INFLUENCE OF TEMPERATURE ON THE DIGESTIBILITY AND GROWTH OF *MACROPTILIUM ATROPURPUREUM* AND *PANICUM MAXIMUM* VAR. *TRICHOGLUME* IN SUBTROPICAL AND TROPICAL AUSTRALIA

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ABSTRACT

Herbage from a multi-site trial of bred lines of the legume Macroptilium atropurpureum *was collected at regular six-weekly harvests over two growing seasons to determine the effect of temperature on dry matter digestibility (DMD) under field conditions. The 18 sites were located throughout the subtropics and tropics of Australia (30°S to 13.5°S). At 10 sites,* Panicum maximum *var.* trichoglume *(green panic) was sown as an associate grass. Whole tops and the most recent fully expanded leaves for two of the* Macroptilium *lines and for green panic were collected.*

Regression analysis showed that for each rise of 1°C in daily maximum or minimum temperature the DMD of Macroptilium *decreased respectively by 0.25 or 0.26 percentage units for tops and 0.19 or 0.14 units for leaf. The decrease in DMD for the grass was larger, being 0.43 and 0.74 units for tops and 0.29 and 0.18 units for leaf. The average DMD was lower for the tropical northern sites (21°S–13°S) than the sub-tropical southern sites (30°S–23°S) by 2.5 and 1.9 units for tops and leaf of* Macroptilium, *and by 3.0 and 1.5 units for tops and leaf of green panic. The DMD advantage of the sub-tropical sites was generally greater in spring and autumn than in summer. The DMD of tops tended to increase with water stress.*

Active growth of both Macroptilium *and green panic was initiated at a daily minimum temperature above c. 12°C (daily mean temperature 17°C) but the responsiveness to temperature of the legume (4.8 kg ha^{-1} day^{-1} per °C) was only half that of the grass (10.8 kg ha^{-1} per day^{-1} per °C).*

The DMD responses to temperature are considered in relation to temperature effects on yield, leaf/stem ratio and leaf development. Some practical implications of the adverse effect of high temperature on herbage quality are considered.

INTRODUCTION

Investigations of the seasonal variation in herbage quality of ryegrass (Deinum *et al.* 1968) and of several tropical and temperate grasses (Minson and McLeod 1970) drew attention to the possible adverse effect of high growth temperatures on dry matter digestibility. Numerous experiments under controlled laboratory conditions have confirmed this effect and provided a good understanding of it (Dirven and Deinum 1977; Wilson 1982).

Wilson and Minson (1980) reviewed the controlled temperature experiments and calculated an average decrease in digestibility of 0.6 and 0.28 digestibility units per 1 °C increase in growth temperature for tropical grasses and legumes, respectively. Using these data and the long-term average summer temperatures for various sites in

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northern Australia, we can calculate that, compared to Samford (27°22′S) near Brisbane, the digestibility of herbage grown at Townsville (19°19′S) and Kununurra (15°39′S) might be expected to be lower on average by 2.3 and 4.3 units respectively for grasses, and 1.1 and 2.0 units for legumes. Similar comparisons based on spring and autumn temperatures indicate that the potential effect should be larger for these seasons than in summer.

However, for pastures in the field there are many other climatic, nutritional and plant factors (Wilson and Minson 1980; Wilson 1982) which may influence digestibility and possibly mask the influence of temperature. A rare opportunity to test the hypothesis that the digestibility of pasture grown in the hotter northern areas of Australia would be in general of lower digestibility than the same pasture grown further south in the sub-tropics, was provided by a multi-site trial originally established by R. J. Jones and site collaborators in N.S.W., Qld and N.T. to test the growth of new lines of *Macroptilium atropurpureum* against the commercial cultivar Siratro.

The trial was established in 1978 at the 18 sites from northern N.S.W. to Darwin. *Panicum maximum* var. *trichoglume* (green panic) was sown as the associated grass at 10 of the sites. All sites were established and managed in a similar manner and harvests taken at 6-weekly intervals during the growing season. To study the effect of temperature on digestibility, samples of whole tops and leaf material were obtained over two growing seasons for two of the *Macroptilium* lines and green panic. This paper presents an analysis of the digestibility and growth data of this material in relation to site variation in temperature.

MATERIALS AND METHODS

Experimental

The trials were established in 1978 and the site locations, soil type and average annual rainfall are are shown in Table 1 (R. J. Jones and site collaborators, *personal communication)*. The sites covered a range of 16° of latitude, with locations up to 1700 km apart from south to north and 1900 km from east to west.

Inoculated seed of the eight bred lines of *Macroptilium atropurpureum* (Hutton *et al.* 1978) and cultivar Siratro were sown at each site at 5 kg ha^{-1} in 3 m × 3 m plots with a 1 m mown guard strip; four replicates of each line were sown. Grass was sown in each plot at 2 kg ha^{-1}, *Panicum maximum* var. *trichoglume* cv. Petrie (green panic) was the most commonly used associate species and the sites at which it was sown are indicated in Table 1. The sown grasses other than green panic were not collected for analysis in the current work. Annual dressings of fertilizer were at the rate of 400 kg single superphosphate ha^{-1} and 160 kg K_2SO_4 ha^{-1}, given as four equal split applications. Minor elements were applied if required.

The KRS site (Table 1) near Kununurra was sown later than the other sites in October 1979 and involved only Siratro and line 105 with green panic as the associated grass. This site provided samples only from February to October 1980. The site at Pennard provided one sample only.

Plots were harvested on a six-weekly schedule from the end of October to the end of May for three consecutive growing seasons 1978/79 to 1980/81. Optional harvest dates were set for six-weekly intervals during the remainder of the year if growth warranted a harvest. Plots were cut to a 10 cm stubble, tops were separated into sown legume, sown grass and weeds, oven-dried and weighed.

Samples for analysis of digestibility were requested only from plots sown with either Siratro or line 105 (white flowering line) and only from two of the four replicates. Also, they were obtained only for the second and third years of the experiment. A sub-sample from the legume and green panic received for digestibility analysis was separated into leaf and stem (including sheaths) to determine leaf/stem ratio. This material was then reconstituted, ground to pass a 1 mm sieve, and analysed for dry matter digestibility percentage (DMD) of the plant tops using the cellulase technique (McLeod and Minson 1978). Yield of legume and green panic for the plots for which digestibility determinations were made, were obtained from records of the multi-site trial (R. J. Jones *et al.*, *unpublished data*).

Collaborators at the sites also tagged stems of the legume lines and tillers of the green panic about two to three weeks before harvest and recorded rate of new leaf appearance for the period between the date of tagging and the harvest. A sample of recently fully-expanded leaves of the two *Macroptilium* lines and green panic was then picked from the experimental plots immediately before each scheduled harvest of the sward. Legume leaves were picked at the petiole and grass leaves at the ligule. These samples were oven-dried, ground to pass a 1 mm sieve, and analysed for DMD. The Kairi site provided only leaf samples and no sward samples.

Environmental data for maximum and minimum temperatures, rainfall and pan evaporation for the period of this experiment were recorded from meteorological stations on site or nearby; details of sources are given in Table 1.

Analysis of data

Average daily maximum and minimum temperatures were calculated for the six week period before each harvest. A water stress index indicating the favourability of the soil water environment for pasture growth was calculated for the same periods from the weekly rainfall and pan evaporation totals using the model described by McCown (1980–81). The model estimates the ratio of actual to potential evapotranspiration as a water stress index; values range from 1.0 (no stress for growth) to 0.0 (no pasture growth).

Simple linear regressions were determined for tops % DMD and leaf/stem ratio and for leaf % DMD and leaf appearance rate against daily maximum and minimum temperature, water index, and yield, for the six weeks preceding each harvest. The number of samples (harvests) varied greatly between the different sites, which prevented direct comparisons being made between individual sites. The total number of samples was 584 for the *Macroptilium* lines and 248 for green panic. Multiple regression analysis to partition temperature, water stress and other effects was tried but little improvement was obtained in interpretation of the results compared to the simple linear regression approach, and there was overfitting of constants in poorly represented sites.

RESULTS

Dry matter digestibility

Regression analysis indicated no difference in DMD between the bred line 105 and cultivar Siratro, as found previously in a controlled environment experiment (Wilson and Minson 1983). Therefore, the data for the two *Macroptilium* lines were combined for the relationships shown in Table 2.

The DMD of whole tops of both legume and grass was negatively related ($P < 0.001$) to both daily maximum and minimum growth temperatures in the six-weekly period before each harvest (Table 2). The decrease in DMD per 1 °C increase in growth temperature of 0.43 units (max. temp.) and 0.74 (min. temp.) was considerably greater for the grass than for the legume with changes of 0.25 and 0.26 units, respectively. Probable contributing factors to this temperature effect on DMD were the increasing yield with higher growth temperature for both grass and legume (Fig. 3), and the decrease in leaf/stem ratio with both higher yield and higher temperature. The effect of higher temperatures on decreasing leaf/stem ratio were significantly greater for green panic than for *Macroptilium*.

The relationship between DMD of tops and the water stress index (Table 2) was not significant for *Macroptilium* but was significant for green panic ($P < 0.05$). The regression coefficient was negative for both legume and grass which indicated a higher DMD of tops with greater levels of soil water stress. The regression relation for leaf/stem ratio on water stress index was not significant for *Macroptilium* but was

TABLE 1

Location, soil type, average annual rainfall and origin of the meteorological data for the various sites

Site		State	Location	Map reference	Soil type	Rainfall (mm)	Source of meteorological data
1.	Nana Glen	NSW	50 km S of Grafton	30°08′S; 153°01′E	Yellow earth Gn4.35	996	Nana Glen[1]
2.*	Grafton	NSW	Grafton (Dept Agr. Res. Stn.)	29°41′S; 152°56′E	Kraznozem red earth Uf6.71	1015	Grafton Res. Stn.
3.*	Wollongbar	NSW	Wollongbar (Dept Agr. Res. Stn.)	28°50′S; 153°25′E	Kraznozem Gn4.11	1656	Res. Stn., Wollongbar
4.*	Peak Crossing	QLD	40 km SW of Brisbane	27°49′S; 152°46′E	Loamy sand Dy3.41	876	Glenlogan Field Stn.
5.*	Wivenhoe	QLD	40 km W of Brisbane	27°22′S; 152°38′E	Red podzolic Dr2.22	1020	Rainfall (Wivenhoe), other[2]
6.	Beerwah	QLD	70 km N of Brisbane	26°50′S; 153°02′E	Lateritic podzolic Gn2.74	1524	Beerwah Res. Stn.
7.	Tandur	QLD	15 km SE of Gympie	26°17′S; 152°45′E	Red podzolic Dr3.21	1088	Gympie P.O.[3]
8.	Upper Wonga	QLD	15 km W of Gympie	26°09′S; 152°28′E	Solodic Dy3.13	914	Gympie P.O.[3]
9.*	Brian Pastures	QLD	20 km E of Gayndah (DPI Res. Stn.)	25°39′S; 151°45′E	Brown clay Ug5.34	730	"Brian Pastures" Res. Stn.
10.	Narayen	QLD	64 km W of Mundubbera (CSIRO Res. Stn.)	25°41′S; 150°50′E	Acid podzolic Dy3.41	722	Narayen Res. Stn.
11.*	Rosedale	QLD	55 km NW of Bundaberg	24°38′S; 151°55′E	Clay loam Dr3.2	1207	Rainfall (Rosedale), other[4]
12.*	Pennard	QLD	20 km N of Rockhampton	23°22′S; 150°32′E	Light clay Uf6.33	931	Rockhampton
13.*	Kuttabul	QLD	30 km NW of Mackay	21°04′S; 148°52′E	Brown earth Gn3.24	1789	Bur. Sug. Expt Stn. Mackay
14.*	Lansdown	QLD	30 km S of Townsville (CSIRO Res. Stn.)	19°39′S; 146°51′E	Solonized solonetz Dy3.43	898	Lansdown Res. Stn.
15.	South Johnstone	QLD	15 km S of Innisfail (DPI Res. Stn.)	17°35′S; 146°00′E	River alluvium Um6.34	3219	S. Johnstone Res. Stn.
16.	Kairi	QLD	10 km NE of Atherton (DPI Res. Stn.)	17°13′S; 145°33′E	Kraznozem Gn3.11	1272	Kairi Res. Stn.
17.*	KRS	WA	20 km NW of Kununurra (CSIRO Res. Stn.)	15°39′S; 128°43′E	Sandy loam Gn2.1	760	Kimberley Res. Stn.
18.	Darwin	NT	10 km E of Darwin (DPP Res. Stn.)	12°26′S; 130°55′E	Red earth Gn2.11	1594	Darwin Airport

* *Panicum maximum* var. *trichoglume* (green panic) used as the associate grass.

[1] Rainfall and evaporation from Grafton Res. Stn. [2] Qld Water Res. Comms. at Kirkleagh

[3] Evaporation (Res. Stn., Nambour). [4] Sugar Expt Stn. Bundaberg.

TABLE 2

Linear regression relations for whole tops and individual leaf material between dry matter digestibility (DMD), leaf/stem ratio or leaf appearance rate and environmental parameters for the six week period before each harvest and the yield at harvest for the Macroptilium *lines and green panic*

Plant fraction	Variable	Factor	*Macroptilium*		Green panic	
			Reg. Coeff. (±S.E.)	*t* (slope)[4]	Reg. Coeff. (±S.E.)	*t* (slope)
Tops[1]	DMD (%)	Max. temp. (°C)	—0.25±0.06	—4.6***	—0.43±0.09	—4.6***
		Min. temp. (°C)	—0.26±0.06	—4.4***	—0.74±0.10	—7.2***
		Water index[3]	—1.29±0.68	—1.9n.s.	—4.02±1.20	—3.2**
		Yield (t ha^{-1})	—1.66±0.43	—3.8***	—3.36±0.42	—8.1***
	Leaf/stem ratio	Max. temp. (°C)	—0.10±0.01	—7.9***	—0.46±0.11	—4.1***
		Min. temp. (°C)	—0.06±0.01	—4.6***	—0.98±0.12	—8.2***
		Water index	—0.15±0.16	—0.9n.s.	—9.51±1.39	—6.9***
		Yield (t ha^{-1})	—0.38±0.11	—3.6***	—1.87±0.56	—3.4***
Leaf[2]	DMD (%)	Max. temp. (°C)	—0.19±0.06	—3.2**	—0.29±0.04	—6.5***
		Min. temp. (°C)	—0.14±0.06	—2.2*	—0.18±0.06	—3.3***
		Water index	1.97±0.70	2.8**	—0.64±0.66	1.0n.s.
	Leaf appearance rate (days/leaf)	Max. temp. (°C)	—0.29±0.19	—1.5n.s.	—0.64±0.37	—1.7n.s.
		Min. temp. (°C)	—0.94±0.19	—5.0***	—1.85±0.41	—4.5***
		Water index	—11.01±2.25	—4.9***	—29.82±4.32	—6.9***

1. Cut to stubble height of 10 cm.
2. Last fully expanded leaf on runners or tillers.
3. Water index calculated from rainfall and evaporation 1 = maximum water available (no growth restriction), 0 = no available water.
4. *t*, test significance for regression coefficient; ns, non-significant; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

significant ($P < 0.001$) for green panic; the sign of the regression coefficient in both species indicating an increase in leaf/stem ratio with higher water stress.

The DMD of leaf was also negatively related to growth temperature (Table 2) but the decrease in DMD per 1 °C increase in growth temperature for green panic of 0.29 (max. temp.) and 0.18 units (min. temp.) and for *Macroptilium* of 0.19 (max. temp.) and 0.14 units (min. temp.) was much smaller than for the whole tops. The adverse effect of high temperature on DMD was, however, again greater for the grass than the legume. The smaller effect of temperature on DMD of leaf than tops may be related to the increase in rate of leaf appearance with warmer temperatures, with a highly significant ($P < 0.001$) relation with daily minimum temperature (Table 2). Thus, the last fully-expanded leaves sampled would be younger under the higher temperature conditions.

Leaf DMD decreased with higher water stress in *Macroptilium* ($P < 0.05$) but the effect was the opposite in green panic, although the latter regression relation was not significant. For both legume and grass, leaf appearance rate decreased (Table 2) with greater water stress ($P < 0.001$).

The regression relationships of DMD against temperature include both seasonal and site differences. To investigate differences associated with site, several comparisons have been made.

Sites (see Table 1) were divided according to latitude into southern and northern groups, each embracing *c.* 7° of latitude. The southern sub-tropical group comprised sites 1–12 and the northern tropical group sites 13–18, excluding site 16 which was on

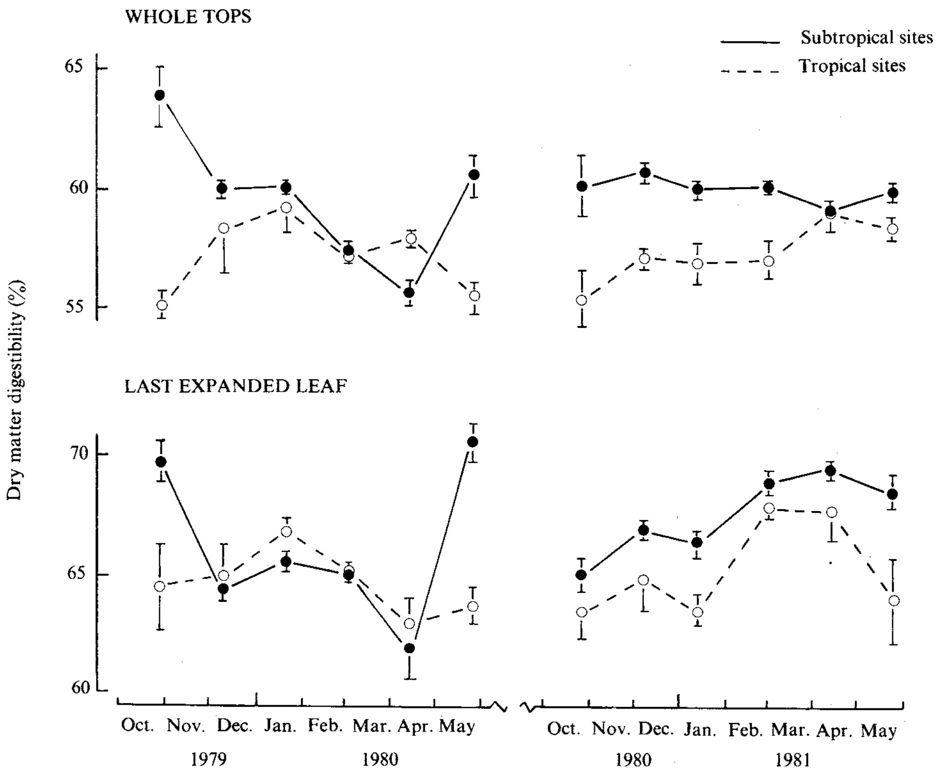

FIGURE 1

Average dry matter digestibility (%) (± standard error) for whole tops and leaf of the *Macroptilium* lines (siratro and 105) for the sub-tropical southern sites (30.1 °S–23.4 °S) and the tropical northern sites (21.1 °S–13.8 °S) for harvests from 1979 to 1981.

the Atherton Tablelands and provided leaf samples only. The average DMD of whole tops and leaf of *Macroptilium* for the southern sites was generally higher than that for the northern sites (Fig. 1) with the difference being most consistent in 1980/81 and generally larger in spring and autumn than in summer. The latter effect probably relates to the size of the temperature differences between southern and northern sites, which for daily maximum and minimum temperature was 5.0 and 5.2 °C for the October sampling, 1.3 and 2.8 °C for the December to April samplings, and 3.7 and 3.2 °C for the May sampling respectively. The overall difference in DMD between south and north for the two years was 2.5 percentage units for tops (t test $P < 0.01$) and 1.9 units for leaf (t test $P < 0.05$). The difference in average temperatures were significant with the southern sites lower by 3.3 °C ($P < 0.01$) in minimum temperature and 2.3 °C ($P < 0.05$) in maximum temperature.

The comparison between southern and northern sites for DMD of green panic (Fig. 2) was not as complete and slightly less consistent than that for the legume because fewer sites and many fewer samples were involved. However, the results were essentially similar with the average DMD of the southern sites higher by 3.0 units for tops (t test $P < 0.05$) and 1.5 units for leaf (t test, non-significant). Southern sites had a lower average minimum and maximum temperature by 4.5 and 4.9 °C, respectively ($P < 0.01$).

A similar comparison with *Macroptilium* for the three southern-most sites (sites 1–3) and the three northern most sites for which substantial numbers of samples were available (sites 14, 15 and 17) gave essentially similar results to those in Fig. 1. The

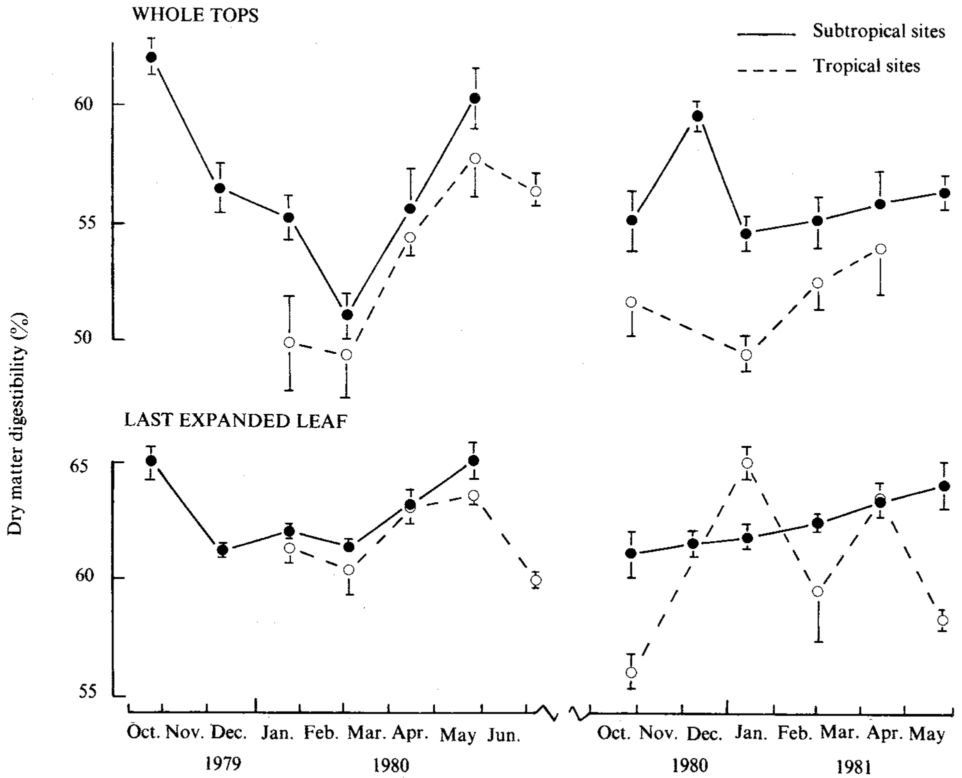

FIGURE 2

Average dry matter digestibility (%) (± standard error) for whole tops and leaf of green panic for the subtropical southern sites (30.1 °S–23.4 °S) and the tropical northern sites (21.1 °S–13.8 °S) for harvests from 1979 to 1981.

average DMD was 2.5 (tops, $P < 0.01$) and 2.2 (leaf, $P < 0.05$) units higher in the south and average temperature 3.8 °C (daily minimum) and 3.0 °C (daily maximum) lower than in the north.

A further comparison of data for leaf DMD from the South Johnstone and Kairi sites is also of particular interest. These sites are at the same latitude, but South Johnstone is at sea level on the coast and Kairi is inland on the Atherton Tablelands at an altitude of 700 m. The average daily minimum and maximum temperatures between October and June for Kairi were 3.6 and 2.5 °C, respectively, lower than for South Johnstone and the average DMD of leaf measured in this same period was 5.9 units higher at Kairi, the cooler site. Rainfall at Kairi in this period was 693 mm compared to 2253 at South Johnstone but average daily pan evaporation was similar at the two sites, 4.8 and 5.5 mm respectively.

Yield response

The relation between the 6-weekly yields, and the average daily minimum and maximum temperatures for each growth period is shown for the *Macroptilium* lines

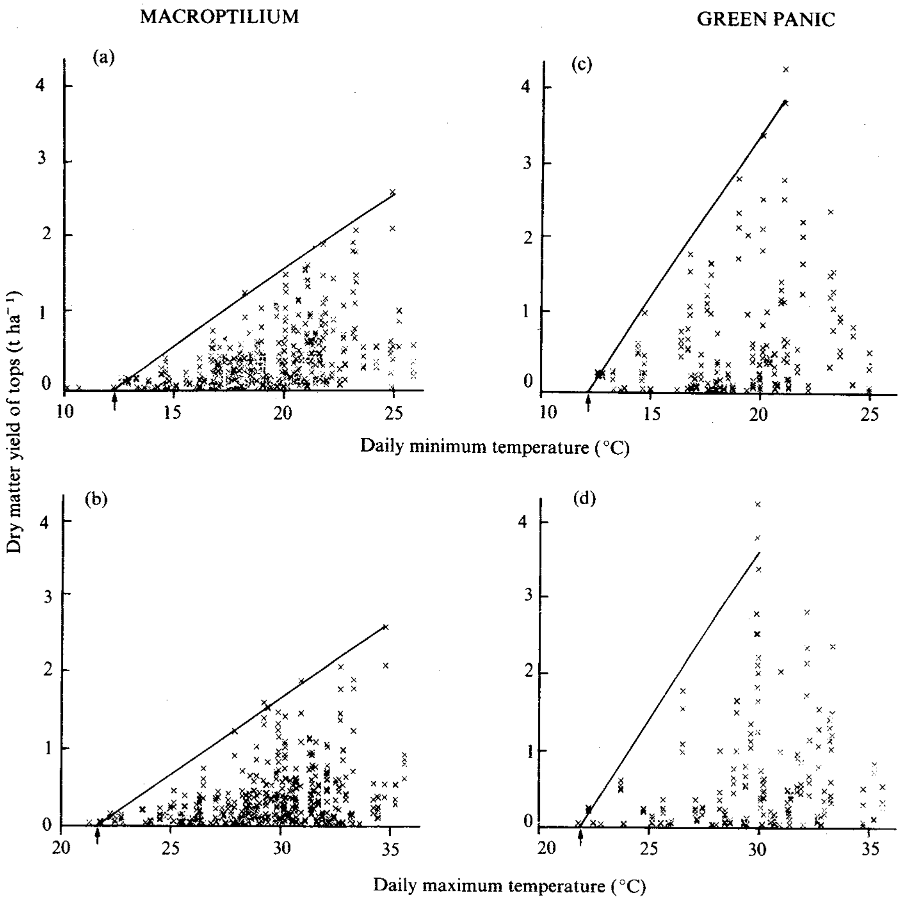

FIGURE 3

Relation between dry matter yield of 6-week regrowths and mean daily minimum or maximum temperature over the period of regrowth for *Macroptilium atropurpureum* and green panic (*Panicum maximum* var. *trichoglume*). The lines indicating response to temperature are fitted by eye to the response surface (see text p. 10). Estimated temperatures for the initiation of growth are indicated by arrows.

(Fig. 3a and b) and green panic (Fig. 3c and d). The data suggest that growth of both *Macroptilium* and green panic is initiated at a minimum temperature of *c.* 12°C and average daily temperature of *c.* 17°C. An optimum growth temperature is not clear for the legume but is indicated at about 30°C daily maximum for the grass. The scatter of data is similar to that found with measurements of stomatal conductance in the field. Jarvis (1976) in an analysis of such data interpreted the surface of the cluster of points as representative of the optimal response to the particular level of the parameter being investigated. Applying this argument to data in Figure 3, the line delimiting the highest values of yield for a given temperature would indicate the yield response to temperature unrestricted by other factors (e.g. water supply, nutrition, etc.). The slopes of these visually estimated lines (Fig. 3) were approximately parallel for maximum and minimum temperature and indicate a yield response of *c.* 4.8 kg ha^{-1} day^{-1} per °C for *Macroptilium* and *c.* 10.8 kg $ha^{-1}day^{-1}$ per °C for green panic.

DISCUSSION

We believe this analysis of digestibility data for the same species grown in a uniform trial over such a wide climatic range is unique. Several comparisons of the digestibility of temperate grasses grown at widely different latitudes in northern Europe have been made (van Soest *et al.* 1978; Deinum *et al.* 1981; Wedin *et al.* 1984) but no analyses of temperature effects were undertaken. However, the plants grown at high latitudes (probably cooler conditions) were generally higher in digestibility than those at lower latitudes for the same date or growth stage.

The current data confirm that the adverse effect of high growth temperature on DMD of plants found under controlled conditions in the laboratory is still strongly expressed over a wide range of climatic environments in the field despite the many other factors that might influence DMD in these situations. The factors include soil type and plant nutritional status. However, all sites were well fertilized so that tissue levels of phosphorus, potassium, sulphur and calcium were more than adequate for growth and unlikely to have contributed to any important extent to variability in DMD (Wilson 1982). Nitrogen status of the grass will have varied between site and with season and could have contributed to variations in DMD (Wilson 1982). Despite the additional factors which could have influenced DMD the average decreases in DMD of plant tops per °C increase in growth temperature for *Macroptilium* and green panic agree well with the magnitude of the temperature response derived from controlled environment experiments (Wilson 1982; Wilson and Minson 1983). The values are also similar to other field-derived values for some temperate grasses and legumes (Takahashi *et al.* 1984).

The proposition that herbage grown in the hotter tropical areas would be of lower quality is confirmed. The average DMD of tops over the whole growing season for the tropical northern sites was 2.5 units lower for *Macroptilium* and 3.0 units lower for green panic than the subtropical southern sites for which average temperature over the growing season was 2–4°C lower. The difference in DMD tended to be greater at either end of the growing season when temperature difference between northern and southern sites were larger.

The adverse effect of high temperature on DMD of tops was probably in part associated with increased yield. Overall, yield was negatively related to DMD as has been found in many other experiments (e.g. Ivory *et al.* 1974). Much of this effect may arise from the decrease in leaf/stem ratio of the herbage with increasing yield. The greater adverse effect of temperature on DMD of the tops of green panic than of *Macroptilium* is probably because leaf/stem ratio of the grass was more responsive to temperature and increase in yield than was the leaf/stem ratio of the legume. The adverse effect of high temperature on DMD is usually greater for stem than leaf (Wilson 1982; Wilson and Minson 1983).

However, not all the temperature effect on DMD of tops can be explained by plant yield, development and maturity effects because the DMD of recently-grown leaf was also decreased by temperature. The latter would be explained by changes in the chemical composition of cell wall material at high growth temperature which lower its digestibility (Moir *et al.* 1977). This adverse effect is partly ameliorated in tropical species by the more rapid development of leaves under higher temperatures. Thus the leaves harvested would have been younger under the warmer than the cooler growth conditions. The stronger interaction of leaf appearance rate with daily minimum temperature than with daily maximum temperature (Table 2) may explain why the decrease in DMD of leaf with increase in minimum temperature was less than with increase in maximum temperature.

Water stress was the only other environmental parameter investigated. The DMD of tops of green panic increased with greater water stress, no doubt partly associated with the accompanying increase in leaf/stem ratio. The DMD of the tops of *Macroptilium* showed a similar (but non-significant) response. However, for leaf DMD the relation with water stress was not significant for green panic and for *Macroptilium* was the opposite of the response for tops, i.e. DMD decreased with greater water stress. The explanation for this may be the slower leaf appearance rate with greater water stress, thus older leaves would have been harvested. These results illustrate the inconsistency and complexity of water stress effects on DMD. They generally support Wilson (1982) that water stress usually has either no effect or a beneficial effect on DMD. Nevertheless, a few studies (Pitman *et al.* 1981; Henderson and Robinson 1982; Pitman and Holt 1982) have reported a strong decrease in DMD of water-stressed plants.

The yield response to temperature is useful in view of the attempts to provide climatic growth indices for tropical species (Fitzpatrick and Nix 1970; Ivory 1981) and to model pasture growth and animal production (McKeon *et al.* 1980; McCown 1980–81). Most temperature indices have been derived from growth of plants in pots in controlled environments. The estimated minimum daily temperature above which active growth commenced of *c.* 12 °C for *Macroptilium* and green panic in this trial was similar to the value of 13 °C derived from controlled environment experiments for these same plants (Sweeney and Hopkinson 1975; Kitamura and Nishimura 1980). The only comparable field value found was a minimum daily temperature of 13.8 °C for siratro (Whiteman and Lulham 1970). However, the mean daily temperature ((max + min)/2) for start of growth, 17 °C for *Macroptilium* and green panic in this trial, was higher than the values used in predictive models (e.g. McKeon *et al.* 1980; McCown 1980–81) of 14 °C for legumes and <14 °C for grass from Fitzpatrick and Nix (1970), and 12 °C for green panic from Ivory and Whiteman (1978). Jones (1971) commented that the growth of siratro at Samford, S.E. Queensland, in spring was lower than would be expected from the model of Fitzpatrick and Nix (1970).

Responsiveness of yield to temperature is another parameter of potential value for modelling pasture growth but few field data exist. This experiment indicates a dry matter yield response of 4.8 kg ha^{-1} day^{-1} per 1 °C increase in growth temperature for *Macroptilium* and 10.8 kg ha^{-1} day^{-1} per 1 °C for green panic. The latter value agrees well with the only other field value found which was 6–10 kg ha^{-1} day^{-1} per 1 °C for kikuyu (Pearson *et al.* 1985). The green panic was much more responsive to temperature than *Macroptilium*, which does not agree with the similar degree of responsiveness of grass and legume proposed by Sweeney and Hopkinson (1975) and the lower responsiveness of grass than legume indicated by Fitzpatrick and Nix (1970). However, these authors derived data from plants grown in monoculture, whereas the species were grown in mixture in this experiment. Our results from a competitive situation should be more relevant to field pasture performance.

What are the practical implications of the difference in DMD of herbage grown in the hotter, more northern tropical latitudes of Australia compared to the subtropics further south? Northern summer temperatures are only about 1–3 °C hotter than those in the south and consequently the difference in DMD of legume or grass due to temperature at this time of year was generally less than 2–3 units. Given the surfeit of feed available in summer and consequently the ability of cattle to select a leafy diet, then this small difference in quality would probably have little effect on rate of animal liveweight gain. However, in spring and in autumn, the temperature differences and hence the digestibility differences are much larger, and a 5–8 units lower DMD in the tropics may have an important influence on forage intake and animal production. Also, in autumn the grasses are more stemmy which may restrict the ability of animals to select leaf, and stem DMD is decreased more by high temperature than is leaf DMD (Wilson 1982). Possibly, the gain in feed quality in the cooler spring in the sub-tropics may in some circumstances be offset by restrictions in feed quantity.

The data reported are for six-week regrowths; if older herbage is to be grazed then the adverse effect of temperature on DMD will be magnified and the consequences for animal production greater. Perhaps the greatest detriment to animal production from the adverse effect of high temperature on DMD in the tropics might arise from the lower quality of the old, stemmy grass which proceeds to maturity under high autumn temperatures and on which animals must be carried through the winter. The digestibility of the herbage at this time is a prime limitation to cattle growth (Romero and Siebert 1980). Finally, legume quality is less sensitive to high temperatures and this is another reason why legumes should be an especially important component of tropical pastures.

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TEMPERATURE CONSTRAINTS TO SOWING TIME OF LEUCAENA IN SOUTHEAST QUEENSLAND

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ABSTRACT

*The relative growth rate (RGR) of establishing leucaena (*Leucaena leucocephala *cv. Peru) sown at different times in spring and summer was studied. Early growth was best related to minimum air temperature which accounted for 74% of the variation in RGR. Maximum air temperature and solar radiation had little influence on RGR. The results indicate that leucaena should be planted when the mean daily minimum air temperature is likely to be above 15°C.*

INTRODUCTION

Leucaena (*Leucaena leucocephala*) is a forage shrub from central America (Hill 1971), and is a useful fodder plant for cattle production in the sub-humid subtropics.

Leucaena may be sown from early spring to late summer depending on land preparation, potential weed problems, rainfall, and temperature. Early spring sowing is desirable as it produces seedlings of sufficient size to tolerate mechanical weed control in the first summer and frosts in the winter (Cooksley 1982). However, leucaena is slow to establish, and low temperatures, if sown too early in the spring, may suppress seedling growth (Hutton and Gray 1959). The critical minimum daily maximum or daily minimum temperature below which seedling growth is too slow to obtain reliable establishment has not been adequately defined.

This paper examines the establishment of leucaena in a number of experiments at "Brian Pastures" in southeast Queensland and explores the relationship between the growth rate of leucaena seedlings in the establishment phase and several associated climatic variables.

METHOD

Ten plantings during spring and early summer from 1971 to 1975 were conducted at "Brian Pastures" Pasture Research Station Gayndah (25°39′S, 151°47′E, Alt. 130 m, average annual rainfall 735 mm) on a basalt derived soil Ug 5.13 (Northcote 1971).