Effect of defoliation interval and height on the growth and quality of *Arachis pintoi* cv. Amarillo

K. SINCLAIR[1], K.F. LOWE[2] AND
K.G. PEMBLETON[3]
[1] *NSW Department of Primary Industries, Wollongbar, New South Wales*
[2] *Department of Primary Industries and Fisheries, Mutdapilly Research Station, Peak Crossing, Queensland*
[3] *University of Queensland, School of Agronomy and Horticulture, St Lucia, Queensland, Australia*

Abstract

The effect of defoliation on Amarillo (*Arachis pintoi* cv. Amarillo) was studied in a glasshouse and in mixed swards with 2 tropical grasses. In the glasshouse, Amarillo plants grown in pots were subjected to a 30/20°C or 25/15°C temperature regime and to defoliation at 10-, 20- or 30-day intervals for 60 days. Two field plot studies were conducted on Amarillo with either irrigated kikuyu (*Pennisetum clandestinum*) in autumn and spring or dryland Pioneer rhodes grass (*Chloris gayana*) over summer and autumn. Treatments imposed were 3 defoliation intervals (7, 14 and 28 days) and 2 residual heights (5 and 10 cm for kikuyu; 3 and 10 cm for rhodes grass) with extra treatments (56 days to 3 cm for both grasses and 21 days to 5 cm for kikuyu).

Defoliation interval had no significant effect on accumulated Amarillo leaf dry matter (DM) at either temperature regime. At the higher temperature, frequent defoliation reduced root dry weight (DW) and increased crude protein (CP) but had no effect on stolon DW or *in vitro* organic matter digestibility (OMD). On the other hand, at the lower temperature, frequent defoliation reduced stolon DW and increased OMD but had no effect on root DW or CP. Irrespective of temperature and defoliation, water-soluble carbohydrate levels were higher in stolons than in roots (4.70 *vs* 3.65%), whereas for starch the reverse occurred (5.37 *vs* 9.44%).

Defoliating the Amarillo-kikuyu sward once at 56 days to 3 cm produced the highest DM yield in autumn and spring (5832 and 7121 kg/ha DM, respectively), although the Amarillo component and OMD were substantially reduced. Highest DM yields (1726 kg/ha) were also achieved in the Amarillo-rhodes grass sward when defoliated every 56 days to 3 cm, although the Amarillo component was unaffected.

In a mixed sward with either kikuyu or rhodes grass, the Amarillo component in the sward was maintained up to a 28-day defoliation interval and was higher when more severely defoliated. The results show that Amarillo can tolerate frequent defoliation and that it can co-exist with tropical grasses of differing growth habits, provided the Amarillo-tropical grass sward is subject to frequent and severe defoliation.

Correspondence: K. Sinclair, NSW DPI, Wollongbar Agricultural Institute, 1243 Bruxner Highway, Wollongbar, NSW 2477, Australia. E-mail: katrina.sinclair@dpi.nsw.gov.au

Introduction

From late spring to mid-autumn, tropical grass pastures provide a low-cost feedbase for grazing cows in the subtropical dairy region, which extends from the north coast of New South Wales (NSW) to the Atherton Tablelands in far north Queensland (Qld). Kikuyu (*Pennisetum clandestinum*) and other tropical grasses such as setaria (*Setaria sphacelata*), rhodes grass (*Chloris gayana*) and paspalum (*Paspalum dilatatum*) are capable of producing >15 t dry matter (DM)/ha/yr, when fertilised with nitrogen (50-60 kg N/ha/month) (Fulkerson 1997). Reeves *et al*. (1996) found that grazing well fertilised kikuyu at the 4.5 leaves/tiller stage optimised forage quality for dairy cattle and DM yield. On the north coast of NSW, the leaf appearance interval for kikuyu can be as short as 3 days in summer and as much as 8 days in autumn-winter (Fulkerson *et al*. 1999).

Cowan *et al*. (1974; 1975) and Davison *et al*. (1985) showed that, although twining tropical legume-based pastures were of higher quality than tropical grass pastures fertilised with N, twining legumes failed to persist under the high stocking rates required by intensive subtropical dairy systems. In another study seeking to improve the forage quality of tropical grass pastures, Fulkerson and Slack (1996) established and maintained white clover (*Trifolium repens* cv. Haifa) in an existing kikuyu sward. After 2 years, however, the vigour of white clover declined due to infection by the root-knot nematode (*Meloidogyne trifoliophila*) (Zahid *et al*. 2000).

Subsequently, a range of warm season legumes was evaluated for their ability to spread through a tropical grass sward and to tolerate moderate grazing pressure. Amarillo (*Arachis pintoi* cv. Amarillo), which originates from central Brazil, was identified by Cook *et al*. (1999) to be one of the most promising legume species. They found Amarillo had the ability to withstand grazing by cattle at moderate stocking rates and to be highly productive where annual rainfall exceeded 1500 mm. Compared with N-fertilised tropical grass pastures, Amarillo has been found to increase late summer-autumn milk production by a litre per cow per day (Walker and Chamberlain 2005).

For a productively useful legume to co-exist in a tropical grass pasture grazed by dairy cows, it should possess a number of attributes, including: a similar growth pattern to the grass; sufficient aggressiveness to maintain its contribution to sward productivity; and the ability to improve forage quality. The aim of this study was to determine, in a subtropical environment, the effect of defoliation frequency and temperature on the growth and quality of Amarillo and the effect of defoliation management on production and forage quality of an Amarillo-tropical grass sward.

Materials and methods

Study 1

This study was undertaken in a glasshouse under natural light at the Wollongbar Agricultural Institute (WAI), Wollongbar (28°50′S, 153°25′E), NSW, Australia to determine the effect of temperature and defoliation on the growth and forage quality of Amarillo. Consecutive experiments were conducted from March to July 2004 (Study 1a) and from July to December 2004 (Study 1b) using 3 temperature-controlled chambers.

Plant establishment. Thirty-six Amarillo plants were established in plastic pots (190 mm diameter × 190 mm depth, 1 plant/pot) for Study 1a and a further 36 plants for Study 1b from seed sown on March 4 and July 14, 2004, respectively. In each study, 3 groups of 12 pots were randomly selected following sowing and one placed in each of the 3 temperature chambers, which were set at 25°C (day, 12 h) and 20°C (night, 12 h) for the first 8 weeks. The Amarillo plants were placed on the glasshouse tables so as to have sufficient space between them for the stolons to extend beyond the pot rim and spread over the table.

Each pot contained a potting mixture of 50% hardwood sawdust, 30% composted pinebark fines and 20% coarse river sand with micro- and trace elements. Plants were fertilised every 30 days with a controlled-release fertiliser (14% N, 6.1% P, 11.6% K) to ensure nutrient availability was non-limiting. Plants were watered 4 times daily to compensate for evapotranspiration losses.

Experimental design. In Studies 1a and 1b at 8 weeks after sowing, half of the leaves were removed from all Amarillo plants by cutting one leaflet from each leaf on each stolon. At the same time, the temperature regime in the 3 chambers in Study 1a was reset to 30°C (day, 12 h) and 20°C (night, 12 h) based on the mean long-term summer maximum and minimum temperatures for Casino (28°53′S, 153°25′E; elevation 40 m), a coastal plain site, which was the most likely environment for commercial planting of Amarillo, and in Study 1b, it was reset to 25°C (day, 12 h) and 15°C (night, 12 h) based on the mean long-term spring/autumn maximum and minimum temperatures for Casino. In both studies, the temperature regimes were imposed until the completion of the experimental period 60 days later.

Defoliation treatments were also imposed at 8 weeks after sowing in both studies with 4 randomly selected Amarillo plants in each chamber being defoliated at 10- (10 × 6), 20- (20 × 3) or 30- (30 × 2) day intervals for the next 60 days.

Measurements. At the assigned defoliation intervals, the Amarillo plants were defoliated by cutting one leaflet from each leaf on each stolon and the harvested leaf material was dried in a

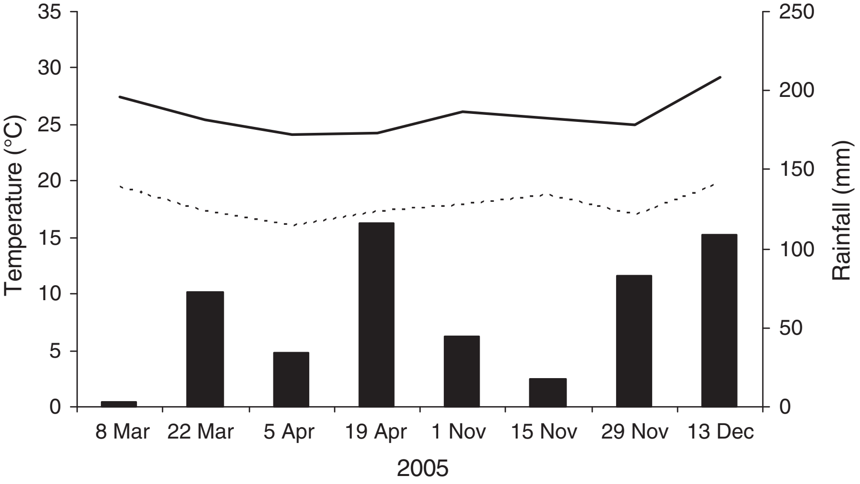

Figure 1. Mean fortnightly rainfall (solid bars) and mean fortnightly maximum (solid line) and minimum (dashed line) temperatures at Wollongbar Agricultural Institute during the studies.

forced-draught oven at 80°C for 24 hours to determine leaf DM. At 60 days, all plants were destructively harvested, material was sorted into leaf, stolons and roots and DM yields of each determined as described above. Branching was determined by counting the primary stolons that originated from the crown and the secondary stolons that formed from the primary stolons.

The roots were separated from the potting mix by washing the contents of the pot in water immediately after the above-ground plant material had been removed. The dried leaves, stolons and roots were ground through a 1-mm sieve in preparation for analysis. Leaf material was analysed for *in vitro* organic matter digestibility (OMD), crude protein (CP) and minerals. Stolons and roots were analysed for water-soluble carbohydrates (WSC) and starch.

Chemical analyses. OMD was determined using the pepsin-cellulase method, in which the sample was digested at 40°C with acidified pepsin, heated to 80°C and digested with thermo-stable alpha amylase and then digested at 40°C with a buffered cellulase solution following pH adjustment to 4.6 (AFIA Fodder Analyst's Lab Manual — Method 5 2002).

The concentration of total N was determined by dry combustion using the LECO™ instrument (based on Plant method 9B, Horneck and Miller 1998) and CP concentration was calculated as N% × 6.25. Phosphorus, K, Ca, Mg and Na concentrations were determined using a nitric-perchloric acid digest and inductively coupled plasma atomic emission spectrometry (ICP-AES) (USEPA 2000).

WSC and starch concentrations were determined by cold extraction of the plant material and the use of an auto-analyser (Sinclair *et al.* 2006).

Study 2

This plot study was undertaken to determine the effect of defoliation management (frequency and height) on forage production and quality of an Amarillo-kikuyu sward at WAI (average annual rainfall 1600 mm) from February 24 to April 19, 2005 and then from October 19 to December 14, 2005. The experimental pasture was an established 'common' kikuyu pasture, into which Amarillo seed had been direct-drilled at 20 kg/ha in February 2003.

Site. The soil was a highly permeable Red Ferrosol (Isbell 1996) with analysis in the top 75 mm: pH($CaCl_2$) 4.60, P(Bray I) 47 mg/kg, Al 0.68 cmol(+)/kg, Ca 4.9 cmol(+)/kg, K 0.55 cmol(+)/kg, Mg 0.78 cmol(+)/kg and Na <0.1 cmol(+)/kg. The 2-weekly rainfall and 2-weekly mean maximum and mean minimum ambient temperatures for the experimental periods are shown in Figure 1.

Overhead sprinklers were used to irrigate the plots weekly, when 28 mm was applied.

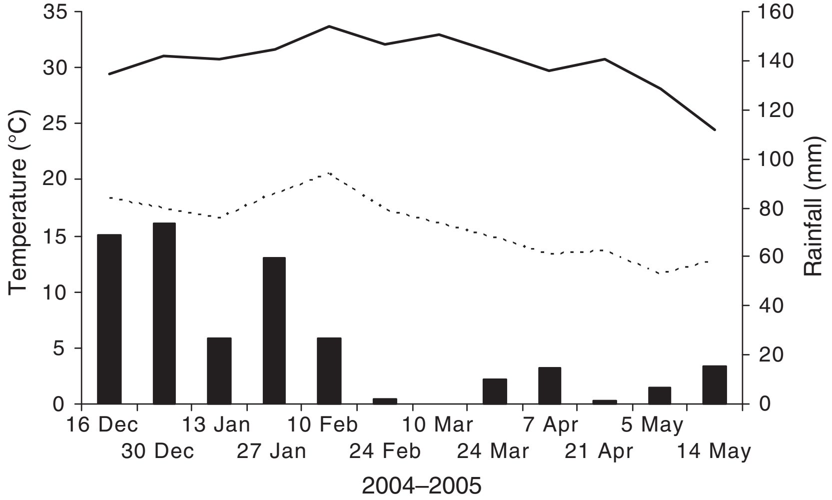

Figure 2. Mean fortnightly rainfall (solid bars) and mean fortnightly maximum (solid line) and minimum (dashed line) temperatures at Mutdapilly Research Station during the study.

Experimental design. Plots (2 m × 2 m) were laid out in a randomised complete block design with 3 replications in a factorial arrangement with 2 extra treatments. The treatment combinations imposed were 3 defoliation frequencies (7, 14 and 28 days) and 2 defoliation heights (5 and 10 cm) with 2 extra defoliation treatments (every 56 days to 3 cm; and every 21 days to 5 cm).

Measurements. At each harvest, the entire plot was cut with a rotary mower to treatment residual height, the harvested herbage was weighed and a subsample taken, which was dried in a forced-draught oven at 80°C for 24 h to determine DM yield. Prior to harvesting a treatment plot, material on a 30 cm × 30 cm quadrat was cut using hand-held grass shears at the relevant treatment height for determining botanical composition. At the final harvest, the dried herbage subsample of legume-grass pasture was analysed for OMD and CP using the methods described in Study 1.

Study 3

This plot study was undertaken to determine the effect of defoliation management (frequency and height) on forage production of Amarillo in a mixed sward with Pioneer rhodes grass at Mutdapilly Research Station (MRS) (27°46'S, 152°40'E; average annual rainfall 800mm), Peak Crossing, Qld, Australia from December 3, 2004 to May 14, 2005.

Site. The soil was a moderately cracking Black Vertosol with analysis in the top 100 mm: $pH_{(H_2O)}$ 6.4, P (Colwell) 217mg/kg, Ca 16.0 cmol(+)/kg, K 1.20 cmol(+)/kg, Mg 20 cmol(+)/kg and Na 2.3 cmol(+)/kg. The 2-weekly rainfall and 2-weekly mean maximum and mean minimum ambient temperatures for the experimental period are shown in Figure 2.

Experimental design. Plots (2 m × 2m) were laid out in a randomised complete block design with 3 replications in a factorial arrangement, with one extra treatment added. The treatment combinations imposed were 3 defoliation frequencies (7, 14 and 28 days) and 2 defoliation heights (3 and 10 cm), with an extra treatment (every 56 days to 3 cm).

Measurements. DM yield and botanical composition were determined as in Study 2. No nutritive quality parameters were measured.

Statistical analyses

In all studies, comparisons between treatment means were analysed using the General Linear Model (Ryan *et al.* 1985), with defoliation interval nested within temperature in Study 1. Differences between means were compared using least significant difference (LSD) at a 5% probability level. If the differences between treatment means were not significant, the treatment mean (± s.e.) is shown.

Table 1. Total dry weights of leaves, stolons and roots and number of primary and secondary stolons (mean ± s.e.) for *Arachis pintoi* cv. Amarillo after 60-days growth, while subjected to defoliation every 10, 20 or 30 days and to a temperature regime of 30/20°C or 25/15°C (day/night).

Defoliation interval	Leaves	Stolons	Roots	No. primary stolons	No. secondary stolons
(d)		(g/plant)			
			30/20°C		
10	18.53 ± 2.09	15.91 ± 2.68	3.68	8.58 ± 1.23	13.83 ± 0.44
20	19.24 ± 2.46	21.90 ± 2.63	5.35	8.58 ± 0.58	14.58 ± 2.11
30	16.87 ± 2.56	20.41 ± 3.75	5.85	8.25 ± 0.75	13.42 ± 1.59
LSD (P = 0.05)	ns	ns	1.23	ns	ns
			25/15°C		
10	29.92 ± 5.57	32.42	9.36 ± 0.83	10.92 ± 1.17	45.75
20	33.41 ± 5.70	40.29	9.93 ± 0.97	12.00 ± 1.18	49.58
30	35.94 ± 7.09	46.62	10.02 ± 0.88	11.25 ± 0.90	57.42
LSD (P = 0.05)	ns	5.43	ns	ns	3.90

Results

Study 1

Defoliation interval had no significant effect on accumulated leaf DM yield of Amarillo plants, irrespective of temperature (Table 1). Leaf:stolon ratio was reduced by extending the defoliation interval, which was a reflection of increasing stolon dry weight.

At the higher temperatures, root DMs of plants defoliated at 20- and 30-day intervals were significantly greater than root DM of plants defoliated at 10-day intervals.

Defoliation interval had no significant effect on the number of primary stolons branching from the crown at high or low temperatures (Table 1). At the lower temperatures, the number of secondary stolons branching from primary stolons increased with less frequent defoliation and this was significant ($P<0.05$) at the 30-day defoliation interval. OMD declined as the defoliation interval was extended from 20 to 30 days but the effect was significant ($P<0.05$) only at the lower temperatures (Table 2).

Extending the defoliation interval from 10 to 30 days at the higher temperatures decreased CP from 24.2% to 21.3% ($P<0.05$), but defoliation interval had no significant effect ($P>0.05$) on CP concentration at the lower temperatures.

The concentrations of P, Mg and Na in leaves were not significantly affected by temperature or

Table 2. Mean (± s.e.) for *in vitro* organic matter digestibility (OMD) and crude protein (CP), potassium (K) and calcium (Ca) concentrations in *Arachis pintoi* cv. Amarillo leaf after 60-days growth, while subjected to defoliation every 10, 20 or 30 days and to a temperature regime of 30/20°C or 25/15°C (day/night).

Defoliation interval (d)	OMD (%)	CP	K (%DM)	Ca
			30/20°C	
10	68.7 ± 0.17	24.17	2.47	1.47
20	68.3 ± 0.93	22.29	2.27	1.60
30	66.8 ± 0.73	21.25	2.23	1.67
LSD (P = 0.05)	ns	1.61	0.19	0.14
			25/15°C	
10	67.8	22.50 ± 0.36	2.17	1.50
20	67.3	22.71 ± 0.75	1.90	1.50
30	61.8	22.08 ± 0.21	2.03	1.33
LSD (P = 0.05)	2.64	ns	0.19	0.14

Table 3. Water-soluble carbohydrate (WSC) and starch concentrations in stolons and roots of *Arachis pintoi* cv. Amarillo after 60-days growth, while subjected to defoliation every 10, 20 or 30 days and to a temperature regime of 30/20°C or 25/15°C (day/night).

	Stolons		Roots	
Defoliation interval	WSC	Starch	WSC	Starch
(d)	(% DM)			
	30/20°C			
10	5.40 ± 0.82	6.56 ± 1.93	4.10 ± 0.79	11.93 ± 0.75
20	6.23 ± 0.92	8.48 ± 0.43	4.13 ± 0.72	14.66 ± 2.32
30	6.17 ± 0.88	9.04 ± 1.85	4.53 ± 0.52	15.15 ± 2.18
	25/15°C			
10	3.57 ± 0.49	2.50 ± 0.54	3.63 ± 0.68	4.37 ± 0.15
20	3.40 ± 0.46	2.79 ± 0.29	3.00 ± 0.25	5.57± 1.11
30	3.43 ± 0.69	2.82 ± 0.79	2.53 ± 0.15	5.04 ± 0.46

defoliation interval, mean values being 0.57 ± 0.04, 0.45 ± 0.02 and 0.14 ± 0.02 % DM, respectively. Irrespective of temperature, the level of K in leaves decreased as the defoliation interval was extended and this effect was significant from the 10- to 20-day interval (Table 2). In response to decreased defoliation frequency, leaf Ca concentration increased at the higher temperatures, and decreased at the lower temperatures.

There was no significant effect of defoliation interval on the concentrations of WSC or starch in stolons and roots at high or low temperatures (Table 3). Irrespective of temperature and defoliation interval, WSC% was higher in stolons than in roots, while the reverse was true for starch.

Table 4. Dry matter (DM) yields of *Arachis pintoi* cv. Amarillo and grass + Amarillo in a kikuyu-Amarillo pasture in autumn and spring and organic matter digestibility (OMD) and crude protein (CP) concentration of the mixed pasture, defoliated at various frequencies and heights at Wollongbar Agricultural Institute.

Defoliation interval	Defoliation height	Amarillo yield	Total yield	OMD	CP
(d)	(cm)	(kg/ha)		(%)	
		Autumn			
7	5	432	2725	68.8	27.2
7	10	376	1847	70.0	27.8
14	5	564	3746	67.0	25.8
14	10	223	3004	66.7	26.1
21	5	468	3374	69.0	26.0
28	5	609	4451	66.0	25.6
28	10	223	3620	66.7	24.8
56	3	0	5832	59.8	19.8
LSD (P = 0.05)		458	462	2.3	1.2
		Spring			
7	5	92 ± 334	2889	65.0	20.6 ± 3.6
7	10	137 ± 86	2975	65.0	22.9 ± 1.5
14	5	212 ± 47	4111	65.0	21.9 ± 0.4
14	10	217 ± 26	4026	63.7	23.1 ± 1.3
21	5	122 ± 36	4934	66.3	18.1 ± 3.3
28	5	312 ± 151	5148	64.3	19.2 ± 0.4
28	10	182 ± 25	4720	63.3	19.6 ± 0.6
56	3	65 ± 86	7121	54.0	18.8 ± 2.2
LSD (P = 0.05)		ns	936	1.4	ns

Study 2

Accumulated DM yield of the Amarillo-kikuyu sward at the completion of a 56-day cycle in autumn and spring was affected by defoliation pattern (Table 4). Defoliating once at 56 days to a 3 cm residual height resulted in the highest total sward yields of 5832 and 7121 kg /ha DM in autumn and spring, respectively. However, the proportion of Amarillo was substantially affected. Lowering the defoliation height from 10 to 5 cm at 7-, 14- and 28-day defoliation intervals significantly increased sward DM yield in autumn but not in spring.

The contribution of Amarillo to sward DM yields differed in response to defoliation and season. In autumn and spring, defoliating at 56-day intervals to 3 cm substantially suppressed the yield of Amarillo, although this was significant only in autumn. Legume yields were higher when the sward was defoliated to 5 cm in autumn, whereas defoliation height had no effect on legume yield in spring.

OMD was affected by defoliation regime in both autumn and spring, whereas CP was affected in autumn only. The mean values for OMD and CP in autumn were 66.8% and 25.4%, respectively, which were 2.7 and 4.9% units, respectively, above mean values in spring (Table 4).

Study 3

Total DM yields at the completion of 168 days (3 × 56-day cycles) differed significantly with defoliation regime, with the highest sward yield (1726 kg/ha DM), when the stand was defoliated every 56 days to 3 cm residual height (Table 5).

Table 5. Dry matter (DM) yields of *Arachis pintoi* cv. Amarillo and grass + Amarillo in a rhodes grass-Amarillo pasture from December 2004 to May 2005 (168 days), defoliated at various frequencies and heights at Mutdapilly Research Station.

Defoliation interval	Defoliation height	Amarillo yield	Total yield
(d)	(cm)	(kg/ha)	(kg/ha)
7	3	100	506
7	10	15	379
14	3	109	897
14	10	30	643
28	3	76	1180
28	10	31	824
56	3	130	1726
LSD (P=0.05)		80	533

Yield of Amarillo was also affected significantly by defoliation regime and its contribution to sward yield varied from 4% to 20%. At the 7-, 14- and 28-day defoliation intervals, increasing the defoliation height from 3 cm to 10 cm substantially reduced the Amarillo yield, but differences generally failed to reach significance.

Discussion

In this study, Amarillo peanut was able to withstand defoliation intervals as short as 7 days to residue heights of 3–5 cm without a substantial decline in yield. In a mixed sward with either kikuyu or rhodes grass, the contribution of Amarillo to sward DM yield was maintained up to a 28-day defoliation interval and was even higher when more severely defoliated. This is in agreement with previous Amarillo-tropical grass grazing studies, in which Amarillo DM yields were higher under high stocking pressure (Hernandez *et al.* 1995; Ibrahim and Mannetje 1998). However, when the grazing interval was extended to 56 days, the Amarillo almost disappeared from the sward irrespective of companion tropical grass or season.

In contrast, the twining tropical legumes such as siratro (*Macroptilium atropurpureum*) (Jones 1974) and Tinaroo glycine (*Glycine wightii* cv. Tinaroo) (Cowan *et al.* 1975) have been found to lack persistence when subjected to severe defoliation, but have a tendency to dominate the tropical grasses under lax defoliation. The differing abilities of tropical legumes to withstand frequent hard defoliation as required in subtropical dairy systems can be explained to some extent by their different growth habits and the extent to which their growing points are vulnerable to grazing (Jones and Jones 1978).

The ability of Amarillo to be persistent under frequent defoliation may also be linked to its ability to retain carbohydrate levels in its tap-root and stolons. Lack of persistency in plants under frequent defoliation is commonly associated with depletion in plant reserves and even more so when exposed to high temperature (Slack *et al.* 2000; Fulkerson and Donaghy 2001). In this study, although root and stolon dry weights were reduced by more than 30% at high and low temperatures, respectively, under frequent defoliation, this was not associated with a decline in starch and WSC concentrations in either the roots or stolons. Similarly, Jones (1974) found that, when siratro was cut every 4, 8 or 16 weeks to 7.5 cm stubble height, neither root size nor concentration of root soluble carbohydrates increased with increasing interval. The concentration of starch in Amarillo roots was almost twice that in stolons, irrespective of defoliation frequency and temperature, indicating that, for Amarillo, starch is the primary energy reserve which is preferentially stored in the tap-root. In contrast, stolon and root WSC showed no definite response to temperature or defoliation frequency.

In the glasshouse, Amarillo appeared to be more productive, particularly in terms of leaf and stolon DM, at a 25/15°C temperature regime than at 30/20°C. This was unexpected as Amarillo was selected from a low altitude humid tropical environment in coastal Brazil (15°S, 39°W). This response of Amarillo to lower temperatures probably warrants further study, particularly as it is expected to be grown in Australia in a subtropical rather than a tropical environment.

The ability of a tropical legume to spread is another important characteristic if it is to compete with an associated tropical grass. Under a lower temperature regime (25/15°C), Amarillo stolon dry weight increased by 44% with increasing defoliation interval and this was attributed to a 26% increase in number of secondary stolons. The number of primary stolons emanating from the crown was unaffected by defoliation and temperature. It could be presumed that early and late season Amarillo growth could be associated with stronger stolon growth, particularly as the grazing interval would be less frequent in response to the lower growth rate of the tropical grasses.

In the glasshouse, OMD of Amarillo fell when the defoliation interval was extended from 20 to 30 days, particularly at the lower (25/15°C) temperature regime (67. 3 *vs* 61.8%) and this was due in part to a marked fall in the proportion of leaf to stolon. In the Amarillo-kikuyu pasture, however, OMD was unaffected by increasing defoliation interval up to 28 days in both the early and later part of the year (66.4 and 63.8%, respectively). However, by 56 days, OMD had fallen to 59.8% in autumn and even further in spring, and this reflected the kikuyu dominance in the pasture. Reeves *et al.* (1996) showed a sharp decline in OMD of kikuyu after 25 days of regrowth, which was associated with a marked fall in the leaf:stem ratio.

Leaf CP of Amarillo in the glasshouse remained above 21% irrespective of temperature and defoliation interval. In the field, at each defoliation interval, CP values in the kikuyu-Amarillo pasture were higher in autumn than spring. Higher CP in autumn is most probably related to the higher Amarillo content in the pasture and a higher growth rate in Amarillo during that period (K. Sinclair, unpublished data). The CP values found in both the glasshouse and field studies are above the recommended CP value (15% DM) for a 600 kg Friesian cow producing 20 L milk/day (NRC 1989).

The concentration of nutrients (except K and Na) in Amarillo leaf under high and low temperature regimes and at all defoliation levels was higher than in kikuyu leaf (Fulkerson *et al.* 1998). Except for Na, Amarillo leaf mineral levels exceeded the recommended levels for lactating cows (NRC 1989).

In subtropical dairy systems, the vigorous summer-autumn growth of tropical grasses, which require frequent and close grazing to maintain forage quality, has been a significant factor against the successful inclusion of a tropical legume (Cowan and Lowe 1998). Amarillo, however, has a number of attributes, such as a stoloniferous and prostrate growth habit and ability to flower readily and set seed (Cook *et al.* 1999), that favour its persistence over other tropical legumes. The results from this study indicate that a mixed Amarillo-tropical grass sward needs frequent and severe defoliation to enable the Amarillo to compete successfully without any loss in productivity. Amarillo also has the added benefit of supplying N to the sward and improving the quality of forage on offer.

Acknowledgements

The authors acknowledge the technical assistance provided by Mr R.H. Bryant in the glasshouse and the field studies. This work was undertaken as part of a Dairy Australia-funded project entitled 'Warm season legumes for tropical and subtropical dairy production'.

References

AFIA (2002) Method – 5: Determination of digestibility using pepsin – cellulase method. *Fodder Analyst's Laboratory Manual.* (Australian Fodder Industry Association: Balwyn, Victoria).

Cook, B. *et al.* (1999) Evaluation and development of persistent legumes in subtropical dairy pastures. *Final report to Dairy Australia for project DAQ139, Department of Primary Industries and Fisheries, Brisbane, Queensland.*

Cowan, R.T., O'Grady, P., Moss, R.J. and Byford, I.J.R. (1974) Milk and fat yields of Jersey or Friesian cows grazing tropical grass-legume pastures. *Tropical Grasslands,* **8**, 117–120.

Cowan, R.T., Byford, I.J.R. and Stobbs, T.H. (1975) Effects of stocking rate and energy supplementation on milk production from tropical grass-legume pasture. *Australian Journal of Experimental Agriculture and Animal Husbandry*, **15**, 740–746.

Cowan, R.T. and Lowe, K.F. (1998) Tropical and subtropical grass management and quality. In: Cherney, J.H. and Cherney, D.J.R. (eds) *Grass for dairy cattle.* (CABI Publishing: Wallingford, UK).

Davison, T.M., Cowan, R.T. and Shepherd, R.K. (1985) Milk production from cows grazing on tropical grass pastures. 2. Effects of stocking rate and level of nitrogen fertilizer on milk yield and pasture milk yield relationships. *Australian Journal of Experimental Agriculture,* **25**, 515–523.

Fulkerson, W.J. (1997) Priorities for forages for the subtropical Dairy Industry. *Tropical Grasslands,* **31**, 276–281.

Fulkerson, W.J. and Slack, K. (1996) Productivity and persistence of irrigated lotus (*Lotus pedunculatus*) and white clover (*Trifolium repens*) in a kikuyu (*Pennisetum clandestinum*) pasture. *Tropical Grasslands,* **30**, 353–362.

Fulkerson, W.J., Slack, K., Hennessy, D.W. and Hough, G.M. (1998) Nutrients in ryegrass (*Lolium* spp.), white clover (*Trifolium repens*) and kikuyu (*Pennisetum clandestinum*) pastures in relation to season and stage of regrowth in a subtropical environment. *Australian Journal of Experimental Agriculture,* **38**, 227–240.

Fulkerson, W.J., Slack, K. and Havilah, E.J. (1999) The effect of defoliation interval and height on growth and forage quality of kikuyu grass (*Pennisetum clandestinum*). *Tropical Grasslands,* **33**, 138–145.

Fulkerson, W.J. and Donaghy, D.J. (2001) Plant-soluble carbohydrate reserves and senescence – key criteria for developing an effective grazing management system for ryegrass-based pastures: a review. *Australian Journal of Experimental Agriculture*, **41**, 261–275.

Hernandez, M., Argel, P.J., Ibrahim, M.A. and Mannetje, L.'t (1995) Pasture production, diet selection and liveweight gains of cattle grazing *Brachiaria brizantha* with or without *Arachis pintoi* at two stocking rates in the Atlantic Zone of Costa Rica. *Tropical Grasslands*, **29**, 134–141.

Horneck, D.A. and Miller, R.O. (1998) Determination of total nitrogen in plant tissue. In: *Handbook of Reference Methods for Plant Analysis*. (Soil and Plant Analysis Council, CRC Press: LLC).

Ibrahim, M.A. and Mannetje, L.'t (1998) Compatibility, persistence and productivity of grass-legume mixtures in the humid tropics of Costa Rica. 1. Dry matter yield, nitrogen yield and botanical composition. *Tropical Grasslands*, **32**, 96–104.

Isbell, R.F. (1996) *The Australian Soil Classification.* (CSIRO Publishing: Collingwood, Victoria).

Jones, R.J. (1974) Effect of previous cutting interval and of leaf area remaining after cutting on regrowth of *Macroptilium atropurpureum* cv. Siratro. *Australian Journal of Experimental Agriculture and Animal Husbandry*, **14**, 343–348.

Jones, R.J. and Jones, R.M. (1978) The ecology of Siratro-based pastures. In: Wilson, J.R. (ed.) *Plant relations in pastures.* pp. 353–367. (CSIRO: Melbourne, Australia).

NRC (1989) *Nutrient requirements of dairy cattle.* 6th Revised Edn. (National Academy of Sciences: Washington DC).

Reeves, M., Fulkerson, W.J. and Kellaway, R.C. (1996) Forage quality of kikuyu (*Pennisetum clandestinum*): the effect of time of defoliation and a nitrogen fertiliser application and in comparison with perennial ryegrass (*Lolium perenne*). *Australian Journal of Agricultural Research,* **47**, 1349–1359.

Ryan, B.F., Joiner, B.L. and Ryan, T.A. (1985) *Minitab Handbook*. 2nd Edn. (PWS-Kent Publishing Company: Boston).

Sinclair, K., Fulkerson, W.J. and Morris, S.G. (2006) Influence of regrowth time on the forage quality of prairie grass, perennial ryegrass and tall fescue under non-limiting soil nutrient and moisture conditions. *Australian Journal of Experimental Agriculture,* **46**, 45–51.

Slack, K., Fulkerson, W.J. and Scott, J.M. (2000) Regrowth of prairie grass (*Bromus willdenowii* Kunth) and perennial ryegrass (*Lolium perenne* L.) in response to temperature and defoliation. *Australian Journal of Agricultural Research*, **51**, 555–561.

USEPA (2000) Test methods for evaluating solid waste, physical/chemical methods. Method 6010B Revision 3, Inductively coupled plasma atomic emission spectrometry. *SW-846 Manual Chapter 3*. 3rd Edn.

Walker, R.G. and Chamberlain, A. (2005) Amarillo-pinto peanut (*Arachis pintoi*) A persistent tropical legume for subtropical and tropical dairy farming. *Occasional publication. Queensland Department of Primary Industries and Fisheries, Peak Crossing, Queensland.*

Zahid, M.I., Nobbs, J., Stanton, J.M., Gurr, G.M., Hodda, M., Nikandrow, A. and Fulkerson, W.J. (2000) First record of *Meloidogyne trifoliophila* in Australia. *Australasian Plant Pathology,* **29**, 280.

(Received for publication August 9, 2006; accepted March 3, 2007)