FORAGE PRODUCTION FROM COOL-SEASON ANNUAL LEGUMES AS AFFECTED BY PLANTING DATE AND TEMPERATURE

K. A. Hughes and A. O. Taylor
Plant Physiology Division
DSIR, Palmerston North

ABSTRACT

Many areas of New Zealand are colder during winter than other countries with Mediterranean type climates where cool-season annual legumes are grown. The cool-season pattern of crop growth and flowering of five legume species was therefore measured at Palmerston North after four sowing dates ranging from early through to late autumn. The species used were *Trifolium vesiculosum* cv. Yuchi, *Medicago polymorpha* SA 4364, *Ornithopus sativus* G19, *Trifolium subterraneum* cv. Woogenellup and *Vicia dasycarpa* cv. Namoi. Dry matter yields ranged from 0.9 to 10 tonnes/ha depending on species and sowing date when final harvests were made on 17 November 1978.

This trial and other published data from Kaitaia and Palmerston North were used to obtain a general relationship between legume yield and accumulated degree-days above 10°C. The results suggest that an accumulation of approximately 500 degree-days within a region's growing season is necessary for yields above 6 tonnes/ha, providing that nodulation, fertilizer and soil water levels are adequate.

INTRODUCTION

A legume crop grown during the cool season in rotation with maize or sorghum has several potential advantages over a small grain cereal or Tama ryegrass. A legume may help reduce fertilizer N inputs, break cycles of pests and disease, and assist in providing balanced forage rations to livestock. Many legumes, e.g. *Lotus, Trifolium* and *Medicago* species, are more difficult to establish than cereals because of smaller seed sizes and the sensitivity of the legume-rhizobia relationship, although some have large seeds, e.g. *Vicia* and *Lupinus* species.

With satisfactory plant establishment and nodulation, annual legumes can provide high quality forage in the spring. At Kaitaia and Palmerston North, the good growing conditions of August-September-October have produced maximum cool-season legume yields of 7-10 tonnes DM/ha (Taylor *et al.*, 1977; Taylor *et al.*, 1979a, b), although many species produced poorly at Palmerston North. Many areas of New Zealand have cooler winter temperatures than other countries where these legumes are successfully grown, so knowledge of the climatic factors which influence the growth of annual legumes is needed.

Experiments with *Trifolium subterraneum* in New South Wales demonstrated that early autumn sowing resulted in plants which had the ability to continue growth at lower temperatures than later sown plants (Kemp, 1975). Late-sown plants appeared not to nodulate before winter and consequently had a lower growth rate during winter than earlier-sown plants which had nodulated. When lines of pre-germinated subterranean clover were grown in nutrient solutions in order to eliminate rhizobia effects, seedling growth continued at 5-10° C temperatures (Williams 1972). Other experiments with *T. hirtum* and *T. subterraneum* by Evans *et al.*, (1976) showed decreased emergence of seedlings below 10°C, while the rate of very early morphological development of T. subterraneum seedlings was decreased markedly at 10°C when compared to temperatures of 15°C and above (Raguse *et al.*, 1970). Van Heerden and Wasserman (1977) demonstrated the importance of early planting and effective autumn rain on subsequent dry matter production and flowering of a range of annual legumes. Excessively late planting often reduced final yield by restricting the period of vegetative growth.

Flowering of many Mediterranean type annual legumes is promoted by long days and warm temperatures (Aitken, 1955; Evans, 1959); therefore planting in February or March after a small grain cereal crop may cause premature flowering of some lines, especially those without a strong vernalisation requirement and those with a naturally short vegetative period (de Ruiter and Taylor, 1979). Early flowering depresses nutritive quality (Taylor *et al.*, 1977) and may cause plants to set seed and senesce (Rossiter, 1966).

This paper describes the late winter-spring pattern of crop growth and flowering of five legume species measured at Palmerston North after four sowings from early to late autumn. Data from this trial has been supplemented with other published information from Kaitaia and Palmerston North to obtain a general relationship between legume yield and accumulated degree-days above 10°C.

MATERIALS AND METHODS

Five cool-season annual legumes were sown at Palmerston North in autumn 1978. These were *Trifolium vesiculosum* cv. Yuchi, *Trifolium*

TABLE 1: Legume species, seeding rate, 1000 seed weight and rhizobia strains, Palmerston North 1978.

Species	Seeding rate (kg/ha)	1000 Seed weight (g)	Rhizobia strain
T. vesiculosum	15	1.2	NZP 550/2
T. subterraneum	15	7.8	PDD 2174 + PDD 2713
M. polymorpha	15	3.5	NZP 4018
O. sativus	15	3.8	PDD 3154
V. dasycarpa	30	35.3	NZP 5225

subterraneum cv. Woogenellup, *Medicago polymorpha* SA 4364, *Ornithopus sativus* G19 and *Vicia dasycarpa* cv. Namoi; and were chosen because they were among varieties which had shown promise as potential forage crops in New Zealand (Taylor *et al.*, 1979a), and covered a wide range of species and seed sizes (Table 1).

The experimental site was on a Tokomaru silt loam soil which had previously lain fallow for 12 months after maize. Seed was sown on 13 March, 4 April, 26 April and 18 May 1978; through a drill mounted with cone seeders. Row spacing was 150 mm. Seeding rates are shown in Table 1 and all seed was innoculated before sowing with effective rhizobia (Taylor *et al.*, 1979a). The seed was mixed with peat cultures plus gum arabic and then covered with powdered calcium carbonate. All species had more than 85% viable seed and the hard seed content was reduced by scarifying. *O. sativus* seed was not dehulled. Molybdenised fertilizer at 48 kg/ha P, 112 kg/ha K and lime 1 tonne/ha was cultivated into the site before sowing. The resultant soil pH was above 6.4. Each plot was 3 m x 5.5 m and the trial was a randomized block design with 3 replicates.

The first two planting dates were established using irrigation because of the atypically dry weather in early autumn. Cumulative yield harvests of 0.5 x 0.5 m^2 were taken on 17 July, 4 September, 26 September, 11 October and 17 November 1978.

Data from this trial were supplemented with data from previous trials at Kaitaia in 1976 and 1977 and Palmerston North in 1977 as described by Taylor *et al.* (1979a), to obtain a general relationship between legume yield and accumulated degree-days above 10°C.

Two trials were run at Kaitaia in 1976, one on a Ruakaka peaty sandy loam and one on a Houhora sand. Both trials were sown on 7 April 1976 and cumulative yield harvests were taken on 28 June, 26 August and 27 October on the Ruakaka loam and on 14 June, 16 August and 18 October on the Houhora sand. Another trial was sown on the Houhora sand on 13 April 1977 and harvested on 28 October. At Palmerston North a trial was sown on 1 April 1977 and harvested on 26 October. Flowering was considered to have occurred when the first petals were visible.

Climatological data for Kaitaia aerodrome (A53021) and Grasslands Division, DSIR, Palmerston North (E05363) were obtained from the New Zealand Meteorological Service.

RESULTS AND DISCUSSION

Seasonal patterns of legume forage accumulation at Palmerston North were markedly affected by sowing rate. The first and second sowings of four species established relatively quickly, grew throughout winter and reached yields of between 5

TABLE 2: Accumulated legume yield (tonnes DM/ha) after four sowing dates at Palmerston North, 1978.

	Legume species				
	M. polymorpha	*T. vesiculosum*	*T. subterraneum*	*O. sativus*	*V. dasycarpa*
Sown 13 March					
Harvest date					
17/ 7	2.9	0.5	0.7	3.0	2.0
4/ 9	4.5	1.3	3.1	5.8	3.5
26/ 9	5.0	2.5	3.2	6.8	4.5
11/10	6.1	2.7	5.2	7.9	5.1
17/11	6.5	6.5	8.1	10.0	7.9
Sown 4 April					
Harvest date					
4/ 9	1.9	–	1.9	4.4	2.7
26/ 9	2.5	0.7	3.0	5.4	3.5
11/10	3.6	1.1	4.9	4.7	4.9
17/11	6.4	2.7	9.0	8.6	5.0
Sown 26 April					
Harvest date					
26/ 9	1.0	–	0.3	0.4	1.6
11/10	1.9	0.4	1.1	1.1	2.3
17/11	4.0	0.9	4.2	4.3	5.3
Sown 18 May					
Harvest date					
26/ 9	0.6	–	0.2	0.1	1.2
11/10	1.7	0.1	0.9	0.9	2.2
17/11	6.1	0.9	4.9	4.7	5.6

L.S.D. 5% (final yields only)
Between sowings 0.9
Between species 0.7

and 10 tonnes DM/ha by mid-November (Table 2), although *T. vesiculosum, V. dasycarpa* and *O. sativus* yielded significantly less in the second sowing than the first.

Excessively wet conditions at the third sowing caused smearing and compaction of the seedbed and reduced germination. This probably caused yields to be comparable with or slightly lower than those of the fourth sowing. Small seedlings from both these later plantings virtually ceased growth over winter, and most species did not recommence growth until October. By mid-November, total yields of the later two sowings (0.9 - 4.9 t/ha) of *T. vesiculosum, T. subterraneum* and *O. sativus* were generally less than half of the yields from the two earlier sowings (2.7 - 10 t/ha). *V. dasycarpa* was an exception and the later sown seedlings maintained some growth over the winter and achieved a final yield in the spring similar to the 4 April sowing. The large seed of this species probably assisted rapid seedling establishment.

At trials near Kaitaia in 1976 and 1977 (Taylor *et al.*, 1979b) these legumes produced final yields of between 4.7 and 10.8 tonnes DM/ha when sown between 7 and 13 April and harvested between 18 and 28 October. Meteorological data from Palmerston North and Kaitaia were obtained in an attempt to explain these sowing date/site/year effects. Data in Table 3 show the correlation between accumulated degree-days above 10°C with individual species yields. Fig. 1 shows the general relationship between yield and accumulated degree-days above 10°C. This temperature was chosen on the basis of Australian experience with subterranean clover, where Kemp (1975) reported reduced establishment and growth at soil temperatures below 13°C and noted that sites with winter soil temperatures below 7°C were unsuitable for subterranean clover. Significant correlations were obtained between yield and degree-days above 10°C for all five species (Table 3).

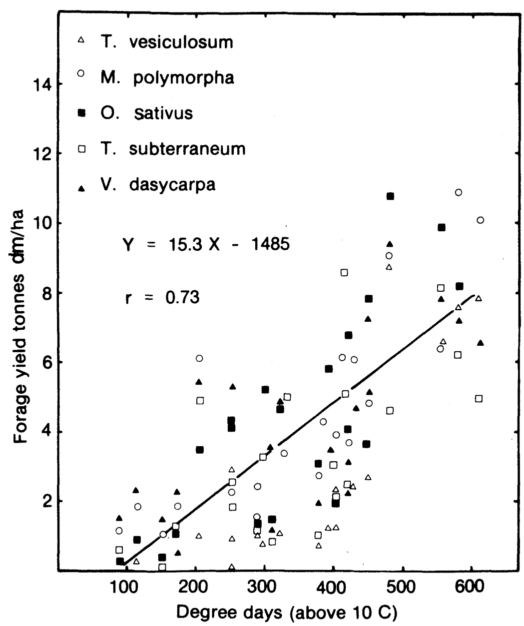
TABLE 3: Correlation between degree-days above 10°C and individual species yields.

Species	r	Regression
T. vesiculosum	0.82***	Y = 15.8X – 3201
M. polymorpha	0.81***	Y = 14.7X – 359
O. sativus	0.83***	Y = 14.7X – 1127
T. subterraneum	0.71***	Y = 14.0X – 1127
V. dasycarpa	0.68***	Y = 11.4X – 170

The general relationship between forage yield and temperature (Fig. 1) can be useful in predicting regions in which annual forage legumes may be grown. A degree-day accumulation of at least 500 units would appear to be required to obtain satisfactory yields (> 6 t DM/ha). Palmerston North sowing 1 and Kaitaia both had greater than 500 degree-days over the growing period (Table 4).

Seedling establishment after sowing was slowed by the progressively less favourable conditions of late autumn. This could be explained by the early diversion of photosynthate into nitrogen fixation. Photosynthate in legumes is used in nitrogen fixation as well as being partitioned into root and shoot growth. This requires considerable amounts of energy

Figure 1: Relationship between annual legume forage yield and accumulated degree-days above 10°C.



with nodules using about 5 g carbon to fix 1 g of nitrogen (Pate and Herridge, 1978). Rates of nitrogen fixation in the Palmerston North trial increased more rapidly than shoot production early in establishment of the legumes and then plateaued well before maximum dry matter accumulation (de Ruiter, in preparation).

Kemp (1975) has also reported that late sowing of subterranean clover in New South Wales resulted in delayed nodulation and reduced growth at low temperatures, while established swards continued to grow well at the same low temperatures. Poor nodulation and energy supply for nitrogen fixation at the low Palmerston North temperatures early in the growth period may have been partly responsible for the very slow growth during winter (Table 4).

TABLE 4: Growth period parameters at Palmerston North and Kaitaia. Final harvests made on 17 November

Site	Sowing date	Degree-days above 10°C		Total days of growth
		1st 6 weeks	growth period	
KT	7/4	225	616	203
PN1	13/3	287	590	252
PN2	4/4	202	439	231
PN3	26/4	65	290	210
PN4	18/5	28	237	189

The time of flowering of the legumes was little affected by sowing date despite the resultant large differences in crop growth. No effect of sowing date on the time of flowering of *T. vesiculosum* (17 November), *T. subterraneum* (1 October). *M. polymorpha* (4 September), or *V. dasycarpa* (6 October) was observed by weekly inspection.

However, flowering of the two early sowings of *O. sativus* occurred on about 2 October, whereas the two later sowings flowered about three weeks later. There was no indication with these legumes that early sowing caused excessively early flowering and subsequent senescence in spring.

CONCLUSIONS

A degree-day accumulation (above 10°C) of at least 500 units during a growth season appears to be necessary for legume yields greater than 6 tonne/ha to be obtained. Temperature data can be used to suggest regions in which forage legumes may be grown.

Most legumes must be sown by early April if yields greater than 4-5 tonne/ha are to be harvested in September. Later sowing results in most yield being produced in the period September - November.

It is unlikely that early flowering and senescence in spring will occur with the five species grown in these trials when they are sown later than 15 March.

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