NITROGEN UPTAKE AND TRANSFER FROM SPRING-SOWN LUPINS, BARLEY OR FALLOW TO A RYEGRASS TEST CROP

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ABSTRACT

Effects of lupins, barley or fallow on yield and nitrogen uptake by a subsequent 'Grasslands Tama' annual ryegrass crop were assessed.

Lupins (*Lupinus angustifolius* cv. Uniharvest) were spring sown at two populations, 25 and 100 plants/m^2. The crop was grazed at primary flowering, maximum dry matter, or harvested for seed. Dry matter production was lower than expected due to disease and adverse weather. Peak nitrogen accumulation in lupin herbage occurred 100 days after sowing and reached 15 g N/m^2.

Lupins increased the yield of a succeeding Tama ryegrass crop. Mean Tama ryegrass production following grazing lupins was 5500 kg dry matter/ha from mid March, till mid November. After harvested lupins, Tama dry matter production was 4400 kg/ha, while ryegrass production after fallow and barley was 4800 and 3400 kg dry matter/ha respectively. There was a significant correlation (r^2 = 0.56) between g N/m^2 in the lupins and g N/m^2 in the ryegrasss herbage. Fertilized sub-plots in the fallow treatment showed that the best lupin treatments provided a benefit equivalent to 85 kg N/ha. Yield of ryegrass following lupin was more than twice that following barley. Implications for soil fertility in crop rotations are considered.

Additional Key Words: fertilizer, greenfeed, soil fertility

INTRODUCTION

Lupins have been grown in New Zealand since at least the 1930's (Hudson, 1934). From approximately 1930 to 1950, lupins were an important crop in Canterbury (Hudson, 1934; Anon, 1942; Inch, 1947). In general, the crop was used for green manuring to improve the soil, as a seed crop or as a green fodder for sheep (Anon, 1938; Hamblyn, 1940; Anon, 1942; Inch, 1947). At present, lupins are not widely grown in New Zealand. The use of lupins for forage declined primarily because of problems with alkaloids (Anon, 1942; Inch, 1947) and the increased use of other forages, particularly lucerne (White, 1961).

Under Canterbury conditions, the crop has produced high yields of forage, with nearly 2000 g dry matter/m^2 from *L. angustifolius* reported (Herbert, 1977; Herbert and Hill, 1978; Burtt and Hill, 1981).

There has been a considerable amount of work published on the feeding value of dry, standing lupin crops (e.g. Gladstone, 1970; Carbon *et al.,* 1972; Arnold and Charlick, 1976). Burtt (1981) and Burtt and Hill (1981) determined the feeding value of lupins used as a green forage for sheep.

Previous reports have shown that lupins can provide a substantial amount of high quality forage for both cattle and sheep. However, no experiments have attempted to determine the effect of grazing lupins on subsequent soil fertility. Therefore, the trial reported here was designed to measure the effect of two different grazing treatments, harvesting, fallow, and barley on soil fertility, using a succeeding crop of annual ryegrass as a bioassay.

MATERIALS AND METHODS

The trial ran for 15 months from September, 1982 until November, 1983. The trial design was a randomised complete block, with 8 treatments and 6 replicates. Treatments consisted of two populations of lupins (*Lupinus angustifolius* cv. Uniharvest), which were grazed at primary flowering or at maximum dry matter, or harvested for seed, barley harvested for seed and a fallow treatment.

The trial site was located on a Templeton silt loam soil and was of low nitrogen status. Its previous cropping history, was wheat, peas, fallow and winter Italian ryegrass in 1982, 1981, 1980 and 1979 respectively.

The site was prepared by rotary-hoeing. Superphosphate (0:8:0) was applied four days before sowing to provide 12 kg P/ha. Immediately before sowing, lupin seed was inoculated with *Rhizobium lupini* in peat inoculum at twice the recommended rate. Atrazine was applied pre-emergence at 1.0 kg a.i./ha to control weed growth.

Lupin plots were sown in 23 September, 1982 with a 'Stanhay' precision seeder. Seed was sown 5 cm deep in rows 15 cm apart. Barley plots were sown on 28 September with cv. Georgie at 350 seeds/m^2. All plots were 6 m by 12 m.

Grazing was with mixed-age, mature ewes at stocking rates which were calculated to remove most green material in five days. Stocking rates were 5 ewes/plot in the low lupin populations and 7 ewes/plot in the high populations. Sheep were starved for 24 hours before being put in the plots and were left without feed for 24 hours before being removed. Sheep were controlled with 'Flexinet' electric fencing. The first grazing occurred after 73 days when 50% of plants had fully open primary flowers and the second commenced 100 days after sowing.

Barley and lupin plots were harvested on 31 January, and 3 March 1983, respectively. After harvesting, all remaining stubble was cut to ground level and removed from plots. Glyphosate was applied to both grazed and fallow plots to control herbage growth. On 23 March 1983, after removal of the stubble, annual ryegrass (*Lolium multiflorum* cv. 'Grasslands Tama') was direct-drilled over the entire trial site at 32 kg/ha. After the ryegrass emerged, each fallow plot had four 1.0 m^2 quadrats randomly located within it. These subplots were fertilized in April with lime-ammonium nitrate at 25, 50, 75 and 100 kg N/ha.

Sampling

Lupin plots were sampled by taking five 0.1 m^2 quadrats both before and after grazing. Final barley and lupin yields were obtained from one 1.0 m^2 quadrat. Ryegrass was sampled by cutting one 1.0 m^2 quadrat per plot four times at six-week intervals, beginning in June.

Measurements

Measurements taken on the lupins were: total dry matter yield, plant components (stem, leaf, pod, seed) and N content of plant components. Only final grain yield was measured in barley plots. Dry matter accumulation and nitrogen percent were measured from ryegrass plots. Nitrogen analyses were carried out using the micro-Kjeldahl technique with final nitrogen being determined on a 'Technicon Autoanalyser'. Nitrogen analysis of the Tama was carried out on the last three harvests. Regrettably, samples from the first harvest were accidently discarded before analysis.

Owing to the severe incidence of subterranean clover red leaf virus in the low lupin population plots, some of the results are reported for the high population plots only. Data from lupin harvests were statistically analysed using analysis of variance. Ryegrass dry matter and nitrogen data were analysed using orthogonal contrasts.

RESULTS

The climatic conditions at the trial site during the experiment are shown in Figure 1. Mean monthly temperature over the season was close to the long-term average. The rainfall in September and January was considerably lower than average, while in October and December, it was considerably higher. There was a severe hailstorm on 19 January which damaged both lupins and barley.

Lupin dry matter accumulation

At both grazings and at the final harvest, lupin total dry matter yield was significantly higher in the high population plots than in the low population plots. Utilisation of the crop by sheep ranged from 90% to 92% and was unaffected by the population (Table 1).

The low dry matter accumulation in the low population plots was accompanied by a rapid increase in weed population (primarily fathen (*Chenopodium album* agg.), dock (*Rumex obtusifolius* L.) and wireweed (*Polygonum aviculare* agg.)). By final harvest, there was 2870 kg dry matter weeds/ha, which was 80% of the total dry matter. In the high lupin population plots at final harvest, weeds were only 16% of total dry matter.

There was no harvestable seed in the low population plots. High population plots yielded 700 kg/ha with a harvest index of 20%.

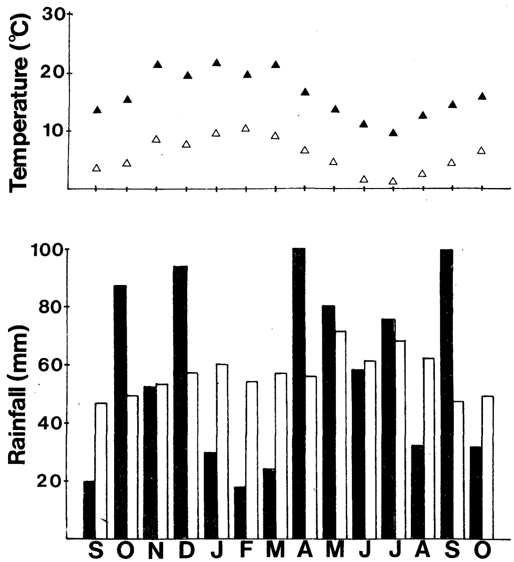

Figure 1: Mean monthly temperature (▲ = maximum, △ = minimum) and rainfall (□ = long term average, ■ = during trial) from September 1982 until October 1983 at Lincoln College.

TABLE 1: Dry matter accumulation (kg/ha) of lupins before (B) and after (A) grazing, and percent utilisation (U).

Population	Grazing 1			Grazing 2			Harvest
	B	A	U	B	A	U	B
25 plants/m^2	2540	240	91	3670	330	91	730
100 plants/m^2	3510	270	92	6530	690	90	3490
	**	ns	ns	**	ns	ns	**
S.E.	190	119	3	337	171	3	284
C.V. (%)	6	46	4	16	83	9	33

Nitrogen analysis of lupins

Maximum N accumulation of 14.7 g N/m^2 was reached 100 days after sowing in the high population plots. This represented approximately 150 kg N/ha in the lupin tops at that time. In the low density plots, weeds made a significant contribution to total N. By final harvest, weeds yielded 4.5 g N/m^2 out of a total N yield of 5.6 g/m^2. Utilization of the crop by sheep was high and minimal amounts of N remained in the stubble after grazing (Figure 2).

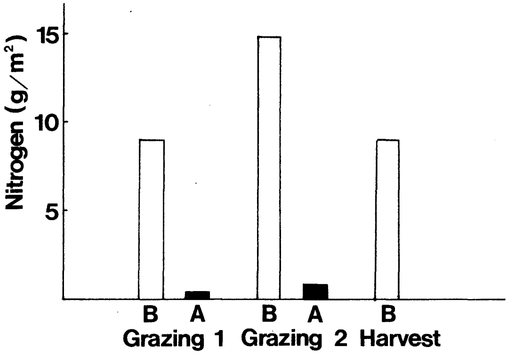

Figure 2: Nitrogen yield (g N/m²) in the tops of a crop of lupins before (B) and after (A) grazing or harvest. Grazing 1 occurred 73 days after sowing. Grazing 2 occurred 100 days after sowing.

Nitrogen analyses showed that N accumulation in plant components varied over time. Shortly after primary flowering, leaf and pod N decreased from highs of 3.0% and 2.7% respectively to 0.25% and 1.08% at crop maturity. Stem N did not vary significantly, and remained at approximately 1.4% from primary flowering until maturity. Seed was 4.7% N at 100 days from sowing and 5.4% at crop maturity.

Dry matter accumulation by Tama ryegrass

Total dry matter accumulation of the ryegrass was significantly affected by the various lupin treatments (Table 2). Tama production from grazed lupin plots ranged from 5330 to 5720 kg dry matter/ha. Harvested lupin plots produced a mean of 4420 kg Tama dry matter/ha. Tama production after barley and fallow was 3410 and 4790 kg dry matter/ha respectively. This trend was found at all ryegrass harvests except at the fourth and final harvest, where the only significant contrasts indicated that the mean of the grazed lupin plots produced 26% more Tama dry matter than the mean of the fallow and barley plots and fallow plots outproduced barley plots by 38%.

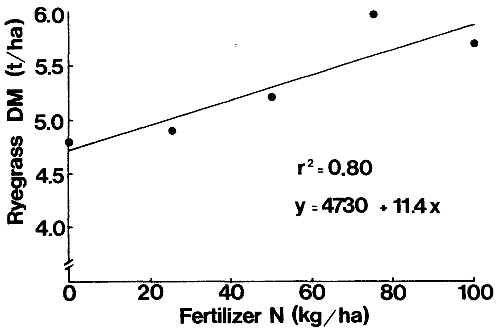

Figure 3: Effect of fertilizer N on ryegrass yield (kg DM/ha) after fallow.

TABLE 2: Total dry matter accumulation (kg/ha) and nitrogen yield (g/m²) of Tama ryegrass as affected by various preceding treatments of lupins, barley or fallow.

Treatment	Dry matter	Nitrogen
Lupins 25 plants/m²		
grazed at 73 days	5 330	11.1
grazed at 100 days	5 720	10.6
harvested	4 080	8.1
Lupins 100 plants/m²		
grazed at 73 days	5 580	12.6
grazed at 100 days	5 610	12.7
harvested	4 790	9.9
Barley	3 410	5.6
Fallow	4 790	9.2
S.E.	508	N.A.
C.V. (%)	10.4	N.A.

N.A.: It was not possible to statistically analyse this data.

Fertilized subplots in fallow treatment

The mean dry matter yields from the sub-plots in the fallow treatment are shown in Figure 3. The dry matter response of Tama to N was linear up to 100 kg N/ha. The mean rate of response over the growing season was 11.4 kg dry matter/kg N applied.

Nitrogen analysis of the ryegrass

Table 2 shows the total amount of N/m² harvested in ryegrass. To estimate total N over the entire growing season, N content in the first harvest was assumed to have been equivalent to that in the second harvest. Nitrogen content at each Tama harvest showed similar trends to total N yield. At each harvest, grazed lupin plots always produced a higher ryegrass N percent than harvested lupins, barley or fallow treatments.

There was a significant correlation ($r^2 = 0.56$) between the amount of N harvested in the lupins and the cumulative yield of N from the ryegrass (Figure 4).

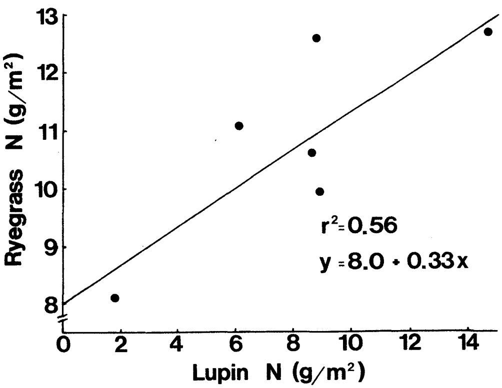

Figure 4: The relationship between nitrogen yield from lupins and cumulative nitrogen yield from Tama ryegrass.

Fertiliser equivalence values of lupin treatments

From the N treatments in the fallow plots, it was possible to compare the equivalent value of lupin, barley and fallow treatments to actual levels of fertilizer N applied. Applying the equation from Figure 3 showed that ryegrass production from the best lupin treatment was equivalent to the addition of approximately 85 kg fertilizer nitrogen/ha to the fallow treatment (Table 3). However, low population harvested lupins showed a fertilizer equivalent of -55 kg N/ha. This equation also indicated that 115 kg N/ha would be required after barley to obtain the same yield as that measured after the fallow treatment.

TABLE 3: Equivalent nitrogen fertilizer values of two lupin populations after grazing or harvesting, and barley and fallow plots.

Treatment	Equivalent N fertiliser value
Lupins 25 plants/m^2	(kg N/ha)
grazed at 73 days	53
grazed at 100 days	86
harvested	-55
Lupins 100 plants/m^2	
grazed at 73 days	73
grazed at 100 days	79
harvested	7
Barley	-115
Fallow	0

DISCUSSION

Climatic conditions during this trial were adequate for lupin growth. However, with no irrigation, the dry January undoubtedly caused yields to be lower than average. The dry matter yield of 3500 kg/ha and the seed yield of 700 kg /ha obtained from the high population plots was considerably lower than yields reported by Herbert (1977), and Burtt (1981). Reasons for the low yield include water stress in January, plant damage because of the hailstorm and disease. Sub-clover red leaf virus was particularly severe in the low population plots. While the high population plots were not free from the disease, it's severity was greatly reduced and plants did not appear to be severely infected until after the second grazing.

The poor dry matter accumulation was paralleled by a drop in the N yield of the lupins. Burtt (1981), reported that with a lupin crop of nearly 10,000 kg/ha maximum N yield was 33 g N/m^2. Furthermore, N yield did not decline as markedly as in this trial. The final N yield of 7.8 g N/m^2 was considerably lower than expected. This was again because of disease and hail damage.

The production of Tama ryegrass in this trial was greater than or equal to previous reports. Scott and Brown (1978) reported that Tama ryegrass sown in March in Canterbury produced 2800 kg DM/ha from May to September, while Janson and Knight (1980), found that a Tama-Amuri oats mixture produced 3800 kg DM/ha from the beginning of March until mid-October. The higher than average rainfall over the Tama growing season in this trial was responsible for the good yields. Additionally, the crop was grown for a longer period of time than during the above trials. However, Tama yields would almost certainly have been even higher if the crop had been sown earlier (Scott and Brown, 1978). This seems particularly likely as the heavy April rainfall probably caused the leaching of some soil nitrate.

There are many reports in the literature which show that legumes usually increase soil fertility and improve the productivity of succeeding crops. Rhodes (1980), Russell (1980), Askin *et al.* (1982) and Askin (1983), all found that grain legumes increased yields of succeeding non-leguminous crops. Furthermore, Sharma and Singh (1970) reported that grain legumes also improved soil physical characteristics such as bulk density and increased stability of soil aggregates.

This trial has confirmed that lupins are beneficial to a succeeding ryegrass crop. Of most importance, however, is the difference in ryegrass growth depending upon whether the lupins were grazed or harvested. Table 2 shows the beneficial effect of grazing compared with harvesting the crop. Of equal importance to arable farmers is the fact that growing lupins and harvesting the crop for seed gave similar ryegrass production to fallowing.

The reason for the increased ryegrass dry matter production after lupins were grazed was most likely due to increased availability of soil nitrogen. Soil nitrate analyses were carried out both before and after the lupin growing season. However, no significant differences were detected. Considering the small percentage of total N which exists as nitrate in soils, this was not surprising.

Considering the poor condition of the lupin crop, it seems likely that a more productive lupin crop would have resulted in even more significant differences than were found in this trial. Nonetheless, it seems obvious that although the lupins were severely infected with disease, there was enough N fixed by the time of the second grazing in both low and high population plots to ensure increased ryegrass production after grazed lupins when compared with harvested lupins, fallow or barley. The apparent anomaly which indicated that the low population lupins grazed late gave the highest fertilizer equivalent value (Table 3), even though the plants had been killed by disease, cannot be explained.

CONCLUSIONS

1. Lupin crops can be harvested for seed with no loss of soil fertility when compared with fallow. When compared with barley in the rotation, harvested lupins benefitted the following crop.
2. Lupins can provide a high quality sheep feed and at the same time markedly increase soil fertility for a following crop.
3. In this trial, a poor lupin crop which was grazed provided the equivalent of nearly 85 kg fertiliser N/ha to a succeeding ryegrass crop, compared with lupins harvested for seed or fallow.

Further work on the crop could indicate other benefits. Still to be determined are the effects on soil fertility that would occur if lupin regrowth were grazed a second time, or of grazing lupin stubble after harvesting for seed.

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REFERENCES

Anon. 1938. Blue lupins. *Canterbury Chamber of Commerce Agricultural Bulletin, No. 110.* 4 p.

Anon. 1942. Lamb fattening: Trials with sweet blue lupins. *Canterbury Chamber of Commerce Agricultural Bulletin, No. 154.* 4 p.

Arnold, G.W., Charlick, A.J. 1976. The use of sweet lupins in pastoral systems with breeding ewes. *Proceedings Australian Society of Animal Production 11:* 233-236.

Askin, D.C. 1983. Nitrogen fixation in peas (*Pisum sativum*). Ph.D. thesis, Lincoln College, University of Canterbury, New Zealand.

Askin, D.C., White, J.G.H., Rhodes, P.J. 1982. Nitrogen fixation in grain legumes. Australian Agronomy Conference Proceedings; July, 1982; Wagga Wagga, N.S.W. Australia. 144 p.

Burtt, E.S. 1981. The potential of *Lupinus angustifolius* cv. Uniharvest in Canterbury as a summer greenfeed for lambs. M.Ag.Sci. thesis, Lincoln College, University of Canterbury, New Zealand.

Burtt, E.W., Hill, G.D. 1981. Dry matter accumulation and nutritive value of lupins (*Lupinus angustifolius*) and their potential as a summer forage. *Proceedings Agronomy Society of N.Z. 11:* 45-50.

Gladstones, J.S. 1970. Lupins in Western Australia. The grazing value of green and mature lupins. *Agriculture Journal of Western Australia 11:* 103-106.

Hamblyn, C.J. 1940. Growing of blue lupins. *N.Z. Journal of Agriculture 60:* 298-299.

Herbert, S.J. 1977. Density and irrigation studies in *Lupinus albus* and *L. angustifolius.* Ph.D. thesis, Lincoln College, University of Canterbury, New Zealand.

Herbert, S.J., Hill, G.D. 1978. Plant population and irrigation studies on lupin. I. Growth analysis of *Lupinus angustifolius* cv. 'WAU11B'. *N.Z. Journal of Agricultural Research 21:* 467-474.

Hudson, A.W. 1934. Practices in the use of blue lupins for feed, seed and green manure. *N.Z. Journal of Agriculture 49:* 346-351.

Inch, R. 1947. Blue lupins. *N.Z. Journal of Agriculture 74:* 369-374.

Janson, C.G., Knight, T.L. 1980. Legumes for winter greenfeed production in South Island arable cropping systems. *Proceedings Agronomy Society of N.Z. 10:* 63-65.

Rhodes, P.J. 1980. Nitrogen fixation by peas and lupins. M.Agr.Sc. thesis, Lincoln College, University of Canterbury, New Zealand.

Russell, J.S. 1980. Crop sequences, crop pasture rotations and soil fertility. Australian Agronomy Conference Proceedings 1980; Queensland Agricultural College, Lawes, Australia. pp. 15-29.

Scott, W.R., Brown, K.R. 1978. How good is Tama ryegrass? *Proceedings N.Z. Grassland Association 40:* 180-183.

Sharma, R.P.R., Singh, A. 1970. Effects of growing winter legumes on certain properties of an alluvial soil of northern India. *Indian Journal of Agricultural Sciences 40 (1):* 45-53.

White, J.G.H. 1961. Lupins. *Canterbury Chamber of Commerce Agricultural Bulletin, No. 386.* 5p.