

VEGETATIVE GROWTH OF NINETEEN TROPICAL AND SUB-TROPICAL PASTURE GRASSES AND LEGUMES IN RELATION TO TEMPERATURE

F.C. SWEENEY*+ and J.M. HOPKINSON*†

ABSTRACT

An experiment was carried out in controlled temperature glasshouse units of the Canberra phytotron to record dry weight accumulation during early vegetative growth in nineteen taxa of tropical and sub-tropical pasture plants in relation to temperature. Eight combinations of day/night temperature rising in 3°C steps from 15/10° to 36/31°C were used.

Plants fell into three categories in their temperature response, measured in terms of relative whole plant growth rate:— (1) those with growth depressed above 30/25°C (Desmodium uncinatum and D intortum, all cvs of Glycine wightii, and possibly Chloris gayana); (2) the legumes with no demonstrable high temperature depression (Stylosanthes guyanensis and S. humilis, Calopogonium mucunoides, Pueraria phaseoloides, Macroptilium atropurpureum and Centrosema pubescens); (3) the grasses with no demonstrable high temperature depression and with maximum potential R values apparently higher than those of the legumes (Melinis minutiflora, Brachiaria ruziziensis and B. mutica, Cenchrus ciliaris, and cvs Hamil, common guinea, and green panic of Panicum maximum). Low temperature depression increased with falling temperature below 30/25 ± 3°C in all taxa, and at 15/10°C relative growth rates never exceeded about one third of the recorded maximum. The ratio of root to total dry weight tended to fall as relative growth rate rose.

INTRODUCTION

In 1964 one of us (F.C.S.) carried out an experiment which recorded effects of temperature on dry matter accumulation of young plants of a range of tropical and sub-tropical pasture grasses and legumes. Circumstances prevented the completion of the project at the time, and only recently has the opportunity to re-examine the results arisen. Much has been learned by practical experience about the temperature preferences of these species since 1964, but published experimental results are few and the inferences made from them sometimes dubious. For this reason we have extracted, documented and attempted to interpret those results from the 1964 experiment that still appear valuable.

The experiment was conceived because of the need for background information on the flood of then newly available pasture species whose environmental needs were largely unknown. Bowen's (1959) field study of centro was the only available quantitative assessment of temperature effects. Because of the dearth of information and the numerous taxa entering use, a general screening of many species was preferred to a more detailed examination of a few.

MATERIALS AND METHODS

Nineteen taxa of nine legume and six grass species were used, necessitating the division of the experiment into three separate runs (Table 1). Stylo was included on each occasion to provide a comparison between runs, but failed to establish on the third.

The experiment was carried out in naturally lit compartments of the Canberra phytotron (Morse and Evans 1962) providing a range of combinations of constant day and night temperatures. The duration of day temperature was 8 hours (8.30 am to 4.30 pm). The light period was extended to 16 hours (4.00 am to 8.00 pm) by the use of incandescent lamps in expectation that most species were short-day plants and would remain vegetative. Relative humidity was maintained at 40%.

* Queensland Department of Primary Industries

+ Present address:— 'Tropic Valley', Mena Creek, 4860

†Walkamin Research Station, 4872

Seed was sown into perlite in 13 cm pots. Fifty pots of each crop were sown and placed in the 30/25° C glasshouse. Pots were watered to excess twice daily with the standard nutrient solution supplied (a Hoagland solution in which the phosphorus content was halved). Seedlings were progressively thinned to one per pot.

Approximately two weeks after germination ten randomly selected plants out of each group of 50 were harvested (harvest 1). Groups of five plants of those remaining were randomly allocated to each of eight temperature regimes, which ranged at 3° intervals, and with night temperature always 5° below day, from 36/31° C to 15/10° C. Each plant remained in the conditions allocated to it until taken for a final harvest (harvest 2).

Oven-dry weights of individual shoots and roots of all harvested plants were determined. Dry matter of replicates from harvest 2 of runs 2 and 3 was bulked, and samples from each bulk analysed for N, P, K and Ca.

Analyses of variances were carried out on root, shoot, and total dry weight figures (log transformation used), and on ratios of root to total dry weight (no transformation). Species were grouped for analysis as shown in Tables 1 and 2.

TABLE 1
Timetables of experiment, divisions made for statistical analysis, and forms of analysis

Run	Date of Sowing	Harvest No.	Harvest Date	Grouping and form of analysis
1	February 8	1	February 22	8 taxa (legumes) x 1 temp. x 10 reps
		2	April 4	8 taxa (legumes) x 8 temps x 5 reps
		1	June 15	4 taxa (legumes) x 1 temp. x 10 reps
2	May 31	1	June 15	6 taxa (grasses) x 1 temp. x 10 reps
		2	July 25	4 taxa (legumes) x 8 temps x 5 reps
		2	July 25	6 taxa (grasses) x 8 temps x 5 reps
3	June 22	1	July 12	2 taxa (grasses) x 1 temp. x 10 reps
		2	August 15	2 taxa (grasses) x 8 temps x 5 reps

RESULTS

Total plant growth

Conventionally calculated whole plant relative growth rate (R) (Watson 1952) was chosen as the most satisfactory criterion of plant growth, in spite of the long interval between harvests.

(a) *Differences in maximum R between species.* Differences between species in maximum R values recorded are confused to some extent by the effects of plant size at harvest 1 and of the specific conditions of each run. The plot of R on log dry weight removes some of this confusion (Figure 1). Besides illustrating the familiar dependence of R on plant size, it suggests that the comparatively low maximum R values of run 1 were a consequence of the greater size of the plants when the period of measurement began. It does not allow useful deductions about differences in growth rate potential

TABLE 2
 First harvest yields, maximum R Values, and temperature regimes producing maximum R values for the grasses
 and legumes grown in controlled environments

Species	Common name and cultivar name or introduction number	Dry weight, at harvest 1 (g plant ⁻¹)	Max. R, recorded (g g ⁻¹ day ⁻¹)	Temp. regime of max. R (°C)
Run 1 :-				
<i>Stylosanthes guyanensis</i>	Stylo (present cv. Schofield)*	0.782	0.052	36/31
<i>Stylosanthes humilis</i>	Townsville stylo (commercial)	0.692	0.054	33/28
<i>Calopogonium mucunoides</i>	Calopo (Q5647)	1.594	0.047	33/28
<i>Pueraria phaseoloides</i>	Puero (commercial)	0.909	0.062	33/28
<i>Macroptilium atropurpureum</i>	Sirato (cv. Sirato)	1.812	0.049	30/25
<i>Glycine wightii</i>	Glycine (cv. Tinaroo)	1.288	0.050	30/25
<i>Glycine wightii</i>	Glycine (cv. Clarence)	0.680	0.062	30/25
<i>Glycine wightii</i>	Glycine (cv. Cooper)	0.638	0.062	27/22
Run 2 :-				
<i>Desmodium intortum</i>	Greenleaf desmodium (cv. Greenleaf)	0.009	0.161	27/22
<i>Desmodium uncinatum</i>	Silverleaf desmodium (cv. Silverleaf)	0.030	0.135	30/25
<i>Centrosema pubescens</i>	Centro (commercial)	0.102	0.107	30/25
<i>Stylosanthes guyanensis</i>	Stylo (present cv. Schofield)*	0.031	0.108	36/31
<i>Chloris gayana</i>	Rhodes grass (present cv. Pioneer)*	0.032	0.169	30/25
<i>Melinis minutiflora</i>	Molasses grass (commercial)	0.008	0.176	30/25
<i>Brachiaria ruziziensis</i>	Ruzi grass (CPI 130623)	0.104	0.135	33/28
<i>Panicum maximum</i> var. <i>trichoglume</i>	Green panic (present cv. Petrie)*	0.081	0.148	33/28
<i>Cenchrus ciliaris</i>	Buffel grass (cv. Biloela)	0.160	0.125	30/25
<i>Brachiaria mutica</i>	Para grass (commercial)	0.073	0.138	30/25
Run 3 :-				
<i>Panicum maximum</i>	Guinea grass (commercial)	0.098	0.174	30/25
<i>Panicum maximum</i>	Hamil grass (cv. Hamil)	0.070	0.180	30/25

* Species and cultivar names follow Barnard's (1969 and 1972) conventions, though here cv. name was not bestowed at time of experiment.

within either the legumes or the grasses, but it does strongly suggest that, size for size, the grasses as a group have potentially higher relative growth rates than the legumes. This deduction has since been amply confirmed by Ludlow and Wilson (1970).

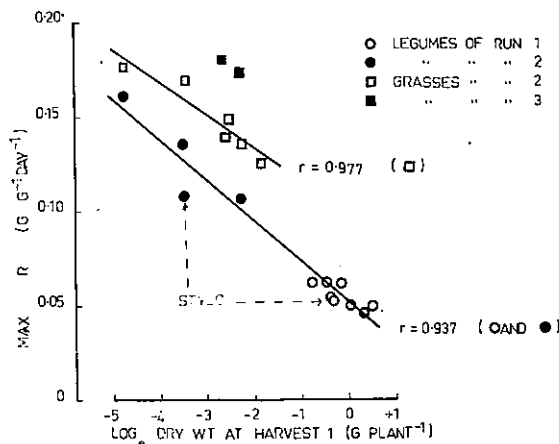


FIGURE 1

Illustration of the relationship between plant size and maximum relative growth rate. The species common to runs 1 and 2, *Stylosanthes guyanensis*, is marked by arrows.

(b) *Effects of temperature within species.* In order to concentrate attention on the response pattern to temperature, a standardized method of presentation has been used for comparisons between temperature treatments within species (Figure 2).

The poor performance of the legumes at low temperature in run 1 (omission of points from the graph indicates net loss of weight between harvests) appears to be due to some condition specific to that run. The performance of the one species common to both runs, stylo, was superior at low temperature in run 2. The most obvious difference between runs 1 and 2 was in plant size at harvest 1, but there is no obvious reason to link the difference in performance with this. A suspicion of P deficiency at low temperature, aroused by both the low P level of the nutrient solution and by visual symptoms akin to those of P deficiency in the field, was not supported by subsequent analyses (see later). The result therefore remains unexplained.

Taking this source of inconsistency into account, we recognize three general patterns of response to temperature within the range of species tested:—

(1) the grasses as a whole (excepting possibly rhodes) in which there was no evidence of adverse performance at the highest temperature regimes, and with a virtual plateau in R above 30/25°C;

(2) the glycines, desmodiums, and possibly rhodes grass, with temperature optima in the range 27/22°C to 30/25°C, and with distinctly inferior performance at the highest temperatures;

(3) the remaining legumes, with high temperature plateaux like those of the grasses, but with more marked depression at intermediate temperatures (18/13° to 24/19°). This depression is possibly exaggerated by five of the seven records for the group being derived from run 1, but is still evident in the stylo and centro which grew beside five of the group 1 grasses in run 2.

The category to which rhodes grass belongs must remain in doubt. The occurrence of a single small, albeit statistically significant, difference is hardly adequate grounds on which to separate it from the other grasses.

At temperatures below the plateau or optimum, there was a tendency in all groups for the depression in R to become more marked with each successive 3°C drop until the point of no growth was reached.

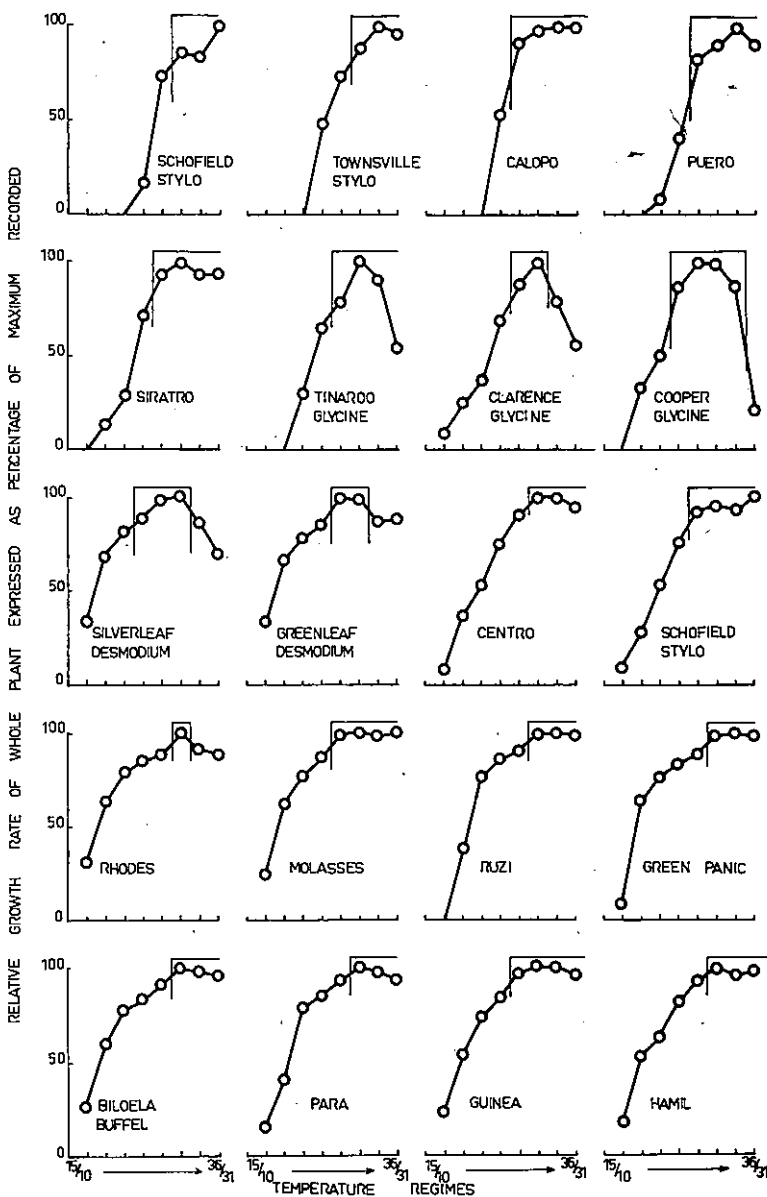


FIGURE 2

Relative growth rate of whole plants, expressed as a percentage of the maximum value recorded in each series, in relation to treatment. Points not differing statistically ($P = 0.05$) from the maximum are grouped within vertical lines.

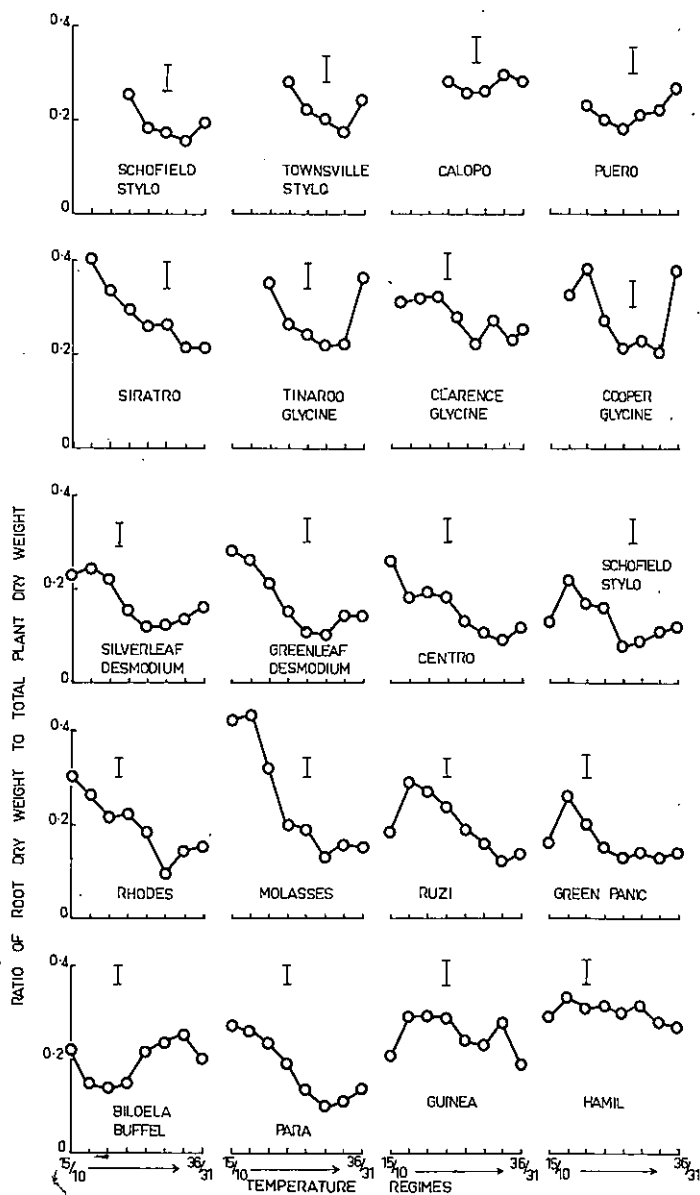


FIGURE 3

Ratio of root to total plant dry weight in relation to treatment. Least significant differences ($P = 0.05$) are indicated by vertical bars.

Root/total plant dry weight ratios

Taken in isolation, the root/total plant dry weight ratio varied inconsistently with temperature between species (Figure 3). Compared with the pattern of change of R values (Figure 2), however, the ratio showed a strong tendency to rise as R fell. In other words, the faster plants grew — or, perhaps more relevant, the greater size they reached — the greater was the proportion of shoot to root. Exceptions to the general

tendency occurred, notably in buffel grass, but these are not surprising. The results may simply reflect ontogenetic drift in weight distribution, a commonly recorded phenomenon with highly variable patterns of change (e.g. Petrie, Watson and Ward 1939, Evans 1972).

Chemical analyses

Undertaken after observation of suspected deficiency symptoms at low temperature in run 1, the chemical analyses in fact contribute little to the understanding of the temperature effects and their detailed results are accordingly omitted. The percentages of N, P and K were almost always greatest at the lowest temperatures, and smallest at those temperatures which produced the highest growth rates. The percentage of Ca was barely affected by temperature treatment. Most nutrient levels were within the range generally accepted as normal, with the exception of P levels in some of the grasses which were below those regarded by Andrew (1968) as critical. For example, minima of 0.13% for buffel, 0.12% for green panic, and 0.17% for rhodes were recorded.

DISCUSSION

Other published results generally confirm the patterns of response to temperature obtained in this experiment. Bowen (1959) observed what he termed "winter retardation" of growth of centro in the field at mean screen temperatures below about 19°C. Cameron (1967), growing Townsville stylo in naturally lit phytotron compartments, obtained maximum dry weight accumulation at 33/25°C, with some depression at 33/28° and 33/21°, and substantial depression at 33/18° and 25/21°. Whiteman (1968) grew Greenleaf and Silverleaf desmodium, *Desmodium sandwicense*, Tinaroo glycine, Siratro, and phasey bean (*Macroptilium lathyroides*) in conditions almost identical to those of this experiment, and with very similar results. High temperature (36/31°) depression was marked in glycine and all the desmodiums, but slight in Siratro and phasey bean. Low temperature depression became increasingly severe at and below 21/16° in all species. Hutton (1970), reporting an unpublished experiment from 1964 carried out also in similar conditions, noted the greatest dry matter production of Siratro at 27/22° and 30/25°, with reduced yield at 33/28° and 24/19°. The reason for the difference in high temperature performance between his Siratro on the one hand, and Whiteman's and ours on the other, is not clear.

Doubts about the legitimacy of temperature effects recorded under phytotron conditions always exist. They derive not only from failure to record other environmental variables that may change with temperature, but also from difficulty in deciding what is a required temperature effect and what is an unwanted interaction with another factor. Further doubts arise as soon as extrapolation to other conditions is made, with its risk of introducing a wholly new set of interactions. Few of the doubts can be satisfactorily resolved, and one is faced with the decision of either abandoning interpretation altogether or accepting the results at their face value until better evidence comes to light. The latter course is implicit in the publication of these and most earlier results of a similar type.

Fitzpatrick and Nix (1970), attempting to generalise on the growth of tropical pasture species in relation to temperature but having to rely on very inadequate information, drew up thermal response curves for tropical legumes and tropical grasses as single separate groups (Figure 4a). The present results lead us to propose modifications to their scheme (Figure 4b) the main points of difference being:—

(a) a division of the legumes into warm and cool tropical groups with, respectively, plateaux and peaks in response at the high end of the range of temperatures in question;

(b) a strong shift to the left in the response curve of the grasses, implying maximum response at lower mean daily temperatures than previously thought (about 27° rather than 38°C).

While conscious of the caution required in extrapolating from phytotron conditions to the field, we are tempted to make the following inferences from these conclusions:—

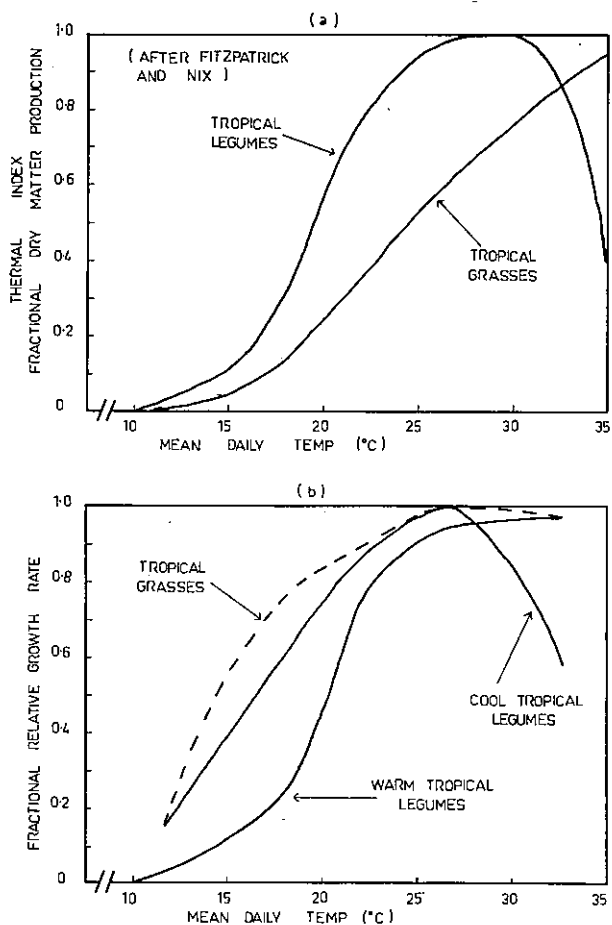


FIGURE 4

Thermal response curves (a) proposed by Fitzpatrick and Nix (1970) and (b) the modifications suggested in the light of present results.

(a) that the generally poor performance of the glycines and demodiums in lowland tropical situations is in part a consequence of intolerance to high temperature;

(b) that otherwise, in the parts of northern Australia where these species are grown and where mean daily temperatures only occasionally exceed 29°C (Anon. 1971), vegetative growth of tropical pasture species is seldom depressed by high air temperature alone; but that of all groups is widely and for long periods depressed by sub-optimum mean daily temperature.

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