EFFECT OF LOCALITY AND SOWING DATE ON SEASONAL RATES OF DRY MATTER ACCUMULATION OF CEREAL FORAGES

A. O. Taylor and K. A. Hughes,
Plant Physiology Division,
D.S.I.R., Palmerston North.

ABSTRACT

Autumn–sown cereals grown from Kaitaia to Invermay as cool season crops produce good forage yields (12 to 16 t DM/ ha) in spring, but some cultivar/locality interactions occur. Closely related Florida oat lines reached similar final yields.at widely spaced sites, while the early maturing wheat cultivar Karamu reached a lesser final height and reduced final yield at Kaitaia and Palmerston North compared to Invermay.

Establishment and winter growth of all cereals was substantially faster at more northern sites, i.e. Kaitaia > Palmerston North > Invermay. At Kaitaia, oats took 24 weeks to reach a forage yield of 15.5 t DM/ha and 33 weeks to reach the same yield at Invermay. Progressive delay in the sowing of oats at the same site (Palmerston North) caused a substantial reduction in establishment and winter growth rates, and late autumn sowings did not reach the final yield of earlier sowings.

Meteorological data was found to correlate strongly with both yield and development of Florida oats. When data from locality and time of sowing trials were combined the highest correlation coefficients between yield or development were with temperature (heat units above 2°C) plus solar radiation (megajoules) rather than with temperature or solar radiation alone. The straight lines describing these relationships were:

Yield (>1 t/ha) = $0.64X - 7.99$

Development (Feekes scale) = $0.36X + 0.49$

where X = (heat units above 2°C + radiation in magajoules) 10^{-2}

INTRODUCTION

Spring sown cereals conserved as whole crop silage have been used in animal production systems in northern Europe and Canada for many years. These crops could be used for the same purpose in New Zealand where they would be autumn sown and probably alternated with some warm season crop such as maize in a double cropping system (Taylor and Hughes, 1978). When used in such intensive crop rotation systems it is important to know the effect of climate and sowing date both on the period necessary to grow the crop and on the yield.

In Iowa, times of grain maturity of oats are reasonably well correlated with degree day accumulations (Wiggans, 1956), but not grain yield. Canadian workers Dermine and Klinck (1966), have also unsuccessfully attempted to predict cereal grain yields from meteorological data using a simple correlative analysis. In Canada, temperatures are suboptimal for growth in early spring, but can become superoptimal for growth and physiological development in summer when soil water is often limiting. With autumn-sown cool season crops in New Zealand, these complications are less likely to exist. Superoptimal temperatures (> 27°C; Smith, 1974) should not occur and soil water is unlikely to be limiting except possibly during establishment after early autumn planting. Therefore, a cumulative heat unit system similar to that used successfully for maize (Gilmore and Rogers, 1958) might be useful in predicting yield. Solar radiation may also limit growth over this period and could be included in a prediction equation.

This paper describes the cool season pattern of forage yield of oats and wheat sown on the same date at three sites covering a latitudinal span of 10°, and of oats sown at four dates on one site. The stage of development and forage yields of these crops is then correlated with temperature and solar radiation.

MATERIALS AND METHODS

In 1975, identical trials were run at three widely spaced sites, namely Kaitaia (latitude 35° 04' south), Palmerston North (latitude 40° 23' south) and Invermay (latitude 45° 51'south). These were sown between 12 and 17 April at a seeding rate of 80 kg/ha into cultivated seedbeds under high fertility conditions. The plots were sampled at three-weekly intervals to provide seasonal patterns of forage yield. Full details of these trials are given in Taylor *et al.,* 1976). The cultivars sown were:

Triticum aestivum cv Karamu – an early maturing Mexican derived spring wheat.

Triticum aestivum cv. Arawa – a New Zealand bred winter/spring wheat of medium maturity.

Avena sativa cv. Florida 501 (at Kaitaia), cv. Ab 113 (at Palmerston North) and cv. Suregrain (at Invermay). These are all moderately early, rust resistant, autumn sown oats from the University of Florida breeding programme. They have been found to yield similarly at Palmerston North (Eagles and Taylor, 1976)

In 1978, a sowing date trial was run at Palmerston North on a Tokomaru fine silt loam with *Avena sativa* cv. Ab113. Seed at 80 kg/ha was drilled into a cultivated seedbed on four dates, namely 22 March, 13 April, 3 May and 22 May. Fertilizer at 56kg P/ha and 112 kg K/ha as potassic superphosphate and 30 kg N/ha as urea was applied prior to sowing. Further nitrogen at 30kg/ha was applied immediately prior to stem elongation. Small test strips showed no growth response to further nitrogen additions. The trial was a randomized block design with four replicates and a plot size of 2.5 x 15m. Samples from randomly selected 1 x 1m subplots were taken at four-weekly intervals to produce seasonal forage production curves.

Temperature data was taken from stations closest to the trial sites, namely Kaitaia areodrome (A

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53021), Grasslands, Palmerston North (E 05363) and Taieri, Invermay (I50831). Degree days were calculated as $(Tmax + Tmin)_2$ minus the base temperature. Solar radiation levels were obtained from Kaitaia aerodrome, DSIR Palmerston North and Dunedin (I 50921). The stage of crop development at each harvest was rated according to Feekes scale (Large, 1954).

RESULTS AND DISCUSSION

Locality effects:

All the cereals showed the same general response to locality in their seasonal patterns of forage production. Cultivars at Kaitaia established and grew far more rapidly to maximum yield than those at Invermay, while growth at Palmerston North was intermediate (Figure 1.) Both wheats reached higher final yields at Invermay than at Kaitaia. The reason or reasons for this are not clear, but Karamu crops were shorter with fewer tillers at Kaitaia and Palmerston North, while relatively serious lodging of cv. Arawa occurred at Kaitaia as heading commenced. The Florida oat lines produced more consistent final yields (in excess of 15 t DM/ha.) at all three localities.

These oat crops took approximately 24, 27, and 33 weeks from sowing at Kaitaia, Palmerston North and Invermay to reach the early milk stage desired for ensiling. If maize were to be grown in alternation with these oats then the warm season period remaining for maize becomes approximately 26, 23 and 17 weeks respectively at the three localities when time is allowed for harvest, cultivation and establishment of each crop. Summer temperatures are different at the three localities and these periods translate into heat accumulations for maize above 10°C; Gilmore and Rogers, 1958) of 144, 969 and 461 for Kaitaia, Palmerston North and Invermay respectively (based on 40 year mean). THese heat unit accumulations are probably sufficient to take a 90 day RM maize hybrid to black layer development at Palmerston North, but the same hybrid would only reach tassel emergence at Invermay (Menalda and Kerr, 1973), whereas a 110 day RM hybrid could be grown at Kaitaia.

Sowing date effects:

Progressive delay in autumn sowing at a single location caused a similar delay in establishment and early growth as planting at successively cooler localities using a common sowing date. However, the spring growth pattern was not the same, because later sowings at the same site did not reach the yield of earlier sowings even by late November (Figure 2). The premature flattening off of the dry matter accumulation curves of these later sowings was consistent with their advanced stage of physiological development.

The other anomalous feature was the relatively poor performance of the first planting later in the season. Plots sown first were considerably taller in August than those of later sowings which surrounded them. They therefore had little protection and very heavy rain and wind at this time caused them to lodge quite severely.

Figure 1: Influence of locality on seasonal patterns of forage production. The wheat cultivars Karamu and Arawa and rust resistant Florida oat lines were planted at Kaitaia (■), Palmerston North (□) and Invermay (▲) in mid April and sampled at three-weekly intervals through until late October/November. Also shown are correlations of yield and of development of oats with temperature plus solar radiation accumulations at the sites. Lines have been fitted by eye.

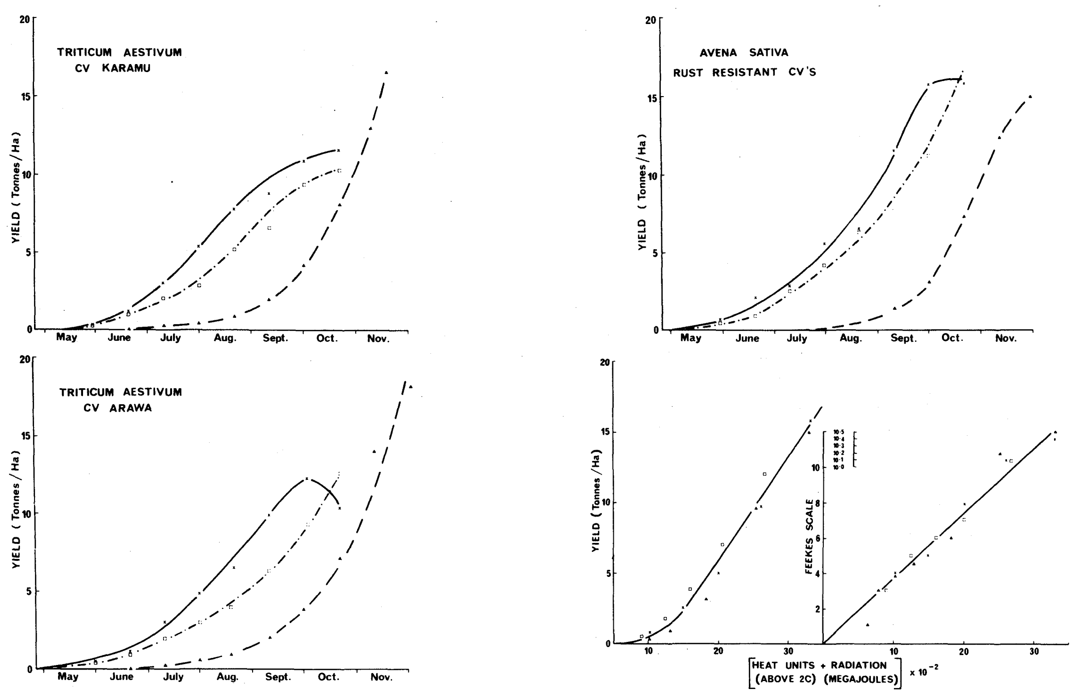
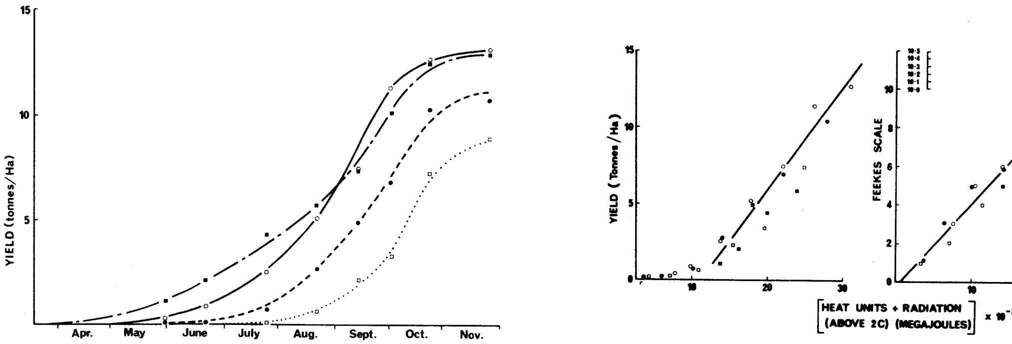


Figure 2: Influence of sowing date on the seasonal pattern of forage production of the Florida oat line Ab 113 at Palmerston North. Sowings were made on 22 March (■), 13 April (o), 3 May (●) and 22 May (□). Correlations of yield and of development of oats with temperature plus solar radiation accumulations are shown. Lines have been fitted by eye.



Climate correlations:

In a double cropping system, it is possible that the growth period available for the cool season cereals could be constrained by the requirements of the warm season crop. It is clear that climate has a marked effect on their cool season growth patterns. If climate data could be used to predict crop development and yield it would be possible to model cereal/maize systems to optimize total annual yield and to decide on maize hybrids of suitable maturity. The ability to predict specific stages of cereal crop development would also be useful because of sharp and substantial changes in crop digestibility that are associated with different development phases (Eagles *et al.*, 1979).

Temperature has been used successfully to predict grain maturity of spring sown oats in Iowa, but not grain yields (Wiggans, 1956). These are reduced by excessive rates of crop development and inadequate rainfall in this environment. Rainfall is unlikely to restrict the growth of autumn sown cereals in New Zealand, except during establishment after early planting, while superoptimal temperatures for growth or development are even less likely.

Suboptimal temperatures and solar radiation would seem the most likely constraints to growth, so these were tested against yield and development data by correlation analysis. Base temperatures for heat unit accumulations are commonly chosen close to the threshold temperature for seed germination. For oats, this temperature is $3^{\circ}C$ (Coffman, 1923), so correlation coefficients between forage yield and heat units were determined using a range of base temperatures around $3^{\circ}C$. This gave the following results:

	$3^{\circ}C$	$2^{\circ}C$	$1^{\circ}C$
Trial 1	0.912	0.934	0.912
Trial 2	0.888	0.909	0.911
Trails 1 + 2	0.889	0.915	0.879

A base temperature of $2^{\circ}C$ was therefore chosen for heat unit calculations.

Correlations were tested initially using data from every harvest throughout the season and with each trial analysed separately (Table 1). Temperature, solar radiation and temperature + solar radiation all gave

TABLE 1: Correlations of yield and development of oats with climate data. Heat units are expressed as degree days above $2^{\circ}C$ and solar radiation and meagajoules. All summations of climate data began at planting.

	Heat units	Radiation	Heat units + radiation
Trial 1. Latitude of planting			
Forage yield (t/ha) v/s	0.834***	0.937***	0.975***
Development (Feekes scale v/s	0.943***	0.925***	0.973***
Trial 2. Time of sowing			
Forage yield (t/ha) v/s	0.909***	0.940***	0.937***
Development (Feekes scale) v/s	0.962***	0.960***	0.974***
Trials 1 + 2			
Forage yield (t/ha) v/s	0.915***	0.934***	0.948***
Forage yield (>1 t/ha) v/s	0.900***	0.913***	0.961***
Development (Feekes scale) v/s	0.952***	0.886***	0.968***

reasonably high and strongly significant (P>0.01) correlation coefficients with both yield and development. Temperature (heat units above $2^{\circ}C$) plus solar radiation (megajoules) generally gave the highest correlations, so these data have been plotted in Figures 1 and 2.

A reasonable straight line correlation exists between yield and climatological parameters at yields above 1 t/ha, with data from both trials seeming to fall on approximately the same line. Some of the poorly correlated points were those from the first planting in trial 2 where dry seedbed conditions presumably delayed establishment. A straight line regression of stage of development on temperature + solar radiation accumulations exists, although the rating of development stages above 10 on Feekes scale has been done rather arbitrarily to obtain the best fit.

When data from both trials were combined the correlation coefficients remained highly significant confirming the similarity of the relationship in both trials. The improved correlation resulting from deletion of yield <1 t/ha is also clear. The straight lines describing these relationships are:

Yield (>1 t/ha) = 0.64X - 7.99

Development (Feekes scale) =0.36X + 0.49 where X = (heat units above 2°C + radiation in megajoules) 10^{-2}

Or for sites where solar radiation data are not available:

Yield (>1 t/ha) = 1.3X - 9.09

Development (Feekes scale) =0.73X + 0.43 where X = heat units above 2°C.

ACKNOWLEDGEMENTS

The use of data from trials at Palmerston North by Peter Menalda and at Invermay by Roy Stephen is gratefully acknowledged.

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