YIELD AND WATER USE OF SWEET LUPINS

Roger Stoker
Winchmore Irrigation Research Station
Ministry of Agriculture and Fisheries
Private Bag, Ashburton

ABSTRACT

Trials were carried out in two seasons to investigate the response of the sweet lupin cultivars, Uniharvest, Uniwhite and Weiko III to different moisture levels during flowering and pod filling. The first season was dry and there was a large response to irrigation. Yield increased significantly with increasing water applied up to the highest moisture level tested. This required five irrigations. The second season was wet and irrigation response was less. The highest moisture regime required three irrigations. Yield again increased with moisture level but not in such a significant manner.

The pattern of irrigation response varied from season to season. Because of this a combined analysis showed no significant difference among irrigation treatments. This is explained at least in part by seasonal differences in rainfall. The amount of water used by the crop increased when irrigation was carried out, but did not vary among the different irrigated treatments.

In the individual trials and in the combined analysis the *L. angustifolius* (vs Uniharvest and Uniwhite consistently yielded better than *L. luteus* cv Weiko III.

INTRODUCTION

Many aspects of the agronomy of lupins have been investigated in detail both in New Zealand and overseas. However two topics that have received scant attention are the water relations of the plant and its field response to irrigation. Work that has been carried out on these topics includes that of Barbacki (1960) who tested the response of several species of lupin to water rationing in pot trials and found that *Lupinus angustifolius* and *Lupinus albus* responded to high moisture regimes better than *Lupinus luteus*, although there were considerable differences between cultivars. Other work by Biddliscombe (1975) investigated the effect of moisture stress levels on flower production, flower drop and seed yield using *Lupinus angustifolius* cv Unicrop in field trials. With increasing moisture stress during flowering the number of flowers that abscissed increased and hence seed yield declined. Post flowering moisture stress also reduced yield but to a lesser extent. This was through a combined effect of the number of pods per plant and seed per pod.

In a field trial using *Lupinus angustifolius* and *Lupinus luteus* Stoker (1975) showed there was no benefit from irrigation during the vegetative phase even when soil moisture fell to wilting point. Irrigation during flowering and pod fill greatly increased yields but little information was obtained on optimum levels during these growth phases. In one trial, irrigation at 20 percent soil moisture was no better than irrigation at 15 percent. In another trial, a treatment irrigated at 20 percent soil moisture yielded 42 percent more than a treatment irrigated at 12 percent moisture. The trials showed that irrigation increased yields mainly through the production of a greater number of pod bearing lateral branches with an additional small increase in the number of seed in each pod. There were no differences in soil moisture content recorded under the different cultivars tested.

The present investigation was a continuation of this previous work and the objects were:

1. To determine the optimum irrigation levels during the moisture sensitive flowering and pod filling period;
2. To determine water usage under a range of irrigation treatments.

EXPERIMENTAL

Field trials were carried out at Winchmore in the 1975/76 and 1976/77 seasons. The first of these seasons was very dry and the second was very wet. Over the critical November to February period, rainfall was 190 mm in 1975/76 and 287 mm in 1976/77. This compares with a 27 year mean of 255 mm for these four months. The soil type at Winchmore is a Lismore stony silt loam. This soil varies in depth between 300 and 400 mm and overlies extensive shingle beds. Soil physical properties were measured on six occasions during the 1975/76 growing season with samples taken from both non-irrigated and irrigated plots. No differences in physical properties associated with time of the season or irrigation treatment were detected. Field capacities were determined in the field of flooding (Salter 1967). Wilting points of disturbed samples were determined in the laboratory by the 15 bar method (Salter and Williams 1965). Bulk density samples were also determined by the method of Salter and Williams (1965) using 100 mm wide cores. Soil physical properties and calculated available moisture values are summarised in Table 1. The top 300 mm of soil contained 59 mm of available moisture. Soil physical properties were also measured in the 1976/77 season and were very similar.

TABLE 1: Soil Physical Properties 0-300 mm Sample Lismore Stony Silt Loam 1975/76.

Depth (mm)	Field Capacity (W %)	Wilting Point (W %)	Bulk Density (g ml^{-1})	Stones (V %)	Available Moisture (mm)
0-75	32.1	10.2	1.17	5.0	18.3
75-150	29.4	10.2	1.21	4.4	16.7
150-225	24.6	9.5	1.28	9.2	13.2
225-300	22.2	9.4	1.29	12.1	10.9
0-300					59.1

In 1975/76 the trial site was out of old pasture and had a soil pH of 5.4 Trifluralin (1.1 l ha^{-1} a.i.) was incorporated on 28 July and weeds were well controlled. Superphosphate (240 kg ha^{-1}) and potassium chloride (60 kg ha^{-1}) were topdressed on 1 September. The trial was sown on 8 September with a belt type precision seeder using an inter-row width of 200 mm and an intra-row spacing of 48 mm.

In 1976/77 the trial site was out of peas preceded by old pasture. Soil pH was 5.6 Trifluralin (0.9 l ha^{-1} ai.i) was incorporated on 30 September and weeds were again controlled well. Superphosphate (100 kg ha^{-1}) and potassium chloride (50 kg ha^{-1}) were topdressed on 4 October. The trial was sown on 6 October using the same plant spacing as in the previous season.

Five irrigation treatments were planned in both seasons. These were:

a. non irrigated
b. non irrigated to flower then at 12% soil moisture
c. non irrigated to flower then at 15% soil moisture
d. non irrigated to flower then at 20% soil moisture
e. 12% to flower then at 20% soil moisture.

Soil moisture did not fall to 12% before flowering in either season. This meant that treatments d. and e. would have become identical. However in 1975/76 treatment e. plots were used to investigate the effect of irrigating at 10% during flowering and pod filling. In 1976/77 treatments d. and e. were left the same. Treatments that occurred in the two seasons are given in Table 2.

TABLE 2: Irrigation Treatments and number of irrigations

Soil moisture Flowering + Pod Fill	1975/76 Number of Irrigations	1976/77 Number of Irrigations
Non irrigated	0	0
10% moisture	2	-
12% moisture	2	1
15% moisture	3	1
20% moisture	5	3

Water was applied each time the moisture content fell to the specified levels. Moisture content was determined gravimetrically from 0-150 mm soil cores taken at least once weekly. Table 2 indicates the number of irrigations required to maintain the soil above these moisture levels. Plots were watered by the border strip method with sufficient water applied at each irrigation to restore the whole soil depth to field capacity.

In both seasons there were three cultivars from *L. angustifolius* and one from *L. luteus* and five replicates. However seed of one of the cultivars of *L. angustifolius* (Unicrop) had a germination of only about 20 percent and was excluded from the analysis of results.

Trial plots were sampled by hand from February 24 to March 15 in the first season and from March 28 to April 5 in the second. The non irrigated treatment was the first ready for harvest. The other treatments followed in order of increasing number of irrigations applied. Grain weights were measured and adjusted to a 14 per cent moisture content.

Water usage in the top 300 mm of soil was calculated from a record of soil moisture, irrigation and rainfall based on the following assumptions.

1. Moisture content measured in the top 150 mm of soil is an accurate assessment of the moisture status of the top 300 mm.
2. The methods of determining field capacity and wilting point correctly measure the upper and lower limits of available water and hence the calculated total available moisture is correct.
3. Water from rainfall or irrigation in excess of that required to bring the 0-300 mm soil moisture above the maximum available is lost as drainage.
4. Each irrigation by the border strip method applies more than sufficient water to return the top 300 mm of soil to field capacity.

RESULTS

Grain yields analysed for the effect of irrigation on each cultivar are given in Table 3 for the 1975/76 season and in Table 4 for the 1976/77 season. Grain yields analysed for the main effect of irrigation for the two seasons individually and combined are given in Table 5. Similar analyses for the main effect of cultivar are given in Table 6.

Water used out of the top 300 mm of soil during the 94 day period from the three node stage until the development of mature green pods is given in Table 7.

In the 1975/76 season soil moisture fell to 15.6 percent in the vegetative phase. The minimum soil moisture recorded in the non irrigated treatment after the start of flowering was 9.6 percent. The corresponding figures in the 1976/77 season was 19.8 percent in the vegetative phase and 10.6 percent after the start of flowering.

TABLE 3: Lupin Grain Yield 1975/76 (kg ha^{-1}).

Irrigation Regime	*L. angustifolius* Uniharvest	*L. angustifolius* Uniwhite	*L. luteus* Weiko III
Non irrigated	1750 CR	2130 DS	910 DR
10%	3010 BQ	3100 CR	1800 CQ
12%	3490 BQ	3670 BQR	2170 BCQ
15%	4550 AP	4290 APQ	2590 BPQ
20%	4690 AP	4810 AP	3250 AP

The s.e. (mean) for vertical comparisons was 194.
The s.e. (mean) for horizontal comparisons was 188.
The interaction was not significant.

TABLE 4: Lupin Grain Yield 1976/77 (kg ha^{-1}).

Irrigation Regime	*L. angustifolius* Uniharvest	*L. angustifolius* Uniwhite	*L. luteus* Weiko III
Non irrigated	3380 BQ	3150 BQ	1520 BQ
12%	3610 BQ	3590 APQ	1880 ABPQ
15%	3590 BQ	3930 AP	1790 ABPQ
20%	4130 AP	3730 AP	2170 AP

The s.e. (mean of 5 plots) for vertical comparison was 156.
The s.e. (mean of 5 plots) for horizontal comparison was 147.
The interaction was not significant.

TABLE 5: Irrigation and Lupin Grain Yield (kilograms hectare^{-1}).

Irrigation Regime	Yield 75/76	Yield 76/77	Yield (combined)
Non irrigated	1600 ER	2680 CR	2140 A
10%	2640 DQ	-	-
12%	3110 CQ	3030 BQ	3070 A
15%	3810 BP	3100 BPQ	3460 A
20%	4250 AP	3340 AP	3830 A
CV%	14.9	9.2	77.1

Notes:
1. The 3340 was a mean of 10 plots.
2. The combined analysis was done on the 4 x 2 table of means, to test for consistent differences among irrigation treatments.

percent. It is seen in Table 5 that in both seasons yield increased stepwise with increasing moisture level up to the maximum tested. However, moisture usage in Table 7 does not show a distinct pattern. In both seasons the irrigated treatments used more moisture than the non irrigated, but differences among the various irrigated treatments were mainly very small and showed no consistent pattern. Further work is required on this soil type to measure moisture usage below 300 mm and to verify the usefulness of traditional concepts of field capacity, wilting point and bulk density.

In both seasons the treatment irrigated at 20 percent soil moisture, gave the highest yields. It is interesting however that the pattern of irrigation response varies between seasons. Because of this the combined analysis shows no significant differences.

TABLE 6: Cultivars and Lupin Grain Yield (kilograms hectare^{-1}).

Lupin	Cultivar	Yield 75/76	Yield 76/77	Yield (combined)
L. angustifolius cv	Uniharvest	3500 AP	3770 AP	3660 AP
L. angustifolius cv	Uniwhite	3600 AP	3620 AP	3680 AP
L. luteus cv	Weiko III	2140 BQ	1910 BQ	2030 BQ
	CV%	13.7	11.3	24.6

Note:
The combined analysis was done on the 3 x 2 table of means to test for any consistent differences among cultivars.

TABLE 7: Soil Moisture Usage by Lupin Crops 1975/76 and 1976/77

Irrigation Regime	1975/76 season Water Use (mm)	1975/76 season No. Irrigations	1976/77 season Water Use (mm)	1976/77 season No. Irrigations
Non irrigated	117	0	234	0
10%	196	2	-	-
12%	220	2	268	1
15%	241	3	261	1
20%	239	5	257	3

DISCUSSION

It has been shown (Stoker 1975) that lupin grain yields are relatively insensitive to the water status occurring during the vegetative phase. In both trials reported here, the soil remained moist during this growth phase and hence yields would not have been affected. The yields from the non irrigated treatments in these trials are, however, a reflection of the moisture conditions during flowering and pod filling. In 1975/76 soil moisture fell to wilting point during flowering, and yields averaged only 1600 kg ha^{-1}. Yield response in the best irrigation treatment was 166 percent. In 1976/77 conditions remained more moist during flowering and the soil did not approach wilting point until the crop was drying off. The non irrigated yield was high at 2680 kg ha^{-1} and yield response on the best irrigation treatment was only 25

The large seasonal difference between yields of the non irrigated treatment can be explained by the differences in rainfall. The seasonal difference in yield in the irrigated treatments was possibly a reflection of the net radiation. The first season could be characterised as hot and dry and the second as cool and moist. Raised pan evaporation recorded between November and February was 665 mm in 1975/76 and the best irrigation treatment yielded 4250 kg ha^{-1}. The evaporation during these months in 1976/77 was 553 mm and maximum yield was 3340 kg ha^{-1}.

In both seasons the *L. angustifolius* cultivars Uniharvest and Uniwhite substantially outyielded the *L. luteus* cv Weiko III. This pattern was consistent enough so that the combined analysis showed Weiko III to be inferior.

There was no evidence of a difference between seasons in the irrigation by cultivar yield pattern. On average over the two seasons, the irrigation responses were similar for the cultivars.

CONCLUSIONS

Grain yield of lupins was highly dependent on moisture conditions during flowering and pod filling. Maximum yield in both seasons was obtained at the wettest regime tested, but the pattern of response varied greatly with the season. Water usage from the top 300 mm of soil increased when irrigation was carried out, but did not seem to vary much between the different irrigated treatments. Then, *L. angustifolius* cultivars outyielded *L. luteus* under all conditions.

ACKNOWLEDGEMENTS

Mr K. Carter for assistance with field work and data handling.

Biometrics Section Ministry of Agriculture and Fisheries for analysis of results.

REFERENCES

Barbacki, S. 1960: Certain physiological properties of varieties of *Lupins luteus, Lupinus albus* and *Lupinus angustifolius* observed on the basis of water rationing trials. *Genetica Polanica 1:* 103-118.

Biddiscombe, E. F. 1975: Effect of moisture stress on flower drop and seed yield of narrow-leafed lupin. *Journal of the Australian Institute of Agricultural Science 41:* 70-72.

Salter, P. J. 1967: Methods of determining the moisture characteristics of soils. *Experimental Agriculture 3:* 163-73.

Salter, P. J. and Williams, J. B. 1965: The influence of texture on the moisture characteristics of soils. *Journal of Soil Science 16:* 1-16.

Stoker, R. 1975: Effect of irrigation on yield and yield components of sweet lupins. *Proceedings Agronomy Society of New Zealand 5:* 9-12.