EFFECTS OF TEMPERATURE ON PASTURE PRODUCTION

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ABSTRACT

Quantitative relationships between pasture growth and climate (temperature, heat sums, radiation, rainfall, soil moisture) were studied for three sites. The influence of air and soil temperature and interactions with other weather factors and pasture management on total yield over the year is discussed.

Regrowth of temperate ryegrass dominant swards following defoliation shows a marked dependence on soil temperature at 10cm depth and daily maximum air temperature. It appears that both autoregressive terms and actual temperature data are necessary to get the best fit with growth data.

It is concluded that multiple regression analyses will provide a basis for constructing simple models of pasture growth.

INTRODUCTION

Understanding the response pattern of pastures to climatic variables and the predictive value of that knowledge is fundamental to technological advancement (e.g. Waggoner 1975, Kerr 1977). Within New Zealand, considerable variation in temperature, light and rainfall occurs between districts and seasons and this is reflected in different patterns of pasture growth throughout the country (e.g. Radcliffe 1974b, Baars 1975).

However, little research has been done on the relative importance of the climatic factors causing this variation. The examination of individual factors by means of simple regressions has often proved disappointing (Hughes 1965). Past attempts may have failed for a variety of reasons:

a) weather factors do not operate independently
b) often cut by cut data and corresponding daily meteorological data have not been available
c) growth periods have not been well defined
d) responses of crop and pasture yield components are not necessarily linear.

Little or insufficient use seems to have been made of multiple regression analysis to quantify the relative importance of climatic factors throughout the year. Regression coefficients and associated equations, although sometimes difficult to interpret should be useful in elucidating the most important climatic factors influencing pasture growth within a particular environment.

A programme has been undertaken to study multiple regression methods using data from a network of national pasture growth rate trials. Interim results are presented for two sites in the Waikato and one in the Hawkes Bay, and for the purpose of this symposium most of the discussion will center on temperature effects throughout the year.

METHOD

Climatic data were summarized over the period between total yield cuts and stepwise linear regressions performed on these data with yield being the dependent or response variable. Predictor variables (e.g. temperature, rainfall) are entered into the regression on the basis of the partial correlation coefficients. The relative importance of each predictor is indicated by the order of inclusion of the variable into the regression equation. The following 5 seasonal periods were examined:

1. Early to mid-spring (August-October), during which growth rate is increasing with time.
2. Late-spring to early summer (November-December), a period of irregular fluctuations in growth rates following defoliation of reproductive tillers.
4. Autumn (March-May), during which growth rate is decreasing with time.
5. Mid-winter (June-July).

DATA

Climate measurements

Local weather records were used. They were daily rainfall (mm); fortnightly soil moisture percentages (Hawkes Bay only); daily radiation in Langleys (Waikato only); heatsums (accumulated temperature above 5.6°C for soil temperature); daily maximum, minimum and mean air temperature in °C at screen height (1.2m); daily soil temperature in °C at 10cm depth and daily grass minimum.

Pasture yield measurements

1. Waikato

Dry matter production data (DM kg/ha) were collected from 2 beef cattle grazing trials:

a. Trial 1 (under irrigation from 1955-1960)

Yields were collected from the following treatments:

i) grazed at 10-11 days interval to a height of 3cm

ii) grazed at 10-11 days interval to a height of 7cm

iii) grazed at 21 days interval to a height of 3cm

iv) grazed at 21 days interval to a height of 7cm

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TABLE 1: The influence of some climatic factors on pasture production in the Waikato and Hawkes Bay.

<table>
<thead>
<tr>
<th>AUGUST-OCTOBER</th>
<th>JANUARY-FEBRUARY</th>
<th>MARCH-MAY</th>
<th>JUNE-JULY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>df</td>
<td>R²</td>
<td>F</td>
</tr>
<tr>
<td><strong>Waikato (Trial 1)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-11 days (3cm)</td>
<td>35</td>
<td>.68 ***</td>
<td>MAX, RAD</td>
</tr>
<tr>
<td>10-11 days (5cm)</td>
<td>34</td>
<td>.74 ***</td>
<td>MAX, RAD, 10 Soil</td>
</tr>
<tr>
<td>21 days (3cm)</td>
<td>18</td>
<td>.70 ***</td>
<td>MAX</td>
</tr>
<tr>
<td>21 days (5cm)</td>
<td>18</td>
<td>.66 ***</td>
<td>MAX</td>
</tr>
<tr>
<td><strong>Waikato (Trial 2)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-11 days (3cm)</td>
<td>28</td>
<td>.83 ***</td>
<td>LACCS, LRAD</td>
</tr>
<tr>
<td>10-11 days (5cm)</td>
<td>28</td>
<td>.76 ***</td>
<td>MAX</td>
</tr>
<tr>
<td><strong>Hawkes Bay</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 weekly</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Soil</td>
<td>23</td>
<td>.83 ***</td>
<td>10 Soil</td>
</tr>
<tr>
<td>Non-Irrigated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 weekly</td>
<td>09</td>
<td>.82 ***</td>
<td>10 Soil, SM 0-10</td>
</tr>
<tr>
<td>4 weekly</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>percentage variation explained by the regression</td>
<td>10 Soil</td>
<td>soil temperature at 10cm depth</td>
</tr>
<tr>
<td>df</td>
<td>degrees of freedom</td>
<td>LACCS</td>
<td>natural log accumulated day degrees above 5.6°C</td>
</tr>
<tr>
<td>Sl order</td>
<td>order of stepwise inclusion</td>
<td>MIN</td>
<td>daily minimum air temperature</td>
</tr>
<tr>
<td>MAX</td>
<td>daily maximum air temperature (°C)</td>
<td>SM</td>
<td>soil moisture percentage at 0-10cm or 10-20cm depth</td>
</tr>
<tr>
<td>LRAD</td>
<td>natural log radiation (kangleys)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION

A condensed summary of results is presented in Table 1. The relative importance of climatic variables is of immediate interest and they have been put in italics. The results, however, are based on the assumption that all variables at each location are independent of each other. This assumption is not valid in the case of climate factors, which are highly correlated. In addition, the results are only valid for the period of observation and may not be representative of the long-term average climate at the site.

Late spring to early summer (November-December)

Over this period, climate seemed to be of little importance to pasture growth. In the Waikato and Hawkes Bay, rainfall was low and temperature was moderate. In the Waikato, daily maximum air temperature was the most important factor, followed by daily minimum air temperature. In Hawkes Bay, rainfall was the most important factor, followed by daily maximum air temperature.

Early to mid-spring (August-October)

In Hawkes Bay, daily minimum air temperature was correlated with yield (r = 0.72***), confirming a similar finding by Brougham (1959) for pasture growth rates near Palmerston North, but the effect of soil temperature at 10 cm was significantly greater than both daily minimum and maximum air temperature. The results are also in agreement with observations by Alcock et al. (1968) in Wales, who found that spring growth had a strong correlation with soil temperature and accumulated heat units above a threshold value of 5.6°C, below which growth stopped.

In the Waikato, daily maximum air temperature and accumulated heat units were all of similar importance. Daily minimum air temperature and accumulated heat units had a strong correlation with soil temperature and accumulated heat units above a threshold value of 5.6°C, below which growth stopped.

In the Waikato, a change of 1°C in daily maximum air temperature was associated with a change in growth rate of 7-12 kg DM/hafday respectively for a 10-11 day rotation interval.

These results suggest that it should be possible to forecast growth rates in spring. Using only meteorological data, it was found that 60-83% of the variation in yield could be explained by the previous mean daily maximum air temperature and rainfall. The results of this study are consistent with those of previous studies, which have shown that climate variables are important in determining pasture growth.

The magnitude of fluctuations in growth rate attributable to weather factors is of interest. In the Waikato a change of 1°C in daily maximum air temperature was associated with a change in growth rate of 7-12 kg DM/hafday respectively for a 10-11 day rotation interval.

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swards to the physiological growth rhythm of grasses as manifested in the development of flowering tillers and the regeneration of vegetative tillers.

Summer (January-February)

Daily maximum air temperature had the highest (negative) correlation with yield in Hawkes Bay, although the multiple regression analyses pointed to soil moisture and soil temperature at the 10cm level, as being the more influential variables. Mitchell (1956) noted that in summer the temperature of the surface layer of the soil may rise for a considerable period each day to 27°C or higher. At 9am, summer soil temperatures at the Hawkes Bay site were about 17°C, therefore rising rapidly throughout the day.

Since rapid decline in ryegrass shoot production rates occurs at temperatures above 18°C (Mitchell 1956) the effect of this variable is obvious, even if secondary to the effect of soil moisture.

The negative effect of high soil temperature levels on pasture production was confirmed on irrigated Waikato pastures and the effect was strongest when pastures were frequently grazed. In this area, the summer and daily maximum air temperatures are well

In Hawkes Bay, growth rates were strongly correlated with soil temperature (0.77***), heat units (0.63***) when swards were cut every 4 weeks, with other temperature variables being of less importance. Under fortnightly cutting, daily maximum air temperature showed the highest correlation with yield (0.55**), followed by soil temperature (0.44**) and accumulated heat units (0.40**). Daily air minimum and grass minimum had low correlations with yield (0.35 NS). Predictive equations were of a rather more complex nature than at other periods of the year. At Palmerston North, Brougham (1969) also found that the only significant positive correlation obtained with weather factors in mid-winter was day-time temperature during early stages of regrowth which is in agreement with our results for fortnightly cutting.

At Hamilton, daily maximum air and soil temperatures explained about 50% of the variation in yield under short rotations. There was however, little difference in the size of the correlation coefficients between temperature variables and yield. The lack of more pronounced weather effects on pasture production over this period might be due to the rather crude yield measurement techniques, or the failure to include appropriate climatic factors in the model. For example, yearly analyses for the Waikato trials indicated the importance of the number of frosts over this period.

Although mean air temperature has often been used to examine temperature growth relationships and even in modelling of pasture growth (Fick 1978), this variable appeared to be of little relevance in the present studies. Peacock (1975), using heat cables in the soil, found that temperature was effective at the level of the stem apex rather than being a general effect of soil and air temperature on leaf growth. While daily maximum temperature strongly relates to canopy temperatures (Coulter 1964), soil temperature at 10cm has a strong correlation with air temperature close to the soil surface (Alcock et al. 1968). This explains the importance of both daily maximum air temperature and soil temperature at 10cm in the analyses.

CONCLUSIONS

Regrowth of temperate ryegrass dominant swards following defoliation shows a marked temperature dependence, which is influenced by the temperature environment prior to defoliation and management, confirming controlled environment findings for single plants (McWilliam 1976). While it is virtually impossible to define the exact influence of each temperature variable, the magnitude and relative importance of temperature can be quantified from these analyses. Our aim is to fit the best possible
empirical relationship. The regression coefficients must be examined to see if they do not violate common sense. The more climatic factors are put in the regression as independent variables the more strongly will the climatic features of that particular area be emphasized, and as a result, the better will the model fit that area. However, on the other hand, by doing so, the widespread applicability of that model is likely to be lost. Because factors of statistical significance might not always be causal, it will be necessary to combine data from groups of sites to identify the causal climatic factors. In spite of the limitations, it is considered that the techniques employed are of considerable value in assessing the relative importance of temperature (and other weather factors), on growth of pasture swards and species. These methods deserve far more attention, as they will provide a basis for constructing simple models of pasture growth.

ACKNOWLEDGEMENT

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