20 cm apart. Production was less from 40 cm rows and fell to 233 g m^{-2} at the second sowing. The December sown lupins did not yield well and produced only 146 g m^{-2} of seed. In the lupins there was no response to changing row spacing and the yield from the 20 and 40 cm rows was also 146 g m^{-2} in each case.

The oil content of the soya been seed was 17.3 percent and of the lupin 6.1 percent, while seed nitrogen concentration was 5.2 percent in soya beans and 6.4 percent in the lupins.

The soya bean seed oil concentration and seed yields obtained are higher than have been previously reported from the South Island of New Zealand. The seed yield also appears to be higher than that obtained for this cultivar in Sweden, where it was bred. Because the 1977/78 season was warmer than usual more experimental work is required before this crop could be recommended for Canterbury.

INTRODUCTION

Experiments with soya beans in the South Island of New Zealand have given variable results (Blair *et al.*, 1966; Dougherty, 1969a,b; Hill *et al.*, 1977). In the North Island however, yields of this crop appear to be more reliable. Gerlach *et al.* (1971) suggested that Hawkes Bay, Gisborne, Waikato, Auckland and the Bay of Plenty would be suited to growing the crop. Trials by McCormick (1974, 1975, 1976) have indicated that yields of up to 3 tonnes of seed per hectare can be obtained in the Waikato. Similarly Turnbull (1976), at Kaipara, obtained experimental yields in excess of 3 tonnes per hectare.

The Swedish soya bean variety, Fiskeby V, was bred specifically to reduce the dependence of yield on high temperatures during the growing season (Holmberg, 1973). In Sweden, when grown at 58°N it has produced up to 2.5 tonnes of seed per hectare.

In the only New Zealand report on this variety (Hill *et al.*, 1977) yield was equivalent to only 410 kg ha^{-1}. The plants however had been sown in October, in Canterbury, in a cooler than normal season and received no irrigation during their growth.

To further evaluate the potential of this soya bean cultivar in the Canterbury environment, a trial was sown at Lincoln during December, 1977. *Lupinus angustifolius* cv. Unicrop was sown at the same time for comparison.

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METHODS

A 2^3 factorial design with four replicates was used. The treatments were:-

Plant Variety:
- *Glycine max* cv. Fiskeby V. (S1)
- *Lupinus angustifolius* cv. Unicrop (S2)

Sowing Date:
- Sown early December 1977 (T1)
- Sown late December 1977 (T2)

Row Spacing:
- Rows 20 cm apart (P1)
- Rows 40 cm apart (P2)

Individual plots were 2 m by 5 m and each plot contained 5 rows of plants at the 40 cm row spacing, and 10 rows of plants at the 20 cm row spacing.

Seed was sown by hand at 5 cm apart within the row, into a Wakanui silt loam at the Plant Science Research Area, Lincoln College. The first sowing took place on December 1 and 2 and the second sowing between December 21 and 24.

Soil test values for the soil concerned were:

P	33 (Olsen)
K	18
Ca	11
pH	5.9

Because of the high soil phosphate level no fertilizer was applied.

To ensure that soil moisture did not limit growth, sprinkler irrigation was applied to each sowing three times during crop growth as shown in Table 1.

TABLE 1. Date of and amount of irrigation applied to each sowing.

Sowing 1		Sowing 2	
Date	Amount	Date	Amount
18.12.77	19 mm	31.1.78	22mm
27.2.78	27 mm	27.2.78	40mm
7.3.78	44 mm	7.3.78	44mm

At maturity, the end 0.5 m of each plot, the outside rows of the 40 cm plots, and the outside two rows of the 20 cm plots, were discarded. The remainder of each plot was then harvested for yield determination. At the same time ten plants were taken at random from each plot for components of yield analysis.

Sub-samples of seed were taken and ground. The seed meal was then analysed for seed nitrogen using micro-Kjeldahl digestion and Autoanalyser measurement of ammonia. Oil was determined gravimetrically by Soxhlet extraction in petroleum ether.

RESULTS

Climate

As can be seen from Table 2, both mean maximum and minimum temperatures were considerably above average for all of the growing season. Sunshine hours were below average for December, January and April, but were well above average during February and March when flowering and seed filling was taking place. Rainfall was below average in every month except April, when it was three times the average for

TABLE 2. Climate data Lincoln College December 1977 to April 1978.

	Month	Temperature °C Mean Max	Mean Min	Sunshine Hours (Total)	Rainfall mm
1977	December	21.1 (+0.2)*	8.4 (-1.2)	192 (-23)	49 (- 9)
1978	January	22 8 (+0.7)	12.5 (+1.8)	205 (-17)	43 (- 13)
	February	23.2 (+1.3)	12.0 (+1.2)	230 (+43)	20 (- 36)
	March	22.4 (+2.4)	10.5 (+1.2)	199 (+23)	27 (- 39)
	April	18.3 (+1.0)	11.1 (+4.3)	86 (- 57)	166 (+108)

* Figures in parentheses indicates deviations from long term average.

TABLE 3. Effect of time of sowing and row spacing on plant population and components of yield in Fiskeby V soya beans and Unicrop lupins.

	Plants m^{-2}	Plant Height cm	Total Pod $Plant^{-1}$	Total Seed $Plant^{-1}$	Seeds Pod^{-1}	Seed wt $Plant^{-1}$ (g)	Mean seed wt (mg)
Species							
Glycine max							
cv. Fiskeby V (S_1)	66.8	36.1	21.6	31.7	1.44	4.94	156
Lupinus angustifolius							
cv. Unicrop (S_2)	38.7	42.4	11.6	37.2	3.17	7.16	192
Significance	***	***	***	**	***	***	***
Sowing date							
Early December (T_1)	52.8	43.3	16.5	32.6	2.21	5.56	170
Late December (T_2)	52.7	35.2	16.7	36.3	2.42	6.55	178
Significance	N.S.	***	N.S.	*	***	***	N.S.
Row spacing							
20 cm apart (P_1)	70.2	40.0	14.1	27.6	2.20	4.80	172
40 cm apart (P_2)	35.3	38.5	19.1	41.3	2.43	7.30	176
Significance	***	N.S.	***	***	***	***	N.S.
Significant Interactions	SXT** SXP*** SXTXP*	SXT***	SXP**	-	SXT*	SXT**	SXT**
$S\bar{x}$	1.23	0.92	0.37	1.06	0.03	0.18	3.00
C.V.	9.21%	9.3%	8.9%	12.6%	5.4%	11.9%	6.9%

that month and caused problems with the final harvest.

Plant Population

At harvest the plant population of each species on a unit area basis, varied. Plant stand of lupins at harvest was only 59 percent of that of the soya beans, because, in both sowings, the lupins were severely infected with a virus disease. There was no significant difference in mean population over the two sowings (52.8 and 52.7 plants m^{-2} respectively) and the number of plants in the 40 cm rows was almost exactly half of that in the 20 cm rows (35.3 and 70.2 plants m^{-2}) (Table 3). The presence of significant interactions between S x T**, S x P**, S x T x P* can be explained on the basis of the different survival rate of the lupins between the two sowings. There was little difference in the final establishment population of soya beans at either sowing.

Plant Height

The soya beans were considerably shorter than the lupins at both times of sowing (36.1 and 42.4 cm: $P \leqslant 0.001$). However there was no difference in plant height between the two row spacings. The apparent decline in plant height between sowing 1 and 2 was almost entirely due to the reduction in stature in the soyabeans at the later time of sowing (Table 3).

Components of Yield

a) *Pods per plant:* The soya beans produced considerably more pods per plant (21.6) than the lupins (11.6). There was no difference in the number of pods produced at the two sowing dates. As could be expected, more pods were produced by plants in 40 cm rows (19.1) than by those in 20 cm rows. There was, however, a significant interaction ($P \leqslant 0.01$) between variety and plant population. The total number of pods per plant on the lupins was less varible than on the soya beans which responded by producing more pods when sown at the wider spacings (Table 3).

b) *Seeds per plant:* Although the soya beans produced more pods, lupins produced more seeds per plant (37.2 compared with 31.7; $P \leqslant 0.01$). Later sown plants also produced, on average, 3.7 more seeds than the early sown plants ($P \leqslant 0.05$). As there were more pods per plant at the 40 cm spacing, there were also more seeds (41.3 compared with 27.6; $P \leqslant 0.001$) (Table 3).

c) *Seeds per pod:* Lupin pods contained more than twice as many seeds (3.17) as the soya bean pods (1.44) ($P \leqslant 0.001$). The increased number of seeds per plant at the second sowing date is partially explained by an increase in the number of seeds per pod from 2.21 to 2.42 ($P \leqslant 0.001$). The difference in the number of seeds per pod at the closer row spacing (2.20) compared to the wider rows (2.43) was not large but was significant ($P \leqslant 0.001$). There was a significant ($P \leqslant 0.05$) variety by sowing date interaction, which was mainly due to a slight increase in the number of seeds per pod in the lupins at the late sowing (Table 3).

d) *Seed weight per plant:* The weight of seeds produced per plant on the lupins (7.16 g) was considerably higher than that on the soya beans (4.94 g) ($P \leqslant 0.001$). Sowing date also influenced seed produced per plant, which increased from 5.56 g at

TABLE 4. Yield of seed, protein and oil, harvest index, seed nitrogen, and seed oil concentration of Fiskeby V soya beans and Unicrop lupins.

	Yield g m^{-2}	Harvest Index %	Seed Nitrogen %	Seed Oil %	Protein Yield g m^{-2}	Oil Yield g m^{-2}
Species						
Glycine max						
cv. Fiskeby V (S_1)	270.7	58.6	5.24	17.27	89.5	46.72
L. angustifolius						
cv. Unicrop (S_2)	146.4	47.8	6.38	6.07	58.7	8.81
Significance	***	***	***	***	***	***
Sowing date						
Early December (T_1)	202.9	49.5	5.71	12.14	69.45	28.9
Late December (T_2)	214.2	56.9	5.92	11.21	78.81	26.6
Significance	N.S.	***	N.S.	***	**	*
Row spacing						
20 cm apart (P_1)	217.4	53.3	5.82	11.58	77.7	29.1
40 cm apart (P_2)	199.8	53.2	5.81	11.77	70.6	26.4
Significance	*	N.S.	N.S.	N.S.	*	**
Significant Interactions	SXT** SXP*	TXP*	-	-	SXT* SXP*	SXT*** SXP** SXTXP*
$S\bar{x}$	5.54	0.50	0.09	0.12	2.23	0.61
C.V.	10.6%	3.8%	1.09%	0.69%	12.1%	8.8%

the first sowing, to 6.55 g at the second ($P \leq 0.001$). Increasing the distance between rows increased seed production per plant from 4.80 to 7.30 g plant^{-1} ($P \leq 0.001$). There was a significant species by time of sowing interaction ($P \leq 0.01$) due to an increase in the amount of seed produced per plant by the lupins at the later sowing (Table 3).

e) *Mean seed weight:* Although the mean seed weight of the lupin seed (192 mg) was higher than that of the soya beans (156 mg) ($P \leq 0.001$), there was no response to either sowing date or row spacing. As with total seed weight per plant, there was a significant interaction between species and time of sowing ($P \leq 0.01$) (Table 3). In this case the interaction was caused by a drop in the mean seed weight of the soyabeans between the first and second sowing.

Seed Yield

The mean yield of the soya beans was 271 g m^{-2}. this was nearly twice the yield of 146 g m^{-2} ($P \leq 0.001$) obtained from the December sown lupins. There was no difference in yield between the two times of sowing, but sowing in 20 cm rows increased the yield from 200 g m^{-2} to 217 g m^{-2} ($P \leq 0.05$).

There were significant interactions between species and sowing date ($P \leq 0.01$), and between species and row spacing ($P \leq 0.05$) (Table 4).

Overall yield of the soya beans declined marginally from 280 to 261 g m^{-2} between the two sowings, while the yield of lupins increased from 126 to 167 g m^{-2}. The two species responded differently with regard to row spacing. In 20 cm rows the soya beans produced 288 g m^{-2}; at 40 cm row spacing this fell to 253 g m^{-2}. The lupins, on the other hand, produced 146 g m^{-2} at both row spacings.

The maximum yield of soya beans (288 g m^{-2}) was obtained, from both times of sowing, when seed was sown in 20 cm rows.

Harvest Index

Calculation of harvest index (Table 4) showed that considerably more of the dry matter of the soya beans was in the seeds than was the case in the lupins (59% versus 48) ($P \leq 0.001$). There was also a significant difference in harvest index between the two times of sowing (50% compared with 57) ($P \leq 0.001$). However, there was no difference between the two row spacings.

A significant interaction ($P \leq 0.05$) between time of sowing and row spacing was the result of the harvest index for plants from the 20 cm rows being slightly less at sowing one and slightly more at sowing two than the values for the plants grown in 40 cm rows.

Seed Nitrogen Concentration

Seed nitrogen concentration in the lupins (6.38%) was significantly higher than that in the soya beans (5.24%) ($P \leq 0.001$). There was no response in seed nitrogen concentration either in response to row spacing, or between sowing dates, although seed nitrogen was slightly lower at the second sowing that at the first (Table 4).

Seed Oil Concentration

The seed oil concentration in the soya beans was 17.27 per cent and that in the lupins 6.07 per cent ($P \leq 0.001$) (Table 4). The mean oil level at the later sowing declined from 12.14 to 11.21 percent. This was mainly the result of a drop of about 1 percent in oil concentration in both species between the two times of sowing.

Total Protein Production

To allow comparison of protein production with other grain legumes, protein yield per metre^2 was calculated (Table 4). Soya beans yielded 89.5 g m^{-2} while the lupins gave 58.7 g. Because seed nitrogen between species was the only factor which was significant for seed nitrogen, the other significant main factor results and interactions were a reflection of seed yield.

Total Oil Production

The total production of oil per unit area was 46.7 g m^{-2} in the soya beans and only 8.8 g in the lupins. Because of the drop in oil concentration between the two sowing dates, there was significant decrease in oil production between the first and second sowing in soya beans (49.6 to 43.8 g m^{-2}). In the lupins, on the other hand, the increase in seed yield between the two sowings compensated for the reduced oil concentration, and production rose from 8.2 to 9.4 g m^{-2}. For total oil production there were significant

TABLE 5. Correlations between yield g m^{-2}, seed plant^{-1} g, harvest index, 1000 seed weight, seed nitrogen % and seed oil % in Fiskeby V soya beans and Unicrop lupins.

Lupins \ Soya Beans	Yield g m^{-2}	Seed Plant^{-1} g	Harvest Index %	1000 Seed wt g	Seed Nitrogen %	Seed Oil %
Yield g m^{-2}		-0.602 *	-0.231	0.027	-0.316	0.008
Seed Plant^{-1} g	0.415		0.053	0.251	0.024	0.105
Harvest Index %	0.714 **	0.436		-0.538 *	0.324	-0.500
1000 Seed wt g	0.174	0.263	0.120		-0.170	0.481
Seed Nitrogen %	0.233	-0.057	0.162	0.300		0.029
Seed Oil %	-0.587 *	-0.335	0.647 **	0.067	-0.089	

interactions between species and time of sowing ($P \leqslant 0.001$), species and population ($P \leqslant 0.01$) and for the three factor interaction species by time of sowing by row spacing ($P \leqslant 0.05$). In the soya beans there was little difference in oil production in 20 cm rows at either sowing (50.6 and 48.6 g m^{-2}) or in the 40 cm rows at the first sowing (48.6 g m^{-2} at the wider row spacing, the oil production fell (39.0 g m^{-2}). In the lupins there was a similar situation between the two narrow row spacings at both times of sowing (8.4 and 8.7 g m^{-2}) and the wider spacing at sowing one (8.00 g m^{-2}). However, at the second sowing in 40 cm rows the lupins produced more oil per unit area (10.1 g m^{-2}).

Relationships Between Yield Components and Seed Composition

To determine if the relationships between yield components and seed composition in the two species were the same, simple correlations were calculated between the following variates for the soya beans and the lupins: yield g m^{-2}, seed plant^{-1} g, harvest index %, mean seed weight mg, seed nitrogen % and seed oil %. The correlation matrix for the two species is shown in Table 5. In lupins there was a positive correlation between harvest index and seed yield (r = 0.714**). Seed oil concentration in this species was negatively related to yield per unit area (r = 0.587*) and to Harvest index (r = -0.647**).

In the soya beans the relationship between seed yield per unit area and per plant was negative (r = -0.602*) as was the relationship between mean seed weight and harvest index (r = -0.538*).

DISCUSSION

The yield of soya beans from this experiment is considerably above the 2,421 kg ha^{-1} obtained from small plots by Blair *et al.* (1966) and the 1,176 kg ha^{-1} from the larger plots used by Dougherty (1969a). The seed oil concentration of 17.2 percent was also higher than the 15.1 percent reported by Dougherty (1969a). Seed yield and oil concentration are therefore higher than previously reported from the South Island of New Zealand for this crop. Seed nitrogen concentration however, was lower (5.24 percent compared with the mean of 6.88 percent obtained by Dougherty, 1969a).

Comparing the soya bean yields with those obtained from trials in the North Island, the yields were considerably below those reported by Gerlach *et al.* (1971) but only marginally below those of McCormick (1974, 1975, 1976) in the Waikato, and similar to those reported by Turnbull (1976) from the Kaipara District. With regard to seed composition, both oil and nitrogen concentrations were below North Island means (oil, 18%; nitrogen 6.40%; reported by Manning *et al.*, 1974).

The yield of Fiskeby V was slightly better than the best yield obtained from this cultivar in Swedish experiments (2,490 kg ha^{-1} at 41 plants m^{-2}) (Holmberg, 1973). The seed oil concentration was similar (16.7 - 17.7%), but seed nitrogen was again higher in Sweden (6.11%).

Radley (1974) has commented that Fiskeby V soya bean plants tend to be extremely short which may cause harvesting problems. The mean height of the soya beans (36 cm) in this experiment was lower than the 43 cm recorded by Holmberg (1973) for this cultivar. However, the plants were 18 to 19 cm taller than the soya beans grown in Dougherty's (1969a) experiment. It appears therefore that, because of short stature, the crop may require careful harvesting to obtain maximum yields.

The yields from the late sown lupins were not particularly good. This is in line with results reported by Withers *et al.* (1974) for late sown lupins in New Zealand, and of Perry (1975) for lupins in Western Australia. Similarly, Hill (unpublished) has obtained reduced yields of lupin seed from *L. albus* and *L. angustifolius* when sown in November. It is unlikely that the reduced yield was due to low plant population at harvest (caused by the bean yellow mosaic virus) as Herbert and Hill (1978) obtained a yield of 7,330 kg ha^{-1} of seed from irrigated *L. angustifolius* at a plant population as low as 27 plants m^{-2}.

Seed oil and protein concentrations, however, were considerably higher than those reported from this species when sown in October in a cooler season (Oil 4.65%; nitrogen 5.05%) (Hill *et al.*, 1977). Nevertheless, the increased concentrations did not compensate for the overall reduction in seed yield, and protein and oil production per unit area from this species were considerably less than had been obtained in the previous season.

The differences in the simple correlations between the two species for yield components and seed composition are of interest. It is often suggested that there is a negative relationship between yield and seed protein content in grain legumes (Evans 1973, Sinha 1977). The evidence presented by Evans (1973) is based on three species, soya beans, *Phaseolus vulgaris* and peas, and draws data from five papers. In only the soya beans and *P. vulgaris* was there a negative correlation between yield and seed nitrogen concentration. The results from our experiment indicate that although this relationship was similarly negative in the soya beans, it was positive in the lupins. On the other hand, in the lupins there was a significant negative relationship between seed oil concentration and yield, while there was no relationship between these two factors in the soya beans. This suggests that the two species are responding in a different way. In the absence of experimental evidence for a particular species of grain legume, it may be safer to assume that there is no relationship between seed composition and yield. As Sinha (1977) comments, similar negative relationships have also frequently been found in cereals. Yields have been improved markedly without reduction in seed nitrogen concentration, mainly by selecting for improved harvest index. This suggests that with increased research it may be possible to breed high yielding grain legumes with high seed nitrogen concentration.

CONCLUSIONS

The results from this experiment suggest that soya bean genotypes exist which could give reasonable yields with a high seed oil concentration under favourable conditions in Canterbury. At present the only commercial oil crushing mill is located in the South Island. If an edible oil industry is to become established, because of high inter-island freight costs the crop would need to be grown reasonably close to this mill.

As the 1977/78 summer was warmer than usual, further work is required to determine the effect of cooler summers on both seed production and oil concentration. Investigations of sowings at even higher plant populations also appear to be warranted. Finally, there would be no point in growing soya beans unless there is a market for the product. Considerably higher commercial and experimental yields can, afterall, be obtained from peas, field beans or lupins when sown at times of year suitable to their growth.

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