A simple model of potato growth and yield

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Introduction

The last 20 years of agricultural research have seen significant advances in what may be termed 'basic' knowledge of crop management. The development of simple to use mechanistic crop models has enabled scientists and growers to identify and exploit combinations of location, genotype and sowing time to maximise yield potential. While spectacular success has been evident for some crops, the advances have been less obvious in others. Historically, decision support systems for potato growers have concentrated on pest and disease management and have ignored the impact of simple management decisions on growth and yield. This is problematic, not just because there is a dearth of information on the control of yield but because, without a reliable estimate of yield, pest and disease models are unable to provide information about the economic impact of management decisions.

Here we present results from an experiment designed to be the first step in constructing a model of potato growth and yield for New Zealand conditions. The growth of tubers of cvs. Fianna and Russet Burbank is examined and related to canopy development and radiation interception.

Materials and Methods

Two cultivars of potato (Fianna and Russet Burbank) were sown on both 16 November and 14 December, 1999. Potato seed was hand-planted with in-row and between-row spacings of 30 and 86 cm, respectively, to give a population of 38,760 plants/ha. Prior to sowing, the experimental area received a total of 120 kg N/ha (DAP + urea), 100 kg P/ha (as DAP) and 100 kg K/ha (as potassium sulphate), which was broadcast and incorporated to a depth of 30 cm. An additional 40 kg N/ha (as CAN) and 30 kg K/ha (as potassium sulphate) was applied to all plots by helicopter in mid-February, 1999. Water deficit was avoided by irrigating when potential ET reached 40 mm from the last irrigation.

The experiment was performed in a cool-temperate climate at Hastings, New Zealand (lat. 39.47°S, long. 176.64°E) where long-term average temperature and radiation during the potato growing season are ca. 16 °C and 18 MJ/m^2/d, respectively. In the 1998-99 growing season, daily average temperature minima and maxima were 12 and 22°C, respectively, and soil temperature at 10 cm depth averaged 21°C. Solar radiation averaged 19.5 MJ/m^2/d. The soil was a Mangateretere silt loam (*Typic Haplaquept*) of ca. 0.6 m depth which overlies a clay subsoil.

Fortnightly measurements of leaf area, crop biomass, tuber fresh mass and tuber water content (%) were made on eight plants from a randomly selected row in each plot. Radiation interception was measured weekly at the same location in each plot, using a 'SunScan Canopy Analysis System' (Delta-T Devices, Ltd, Cambridge, UK). Each combination of cultivar and sowing time was replicated four times. Cultivars were randomised within sowing times, but there was no randomisation of sowing time. Each experimental plot was 6 rows (5.16 m) wide and 22 m long.

For each sowing time data for both cultivars have been pooled because, given the similarity in their response, the relationships presented herein were not improved by examining them separately.

Results

The relationship between leaf area index (LAI) and time from sowing was described well (r^2 = 0.86) by a single curve with an RMSD of 0.73, indicating that the curve is a robust predictor of LAI for all combinations of sowing time and cultivar (Fig. 1).

The proportion of incident radiation intercepted by the crop canopy (%RI) increased linearly (r^2 = 0.93) with leaf area index to a maximum at 4.8, such that %RI could be predicted with *ca* 90% reliability (RMSD = 0.11) using LAI as a predictor (data not shown).

For both cultivars and both sowing times, there was a strong (r^2 = 0.92) linear relationship between crop DM

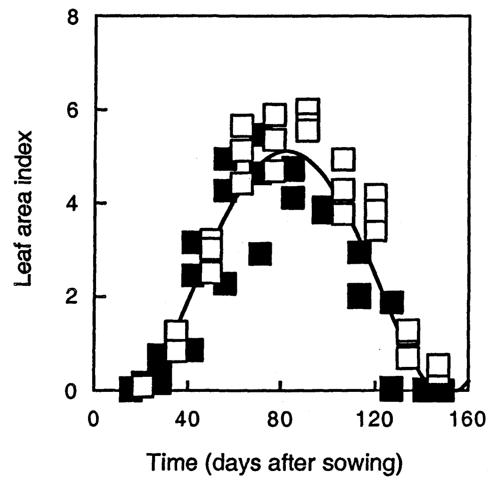

Figure 1. Relationship between leaf area index and time for potato cvs. Fianna and Russet Burbank. □ First sowing; ■ second sowing. Data are pooled for both cultivars.

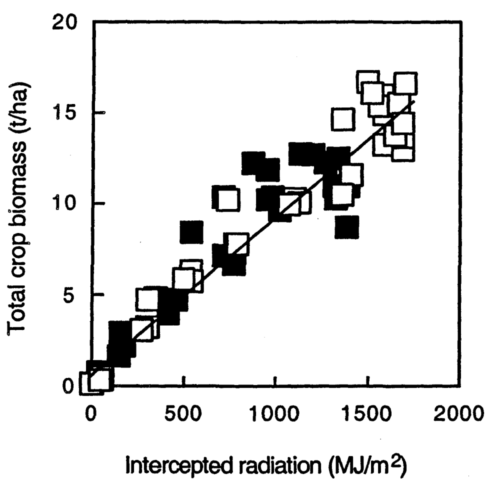

Figure 2. Relationship between total crop biomass and intercepted radiation for potato cvs. Fianna and Russet Burbank. □ First sowing; ■ second sowing. Data are pooled for both cultivars.

and total intercepted radiation (Fig. 2), with the slope of the curve indicating an average radiation use efficiency of 0.9 g/MJ.

The proportion of total crop biomass partitioned to tubers increased linearly with time (r^2 = 0.91; data not shown), such that total tuber DM also increased linearly (r^2 = 0.94) with time (Fig. 3). Importantly, tuber water mass increased linearly with time (r^2 = 0.96; data not shown), so there was a linear change in tuber fresh mass with time (r^2 = 0.95; Fig. 3).

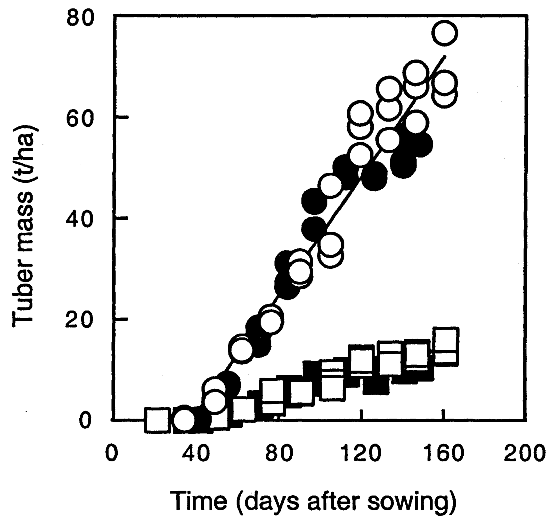

Figure 3. Relationship between tuber mass and time for potato cvs. Fianna and Russet Burbank. □ Tuber dry mass, first sowing; ■ tuber dry mass, second sowing; O tuber fresh mass, first sowing; ● tuber fresh mass second sowing. Data are pooled for both cultivars.

Discussion

These results demonstrate that simple relationships between leaf area index, radiation interception, radiation use efficiency and biomass partitioning can be used to describe the accumulation of potato tuber yield. Furthermore, in this instance, we have shown that these simple relationships were not altered by significant differences in genotype or sowing time. Consequently, we believe that it will be possible to simply describe the growth and yield of both Fianna and Russet Burbank potatoes for a range of sowing times and growth locations, without the need to significantly modify the mathematical description of the underlying physiological relationships outlined above.

In addition to providing a framework from which a potential yield model can be established, these results have a number of more immediate practical implications. The potential yield of potatoes established in this experiment (almost 80 t/ha) is considerably higher than the commercial average of 40-50 t/ha, indicating that there may be considerable scope to improve crop management for yield. Given the strong relationship between leaf area index and radiation interception (and the general stability of radiation use efficiency (Vos and Vanderputten, 1998; Birch *et al.*, 1999) and harvest index (Kooman *et al.*, 1996)), it is likely that management to maximise the size, and particularly duration, of the crop canopy will positively influence yield.

Conclusions

The effects of radiation interception on biomass and yield of potato were described simply and accurately in terms of basic physiological variables. These effects and their implications for models designed to predict potato yield will be discussed further in another more detailed publication.

References

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