DRY MATTER ACCUMULATION AND NUTRITIVE VALUE OF LUPINS (*Lupinus angustifolius*) AND THEIR POTENTIAL AS A SUMMER FORAGE.

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ABSTRACT

Dry matter accumulation was measured in a spring-sown unirrigated stand of *Lupinus angustifolius* cv. Uniharvest from 45 days after sowing to maturity at three weekly intervals.

At each sampling the dry matter yield, its distribution to plant components, nitrogen concentration and *in vitro* digestibility were measured. Maximum dry matter yield of 987 g/m² (9870kg/ha) was achieved 150 days after sowing, by which time most leaf had fallen and nearly 70 per cent of dry matter was in the pods and seeds. Maximum total nitrogen accumulated by the crop also peaked 150 days after sowing when it was estimated at 31.6g/m².

Whole plant nitrogen concentration fell from 4.6 per cent at 45 days after sowing to 2.0 per cent at 163 days after sowing (maturity). There was little variation in leaf nitrogen concentration which ranged from 3.65 per cent 66 days after sowing to 3.35 per cent at 150 days after sowing.

The maximum *in vitro* digestibility of the whole plant (65%) was reached 125 days after sowing. Leaves were 64-65 per cent digestible throughout. Pods reached a peak digestibility of more than 80 per cent 150 days after sowing but this had fallen to 70 per cent by final harvest.

Additional Key Words: nitrogen content, yield components, digestibility

INTRODUCTION

In the period 1930 to 1950, lupins were grown in New Zealand, mainly in Canterbury, both as green manure and as a summer greenfeed, principally for lamb fattening (e.g. Hudson, 1934; McPherson, 1940; Anon., 1942). This practice declined, probably due to the high alkaloid content of the bitter cultivars (Anon., 1942; Lancaster and Adams, 1943; Allen, 1949), pod shattering and the consequent difficulties in obtaining seed (Greenall, 1958). The increasing popularity of other summer greenfeeds, particularly lucerne (Greenall, 1958; Whatman, 1959; White, 1961), also hastened the decline in the use of the crop.

With the more recent introduction of improved, sweet cultivars (Withers, 1975) and increasing problems with lucerne (e.g. Coop, 1977; Burnett *et al.*, 1978), the possibility of lupins being used more extensively as a summer greenfeed for fattening lambs, or in the autumn for flushing ewes, can be considered. Western Australian work on nutritive value (Gladstones, 1959, 1970; Carbon *et al.*, 1972; Arnold *et al.*, 1975, 1976, 1977, 1978; Arnold and Charlick, 1976; Mulhollond *et al.*, 1976; Arnold and Wallace, 1977) was mainly concerned with evaluation of the crop as a dry standing feed and there is little published information on the digestibility of the green fodder apart from that of Allison and Thurston (1952).

Some preliminary results under Canterbury conditions, obtained by Clarke (unpub.) from unreplicated trials showed lupin plants (*L. angustifolius* cv. Unicrop) to have *in vitro* digestibilities of up to 93.7% at 42 days after sowing. Dry matter production in relation to other summer greenfeeds has, however, not been found to be promising (Macmillan and Brown, 1973; Knight, pers. comm.), although a yield of just under 2,000g/m² from irrigated *L. angustifolius* was obtained by Herbert (1977).

The purpose of the experiment reported here was to measure the dry matter accumulation of *L. angustifolius* cv. Uniharvest over time and to measure variation of nutritive value in some of the components to determine a grazing time which will maximise both yield and nutrient quality.

MATERIALS AND METHODS

The Trial Site

This investigation was carried out during the 1978-79 summer season by sampling within the extensive border rows from an existing agronomic trial which was situated on the Lincoln College Henley Block on a Templeton silt loam soil type (Soil Bureau, 1954).

Four different areas of the border (sown on 26 September 1978 at a seeding rate of approximately 200kg/ha in 15 cm drill widths) were selected for replicates. No fertiliser or irrigation was applied. The trial site was of low nitrogen status.

Sampling

Sampling was carried out at approximately 21 day intervals from 9 November 1978 (45 days after sowing) until March 1979, just prior to seed harvest, giving seven sample dates.

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At each harvest, for each replicate, four 0.25m²
quadrats were cut and the material bulked. A sub-sample
for the determination of *in vitro* digestibility and nitrogen
concentration was taken, frozen immediately and freeze
dried at a later date.

Measurements

Both total dry matter and the proportion by dry weight
of the various plant components were measured.

The nitrogen concentration of the bulked whole plant
and of the plant components was determined using the
micro-Kjeldahl digestion and auto-analyser measurement
of ammonia. Crude protein was determined by multiplying
nitrogen concentration by 6.25.

The *in vitro* digestibility of the whole plant and
separate plant components was assessed on 0.5g, freeze
dried samples ground to pass through a 0.5mm screen,
using the two stage *in vitro* analysis outlined by Tilley and
Terry (1968).

Metabolizable energy was calculated using the
following formula:

$$ME(MJ) = DDM (kg) \times GE(MJ) \times .81$$

where: DDM is the digestible dry matter as calculated from
measurements obtained using the *in vitro* method outlined,
and G.E. is gross energy (M.A.F.F., 1975). An average
G.E. value of 18.2 MJ kg/DM was calculated using the
G.E. figures for all green legumes given by M.A.F.F.
(1975). This value should be valid for all stages of growth
measured, with the possible exception of the final mature
dry stage. A value of 20.6 for sweet blue lupin seeds was
given by M.A.F.F. (1975) but the value for pods was only
17.7 and it was therefore decided to use the 18.2 average for
all stages.

RESULTS

Dry Matter Accumulation

Plant emergence was very slow, possibly due to a spell
of very dry weather which was experienced in the two weeks
following sowing (Fig. 1). Not all the plants in the final
population had emerged by the first sampling date (45 days
after sowing) and for this reason a plant count to establish
plant population was delayed until the second sampling
date (66 days). Mean plant population at this stage was 80
plants/m². No attempt was made to control weeds and
these were a problem in two of the plots.

At 45 days after sowing, plants were between 30 and
90mm high and were at the four to eight leaf stage. Total
dry matter accumulation was very low, at only
16.4g/m²(Fig. 2). This had increased by just over four times
to 66.7g/m² by 66 days after sowing. The plants were up to
400mm high and secondary branching had commenced.
Primary (main axis) flowering (see Herbert, 1977) began at
about 84 days after sowing and most plants were flowering
by 87 days. Dry matter was still increasing rapidly with the
growth of secondary branches and had reached 250.4g/m²
at 87 days. By 109 days after sowing, green pods were
beginning to form on the main stem and flowering on the
secondary branches had just finished. Although leaf drop
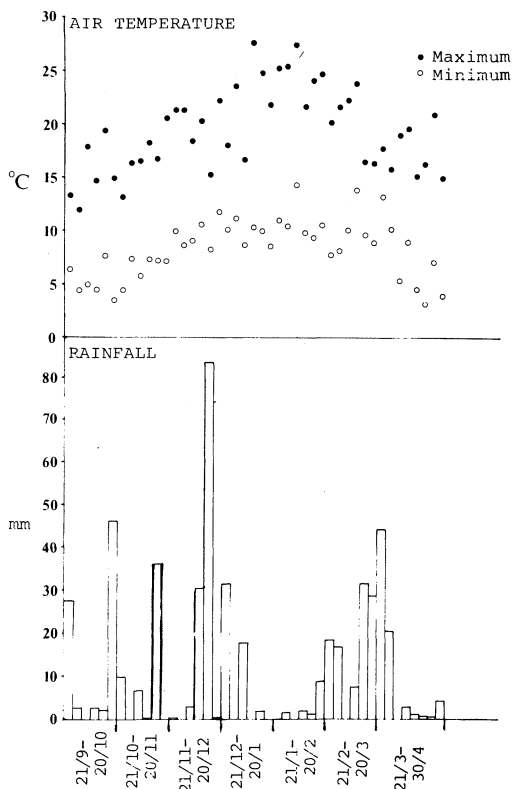had just begun, dry matter was 645.5g/m² at this stage and

Figure 1: **Temperature and rainfall records for the 1978/79 growing season (five day averages).**

was still increasing (as the pods filled) to reach 844.8g/m² at
day 129. A peak of 987.4g/m² was recorded at day 150.
Leaf drop had nearly finished at this stage and the plants
were drying off. Growth rate from day 66 to day 150 was
just under 11.0g/m²/day.

Little or no leaf was left at the final harvest (162 days
after sowing), when the pods were ripe and the plants
almost completely dry. Dry matter totalled 841.3 g/m² at
this stage (Fig. 2).

Plant Nitrogen

Total nitrogen followed very much the same trend as
dry matter accumulation (Fig. 3). Nitrogen concentration in
the whole plant decreased from 4.6% at 45 days after
sowing to just over 2.0% at 162 days (Fig. 4), but with
increasing dry matter the total amount per plant rose from
just under 1.0g/m² at day 45 to 2.3g/m² at day 66 and
7.2g/m² at day 109 is due both to the rapid increase in total
dry matter accumulation, particularly of pods (including
seed) and the fact that the nitrogen concentration of the
pod increased from 3.2% at 87 days to just over 4.0% at
day 135. Total nitrogen content of the forage at day 129
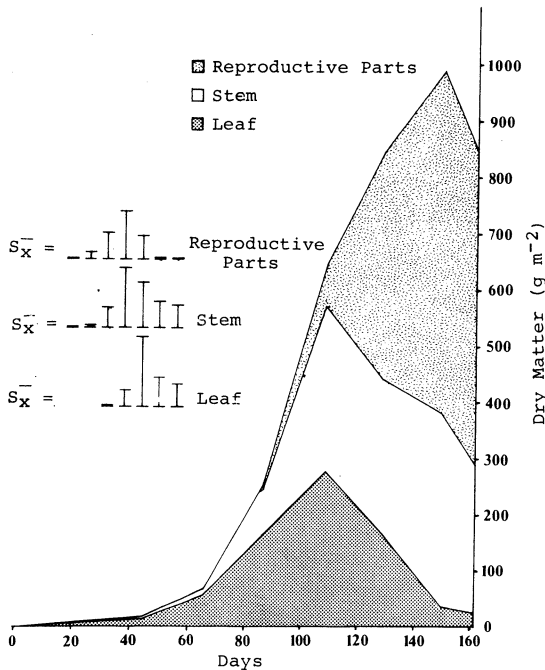was 25.2g/m², and a peak of 31.6g/m² was recorded at day

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Figure 2: Dry matter accumulation of *L. angustifolius* cv. Uniharvest with time.
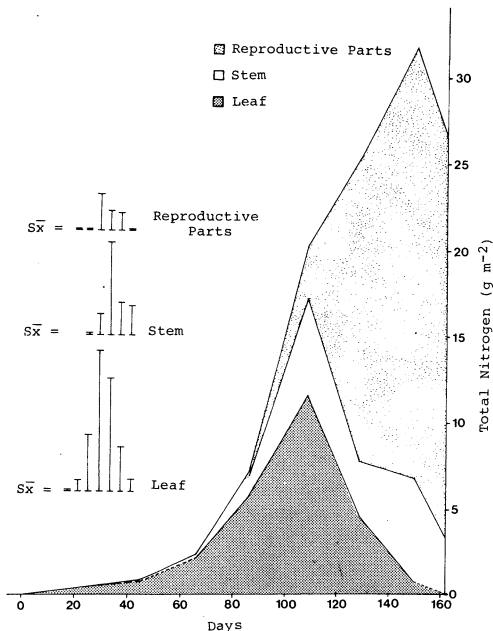

Figure 3: Total nitrogen accumulation in *L. angustifolius* cv. Uniharvest with time.
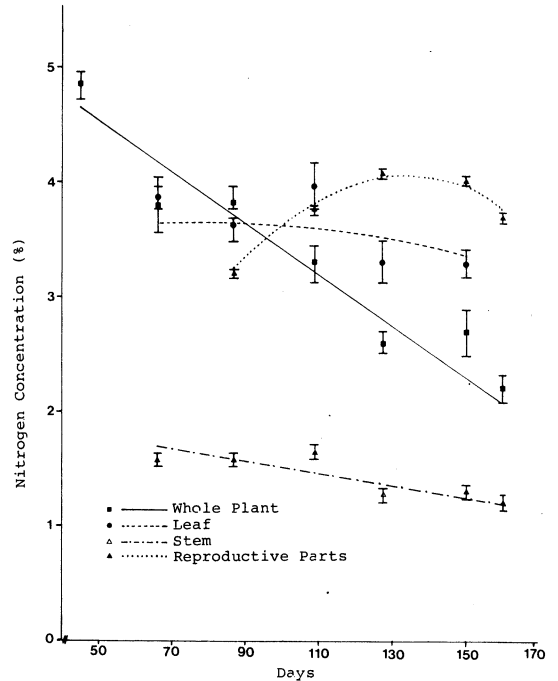

Figure 4: Nitrogen concentration of *L. angustifolius* cv. Uniharvest components with time.

150. This then began to drop and had fallen to 26.7g/m² by day 162 as both the total dry matter and the nitrogen concentration of each of the components had decreased. Total plant nitrogen increased at a rate of 0.29g/m²/day over the 45 day to 150 period. Due to a shortage of plant material from the first sample, the nitrogen in the leaves and stem was not measured at this harvest. Nitrogen concentration was just under 3.75% in leaves at day 66 and dropped slowly to 2.35% by day 150. Leaf nitrogen was not measured for day 162 again due to a shortage of plant material following leaf drop. Stem nitrogen decreased from 1.75% to 1.2% over the same period.

Digestibility

Whole plant digestibility was highest (just under 65% at about day 125 (Table 1), at which point the digestibility of the young pods was rising rapidly. Leaf digestibility, although declining, was still reasonably high at just over 65% and the stem was also still over 51% digestible. Previous to this, whole plant digestibility had fallen from just under 65% at 45 days to just under 59% at about 98 days. After the peak at 124 days, digestibility dropped rapidly to just under 50% at day 162. As might be expected from the small change in protein concentration, leaf digestibility remained fairly constant at between 64 and 65%, and only declined to just over 59% at day 162, when most of the leaf component remaining was petiole. The digestibility of the stem decreased slowly as the plant aged,

from 67% at day 45 to just over 45% at day 162. Peak pod digestibility was 83% at 148 days. The relatively low digestibility of the flowers at just over of 50% at day 98 increased rapidly as pods began to form. Pod digestibility decreased after the peak to just over 70% by day 162.

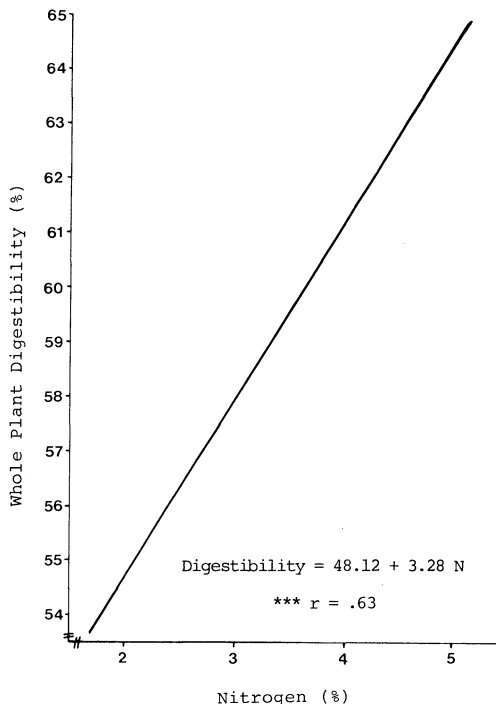**TABLE 1:** **Digestibility of the whole plant and plant components with time.**

Days after sowing	Digestibility (%)			
	Whole Plant	Leaf	Stem	Repr.parts
45	64.0			
66	62.3	64.5	63.0	
87	59.3	64.6	59.3	
109	57.6	65.5	42.5	55.3
129	61.1	64.4	49.1	77.2
150	57.8	61.5	48.3	77.0
162	50.3	59.3	42.5	69.1
S$\bar{x}$ =	1.6	1.7	1.8	1.6

The digestibility of the whole plant was best correlated with the proportion of leaf, rather than with the proportion of stem and reproductive parts. Whole plant digestibility was high when leaf was a high proportion during the early growth stages. It was lower between 55 and 75% leaf, but peak whole plant digestibility was at about 30% leaf (peak pod maturity). With lower leaf proportion following leaf drop, whole plant digestibility intially decreased (following formation of unfilled pod valves) and then increased again until about 50% of the plant's dry matter was pod. The decline in whole plant digestibility after this was probably a result of the poor digestibility of the other plant components at high levels of pod. There was a very high significant relationship (P≤0.001) between digestibility and nitrogen concentration (Fig. 5).
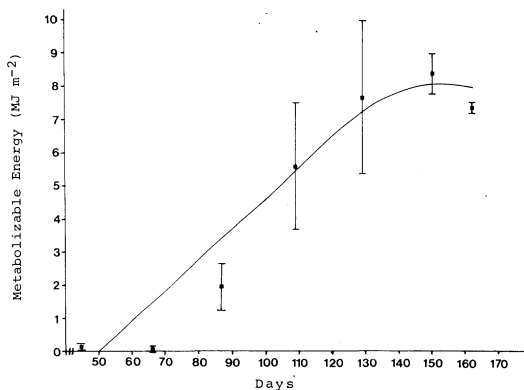
TABLE 2: **Metabolizable energy concentration of lupins.**

Days After Sowing	ME MJ/kg
45	9.36
66	9.18
87	8.74
109	8.50
129	9.00
150	8.52
162	8.73

S$\bar{x}$ = 0.23

Digestibility = 48.12 + 3.28 N

*** r = .63

Figure 5: **Correlation of the whole plant digestibility of L. angustifolius cv. Uniharvest with nitrogen concentration.**

Figure 6: **Metabolizable energy accumulation (MJ/m²) of L. angustifolius cv. Uniharvest, with time.**

Metabolizable Energy Content

The metabolizable energy (ME) of the plant ranged from 8.5MJ/kg to 9.4MJ/kg but only at 45 days was the value of 9.4MJ/kg significantly higher ($P \leqslant 0.05$) than over the rest of the period (Table 2). Total ME accumulation (Fig. 6) increased at a rate of 0.079MJ/m²/day after day 50 and reached a peak of 8.05MJ/m² at day 152, corresponding closely to peak dry matter accumulation. As the digestibility of the plant changed very little over the period, dry matter and total ME available (MJ/m²) were very closely related.

DISCUSSION

Dry matter accumulation followed very much the same trend as that found by Herbert (1977). However, the peak yield of 987g/m² after 150 days, at a plant density of 80 plants/m², was less than 1,200g m² in 116 days reported by him under unirrigated conditions, and considerably less than the 2,000g/m² grown under irrigation. The very slow emergence and poor initial growth in this trial probably decreased the potential total yield. On the other hand, the yield of this trial compared very favourably with the 4,120kg/ha in 104 days obtained by Macmillian and Brown (1973) under summer conditions in Canterbury and with yields of sweet blue lupins obtained by other workers in both New Zealand (Allison and Thurston, 1952; Greenall, 1956; van Stevenick, 1956; Knight, pers. comm.) and overseas (Edwardson and Corbett, 1959; Nel, 1965). This yield was, however, lower than that of a crop of New Zealand Bitter Blue Lupins (van Stevenick, 1956).

Primary flowering began at 84 days, at just under 24% dry matter accumulation. Flowering was later than that observed by Porter *et al.* (1976) (77 days) and Herbert (1977) (62 days), but was within the range of dry matter accumulation (17-25%) at commencement of flowering, reported by Perry (1975). The high dry matter accumulation may well be related to density, as secondary branching was not inhibited and had started by day 84.

The yield of both leaf and stem components peaked at about 109 days, and pod at approximately 150 days, which coincided with peak total dry matter. This was a much greater time span than that observed by Greenwood *et al.* (1975) who found maximum dry matter of leaf, stem and pod to occur at 133, 140 and 147 days respectively under Western Australian spring conditions. At a medium density (92 plants/m²), Herbert (1977) found leaf and stem peaked at the same time (102 days) but this was much later and at different times, at both lower (27 plants/m²) and higher (156 plants/m²) densities.

Nitrogen and protein concentrations were high, and were higher than expected at the pre-flower stage; 24% protein in the whole plant as compared with both bitter and sweet lupins (17 to 18.1%) (Anon., 1938; Lancaster and Adams, 1943; Allison and Thurston, 1952). There was a small drop in protein level at flowering and it was again higher than that recorded by Anon. (1938) for bitter lupins. At maturity, however, the whole plant protein level had dropped to just over 13% which was lower than the 15.9%

of Anon. (1938). Although nitrogen and protein levels fell steadily as the plant aged, increasing dry matter compensated for this and peak total nitrogen coincided with peak dry matter accumulation at 150 days.

The *in vitro* digestibility of the forage was highest 26 days before peak dry matter and nitrogen accumulation at day 124. The value of just under 65% was very much lower than that expected from the preliminary work of Clarke (unpub.), who obtained a peak digestibility of 93% at 42 days after sowing, with the material still 87% digestible after 126 days. Plant component digestibilities in the present trial were all lower than those obtained by Clarke.

Although digestibility was highest at 124 days, total metabolizable energy coincided with peak dry matter and protein at 150 days and it was therefore at this stage, when the plants were drying off, that the maximum total energy and protein would have been available for grazing. This was a little later than the stage recommended by van Stevenick (1956), who found the highest amount of digestible fodder to be present when the green pods were full sized and the lower leaves of the plant were just beginning to drop.

The yield of lupins obtained in this trial compared favourably with that of other fodder crops. Although it was less than the summer production of good lucerne stands (e.g. O'Connor *et al.*, 1968; Vartha and Allison, 1973), it was better than many others, especially those on unirrigated land reported by Iverson (unpub.) and Vartha (unpub.) (both cited by Vartha, 1971) and those where disease and insect damage had occurred (e.g. Burnett *et al.*, 1978; Kain *et al.*, 1979).

Production from this trial was higher than that obtained from summer crops of kale and rape in the south Island (Macmillan and Brown, 1873; Mortlock, 1975), and was considerably higher than the average summer pasture production recorded by O'Connor *et al.*, (1968).

A lupin crop sown in September and grazed at about 150 days after sowing would fit well into the cropping rotations practised on many Canterbury farms. Grazed *in situ,* the crop contributes to the nitrogen level of the soil indirectly, through dung and urine return and could well play an important role as a fertility restoring crop used between cereals, as has been shown in Victoria by White *et al.* (1978).

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