

FRUIT GROWTH AND SIZE PROFILES

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ABSTRACT

Crop estimation is a vital activity for the industry and accuracy is paramount. A project was started last season on ways on which the crop estimate could be improved by taking the fruit size profile into account. For this to be feasible techniques must be developed to calculate weight of the fruit in the field based on a few simple measurements such as length and width of fruit. Information is also required on fruit size distributions and how these change over the season. To obtain this information fruit size (length and two width measurements) has been monitored on samples of tagged fruit at regular intervals over two seasons. A model has been developed which accurately calculates fruit weight based on length and width measurements. The model is robust and has been validated using data from 4 different seasons and on a several orchards. Fruit size distributions were normally distributed other than at the beginning or the end of a season, when they tended to be skewed. Fruit growth follows a double sigmoid pattern with growth slowing down over the winter period.

Keywords: fruit weight, fruit growth, size distributions

INTRODUCTION

A project was started in the 2000/2001 on ways in which the crop estimate could be improved by taking the fruit size profile into account. For this to be feasible the weight of the fruit in the field must be able to be estimated based on a few simple measurements such as length and width of fruit. Models for calculating fruit weight based on length and width of 'Hass' fruit have been developed (Zilkah and Klien, 1987). Secondly, information is required on how fruit size increases over time. Finally, the manner with which the distribution of fruit size changes over time must be known and predictable.

In order to collect this information a monitoring programme for fruit size was begun in the 2000/2001 season. The monitoring programme has been expanded in the 2001/2002 season to include observations from a second orchard.

MATERIALS AND METHODS

2000/2001 season

A sample of 200 fruit was tagged on fruit from several trees from an orchard in Katikati. Measurements of fruit size (length, 2 widths at right angles, volume displacement) were made on each fruit at monthly intervals (10th December 2001, 9th January 2002, 14th February 2002, 7th March 2002 and 7th April 2002). In addition, similar measurements were taken from a sample of 10 fruit, which were then removed from the tree and weighed to the nearest gramme.

A model was developed to estimate fruit weight based on length and width measurements.

2001/2002 season

Fruit growth was measured on two properties. The same orchard in Katikati was used as in the previous season. A total of 400 fruit were tagged and numbered in February 2002. Measurements of the tagged fruit were taken on 26th February, 27th March, 1st May, 31st May, 2nd July, 1st August, 30th August, 30th September, 1st November, and 27th November 2002. For calibration purposes, a sample of 10 fruit were harvested each month, measured, weighed and the volume displacement recorded.

The second orchard was located in Te Puna. A total of 40 fruit were tagged and numbered in early December 2001. Measurements at this site were made by volume displacement at regular intervals. On several occasions individual fruit were harvested and volume displacement and weight recorded.

RESULTS AND DISCUSSION

2000/2001 season

Calculating fruit weight

A model was developed to approximate the shape of an avocado using just the overall length and two width measurements at right angles to one another. This model provided very accurate estimates ($R^2 = 0.99$, $P < 0.0001$) of actual fruit weight (Figure 1). The model was verified with similar results using data obtained over two different seasons in a different region. Rex Sharnweber kindly provided us with fruit measurements and fruit weights taken in the 1999/2000 and 2000/2001 seasons from his Whangarei property. The model also applies across a wide range of fruit development stages (4 to 18 months after fruit set).

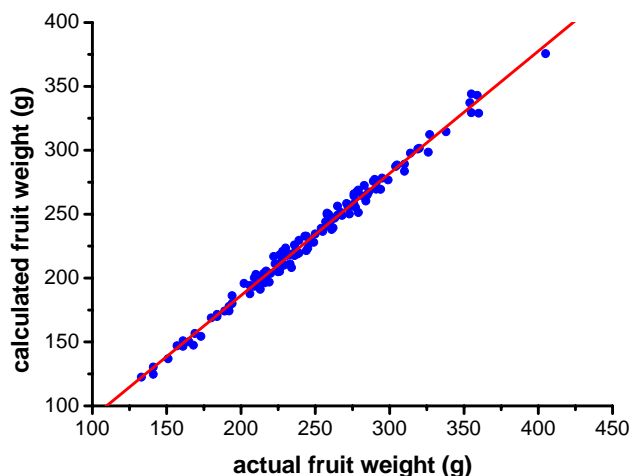


Figure 1. Fruit weight calculated from length and two width measurements in relation to actual fruit weight in the 2000/2001 season. Red line is fitted regression equation: $Y = 0.96X - 4.84$, $R^2 = 99.0\%$, $P < 0.001$, $n = 120$.

Fruit size distribution

Figure 2 shows the frequency of fruit grouped in to different size classes based on calculated weight for a 200 fruit sample measured in January 2002. The fitted

Gaussian distribution closely approximates a normal distribution with the average fruit weight coinciding with the peak in the graph.

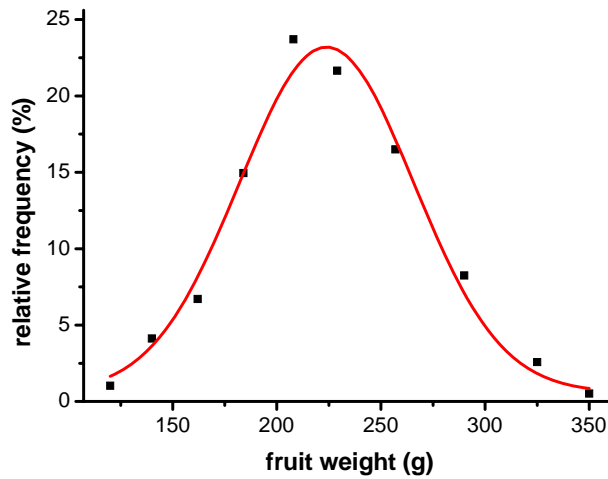


Figure 2. Relative frequency of calculated fruit weights with fitted distribution curve. Data is from January 2002.

The fitted distribution obtained from each sampling date is shown in Figure 3. As the fruit grow, the distributions shift to right with an increase in fruit weight. However, towards the end of the season the distribution becomes skewed towards larger fruit. This change in the distribution suggests that larger fruit are growing at a faster rate than smaller fruit.

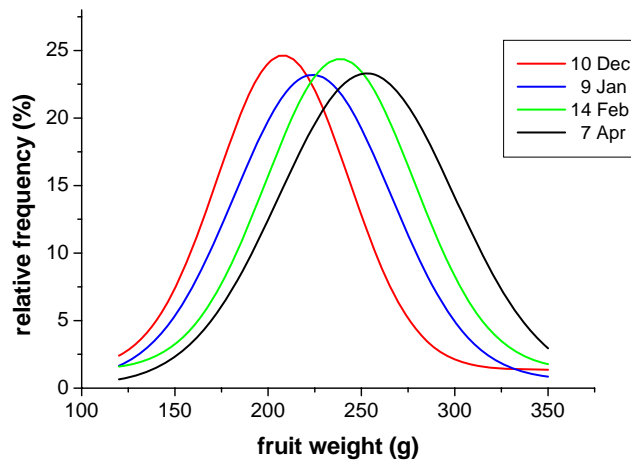


Figure 3. Fitted distribution curves for relative frequency of calculated fruit weights for fruit measured from December 2001 to April 2002.

Fruit growth rates

The relationship between the initial size of individual fruit in December, and their subsequent rate of growth over the next 5 months is shown in Figure 4. Large fruit were indeed growing faster than smaller fruit ($R^2 = 52.4\%$, $P < 0.001$). The rate of growth varied between 0.2 grammes per day for small fruit, up to 0.8 grammes per

day for large fruit. However, fruit size only accounts for about half the variation in growth rates. Clearly, other factors are contributing to the growth rate of individual fruit.

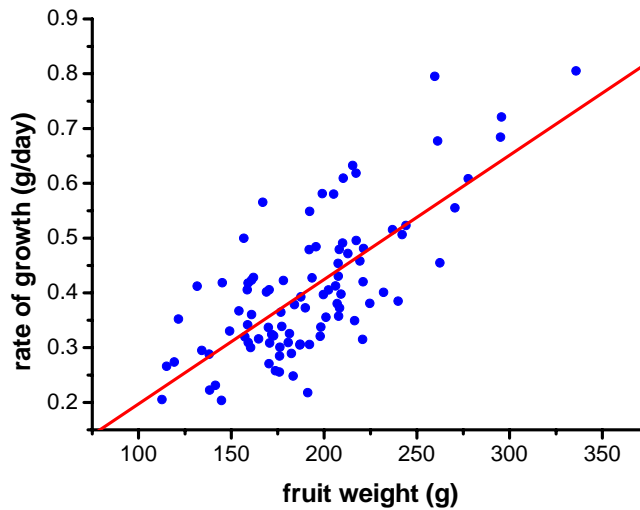


Figure 4. Rate of growth (g/day) for individual fruit (based on calculated fruit weights) in relation to the weight of fruit at commencement of monitoring (December 2001). $Y = 0.0023X - 0.03$, $R^2 = 52.4\%$, $P < 0.001$

Rate of fruit growth is not constant and changes with time. The average estimates of fruit weight for each month is shown in Figure 5. The rate of fruit growth slows down towards the end of the season. The growth rate appears to be following a sigmoidal pattern as has been observed elsewhere (Liu *et al.*, 1999; Moore-Gordon *et al.*, 1995; Zilkah and Klein, 1987). Averaged over the 5 month monitoring period fruit size increased by approximately 11 g per month, although larger fruit on average will have grown more.

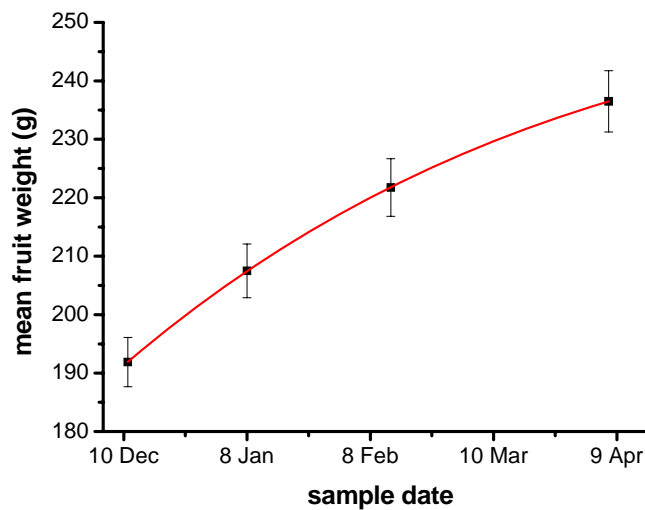


Figure 5. Average estimated fruit weight for each sampling date (\pm mean standard error). A sigmoidal growth function has been fitted (red line).

2001/2002 season

The same model as used in the 2000/2001 season continued to provide accurate estimates of fruit weight based on measurements of width and length in the field (Figure 6). This model has proved to be accurate for samples taken over a total of 4 different seasons.

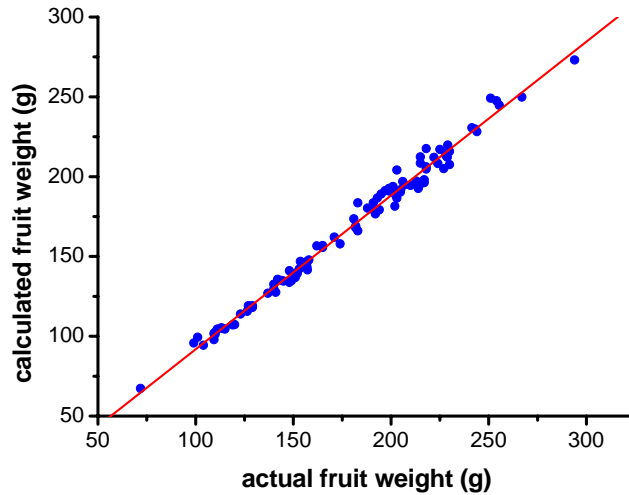


Figure 6. Fruit weight calculated from length and two width measurements in relation to actual fruit weight in the 2001/2002 season. Red line is fitted regression equation: $Y = 0.96X - 4.57$, $R^2 = 99.0\%$, $P < 0.001$, $n = 100$.

Fruit growth curves for the two orchards are shown in Figure 7. Growth rates follow a sigmoidal pattern with maximum rates of fruit growth occurring from January through to March. Fruit growth slows with lower temperatures over the winter period.

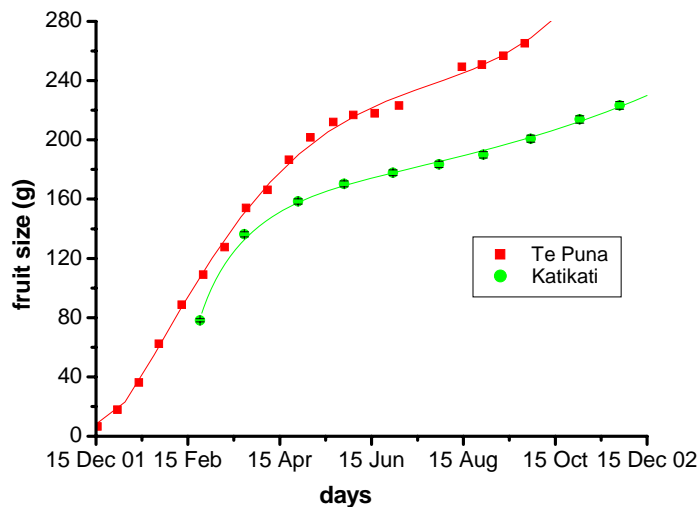


Figure 7. Fruit growth curves for two Bay of Plenty orchards. Fruit size in the Te Puna orchard was obtained by volume displacement and in the Katikati orchard calculated from width and length measurements.

Growth rates over the winter period differed substantially for the two orchards (Figure 7). A second growth phase occurs from September onwards with a repeat of the growth pattern observed in Figure 5. Fruit growth over the August/October period averaged 0.50 g/day for the Te Puna orchard and 0.38 g/day for the Katikati orchard. The factors that contribute to these differences in growth rate need to be identified so they can be taken into account for modelling purposes.

Fruit size profiles in the Katikati orchard at the start of the season (February 2002) were skewed, with some large fruit differentiating very quickly (data not presented). By April, fruit size profiles were normally distributed and remained so for the remainder of the monitored period.

SUMMARY

Fruit weight can be estimated based on non-destructive measurements of width and length in the field. More information on the pattern and consistency of fruit growth curves is required in order to predict fruit growth rates. The same applies to changes in the fruit size profile. Current indications suggest that it should be technically feasible in future to modify the crop estimate based on size profiles.

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