Fruit Size Management Guide

Part 2

An Australian Citrus Growers Publication

Introduction

The information in this guide has been based on the Australian Citrus Industry funded project "Optimisation of Citrus Production and Fruit Size: An Interactive Management Model". The project was led by Dr. Ken Bevington (NSW Agriculture) and the research, which focussed on navel and Valencia oranges, was conducted between 1999-2002. The final report from the project was published in July 2003 and is available from Horticulture Australia.

Fruit size is the single most important factor in determining market returns. Most domestic and export markets have a preference for large fruit (>72mm) and smaller fruit (<65mm) are often hard to sell. Achieving good sized fruit is a complex process and can be affected by a wide range of variables, such as variety, budline, rootstock, tree health, nutrition, irrigation, orchard management and environmental factors.

One of the most important factors affecting fruit size is crop load. When there is a heavy crop load then fruit size is usually small. Throughout the growing season there are several management options available to growers that can be used to help adjust crop load and improve fruit size. These were discussed in Part 1 of this guide.

The Fruit Size Management Guide Part 2 includes:

- Estimating Crop Load;
- The Predictive Fruit Size Model;
- Measuring Fruit Size.

The fruit size model was developed for Washington navel oranges using data collected in the Sunraysia area. If you intend to use this model in other areas and with other orange varieties you will need to test and evaluate its accuracy with your own data over a number of seasons.

The Fruit Size Management Guide Part 2 was compiled by Ken Bevington, Sandra Hardy, Steve Falivene & Tahir Khurshid (NSW Agriculture); Garry Fullelove (QLD Department of Primary Industries) and Peter Morrish (Murray Valley Citrus Board).

December 2003

Measuring Crop Load

Introduction

Assessing crop load is essential in making the right management decisions to achieve the best fruit size. It provides a good indication of whether a heavy, medium or light crop load is expected. It is particularly useful when there is a heavy crop load as it allows you to undertake suitable crop load reduction strategies such as chemical or hand thinning.

Citrus crop load is largely determined by flowering intensity and environmental factors affecting fruit set. In citrus, crop load and fruit number are inversely related to fruit size. This simply means the higher the number of fruits and therefore the crop load, then the smaller fruit size will be. Crop load is largely responsible for the year to year variation in fruit size.

When to measure crop load

Measuring crop load involves counting the number of fruitlets in a given canopy volume which gives you a fruit density count. **If you are considering using chemical thinning the best time to measure the crop load is near the end of the natural fruit drop period. This usually occurs in mid November to December when fruitlets are about 10-15 mm in diameter.** However exact timing can vary depending on the region, variety and seasonal conditions.

Monitoring and recording fruit drop will more accurately identify the correct time to measure the crop load. Fruit drop can be monitored by catching the fallen fruit (using a piece of shade cloth) under a few selected indicator trees every 2-3 days.

✔ Measure crop load when fruitlets are 10-15 mm in diameter.

✔ You may need to recheck crop load in January to determine if further thinning (hand) is required.

What you need

- A 0.125 m^3 counting frame (0.5 m x 0.5 m x 0.5 m) made from 10mm square steel (rolled hollow section, RHS) with 0.5 m prongs at each corner.

How to measure crop load

- **Number of monitoring trees:**
  As a guide choose 20 representative trees (per 1 ha block) to use as monitoring sites. These trees should be the same variety/rootstock combination and age. The trees should be carrying a crop load that is representative of the block. The more fruit density counts you do then the more representative the results will be for that block. For blocks larger than 1 hectare increase the number of monitoring trees.
- **Placing the counting frame:**
  The counting frame is randomly placed in the tree canopy with the prongs pointing towards the trunk and the outer edge of the frame at the edge of the canopy, at a height between 1.0-2.5 m from the ground. Place the frame in a representative part of the tree that is accessible from a standing position.
- **Number of frame counts per tree:**
  The number of frame counts you undertake per tree depends on the planting system used in the orchard and its effect on the crop distribution pattern within trees. Crop load often varies on different sides of the tree. As a guide for a standard planting of mature trees measure all 4 sides of the tree (4 frame counts per tree) or for mature trees planted as a hedge row measure each side of the tree (2 frame counts per tree). If the crop load is fairly even on all sides of the tree (young or small trees) then you may only need to take 1 measurement (1 frame count) per tree, but you will need to increase the number of trees measured.

Placing the counting frame into the tree canopy

Fruits which are paler in colour are about to fall and should not be included in fruit counts.

- **Assessing the crop load distribution within the canopy is critical**
  Sometimes the majority of the fruit can be in the upper parts of the canopy, which may give misleading counts. This is usually the case in orchards with high density tree plantings (e.g. Imperial mandarin orchards in Queensland) which cause shading in the lower parts of the tree canopy resulting in very high crop loads in the tops of trees and none in the lower parts of the canopy. These differences in the distribution of fruit should be taken into account when making crop density measurements.

  You also need to randomly place the frame in the tree and not show preference for areas of high or low crop loads. A good method to help randomly select the area to be measured is to either select it from a considerable distance when fruit are hard to see, or to place the frame into the tree without directly looking at it.

- **Counting the fruitlets within the frame (fruit density counts)**
  The number of fruitlets within the frame are then counted and recorded. This is repeated for each frame count on all monitoring trees throughout the one hectare block. Do not count fruitlets which are about to fall, these are paler in colour and smaller in size. Branches can be shaken to remove fruit that are about to fall.

- **Working out the crop load**
  The individual frame counts are then added together and divided by the total number of frame counts to get the average crop load.
  For example: if you counted a total of 500 navel orange fruit from 40 separate frame counts then you would have an average crop load of 12.5 (500 ÷ 40 = 12.5).

- **Using the crop load measurement**
  As a guide if the average fruit count is greater than about 8-10 fruitlets per frame for oranges, or for Imperial mandarins 8 - 10 fruitlets (NSW, Vic & SA) or 10-15 fruitlets (QLD) per frame, then thinning should be beneficial.

NB. Thinning thresholds will vary between districts, varieties, rootstocks, tree age and tree health. You should be guided by your own experience. It is recommended that you undertake crop load measurements over a number of seasons to build up a more accurate picture of how your orchard performs in regard to optimising yield and fruit size and minimising seasonal variation in yield.

The Fruit Size Prediction Model

Introduction

The fruit size prediction model was developed to help Australian citrus growers and industry to accurately predict final fruit size for navel oranges earlier in the growing season than is currently carried out.

By using the model, predictions of final fruit size can be undertaken in early January, at the beginning of the Stage II or cell expansion phase of growth after natural fruit drop has finished. At this stage there is still time to hand thin a heavy crop and improve fruit size.

Removal of small fruit which will not reach preferred export size would allow greater partitioning of carbohydrates into the remaining fruit and would also reduce the likelihood of alternate bearing problems.

Objectives in developing the model were:

- To determine what fruit size needs to be at specified times during the season to meet export size requirements;
- To be able to predict the final proportion of fruit in different size grades at harvest.

Development of the model

The model was developed using data collected in the Sunraysia district from mature Washington navel orange trees over three growing seasons. Fruit diameter was monitored at fortnightly intervals from January to July throughout Stage II fruit growth. The fruit measured were selected from around the canopy and included fruit growing on strong and weak bearing wood and different inflorescence types. The data for individual fruit were then used to model fruit growth curves for each of the three separate growing seasons (1999/00, 2000/01, and 2001/02).

Mean growth rates for fruit in various size grades were calculated from the analysis of fitted growth curves. Fruit growth can then be predicted by adding the predicted mean growth increment to the actual initial fruit diameter observed at an early stage of development.

Depending on the season fruit size prediction can use either:

- An overall average fruit growth rate or
- Different growth rates for fruit within different size ranges.
  (This may be the better option for heavy crop years).

Using the model

The model can be used to predict navel orange fruit diameter growth for any nominated time interval throughout Stage II fruit growth to harvest.

Average monthly diameter growth increments derived from the fitted growth curves are summarised in Table 1. Despite seasonal differences in climatic conditions and the crop load carried by the trees the predicted growth increments were observed to be fairly stable. Observed seasonal variation in growth was greatest during January and February. It is during this period that climatic factors and cultural practices have the greatest influence on fruit growth rates.

Table 1. Predicted monthly diameter growth increments for Washington navel oranges between January and June.

Month	Predicted diameter growth increment (mm)	
	Average	Range
January	9.1	8.2 - 9.7
February	7.2	6.6 - 7.5
March	6.1	6.0 - 6.3
April	4.0	3.9 - 4.1
May	2.6	2.2 - 3.0
June	1.3	1.1 - 1.8

Based on the predicted monthly growth increments in Table 1, Washington navel oranges can be expected to increase in diameter on average by a total of 28-30 mm between January and early June. Some variation in growth between individual orchards can be expected due to differences in factors such as tree age, rootstock and tree health.

The predicted minimum sizes for Washington navel oranges at various times during January and February for fruit to attain specified size ranges at harvest are shown in Table 2. Fruit need to be > 44 mm in diameter at the beginning of January and > 54 mm at the beginning of February to attain a size of 75 mm by early June. How you use the information in Table 2 when you take your own fruit size measurements is explained in *"Measuring Fruit Size"* under *"Calculating fruit size distribution"* on page 9.

Table 2. Predicted minimum fruit diameter during January and February for Washington navel oranges to attain specified size ranges at harvest in early June.

Measurement date	Size range at harvest		
	69-72 mm	75-77 mm	> 77 mm
01 January	41	44	47
15 January	44	48	50
01 February	50	54	56
15 February	53	57	60

The information in Table 2 can be used as a guide for the need to adjust management programs.

If fruit measurements at the beginning of January show a high proportion of fruit (> 50%) smaller than 40 mm then this indicates either:

- An excessive crop load and the need for remedial action;
- Sub-optimal nutrition or irrigation inputs or poor quality bearing wood;
- Tree health problems; or
- The impact of adverse climatic conditions during the Stage I phase of growth.

If fruit size at harvest is unsatisfactory but fruit size appeared satisfactory at the beginning of January, this may indicate:

- On-going crop load problems (fruit growth slows down earlier on trees carrying excessive crop loads);
- Irrigation and nutritional problems during early Stage II growth (see Part 1 of the Fruit Size Management Guide for recommended cultural practices); or
- Adverse climatic conditions (eg. heat stress during January and February).

Limitations of the model

Although the growth model could be applied to growth predictions at earlier times, citrus fruit growth rates during December are highly variable and far more data need to be collected than was possible during the three growing seasons studied in the fruit size project. Because of the ongoing natural adjustment of crop load through physiological drop and the possible adverse effects of high temperatures on fruit set, any growth estimates made in late November or December would certainly need to be verified at a later date.

The data used to develop the model were obtained from Washington navels grown in the Sunraysia district. Therefore the model will be most accurate when used in this area. However for other regions and other citrus varieties the model needs further testing and refinement.

If you are interested in collecting data in the 2003/04 season to further test and develop the model please contact Ken Bevington or Tahir Khurshid at NSW Agriculture, Dareton.

Further updates of the model will be posted on the ACG website (www.austcitrus.org.au) under "Season Update" on the Fact Sheet page.

Measuring Fruit Size

Introduction

Final fruit size at harvest is a function of fruit growth during the Stage I (cell division) and Stage II (cell expansion) phases of growth. Maximum potential fruit size is largely determined during Stage I growth and this is a critical period for crop management.

To achieve maximum potential fruit size, cultural inputs during Stage II growth (January to April) also need to be optimised and crop load adjusted to suit the orchard.

Measuring fruit size allows you to make informed decisions about possible management and market options. The development of the fruit size model has allowed us to better predict how navel orange fruit grow throughout the season.

Fruit size varies with region, variety, rootstock, soil type, microclimate, tree age and condition. It is important to start monitoring fruit size over a number of seasons in order to build up a better picture of how your own orchard performs.

When and how many fruit need to be measured?

To measure fruit size and use the fruit size prediction model you need to measure the diameter of the fruit. It is a relatively simple task but can be time consuming and it has to be done correctly to give reliable results. Fruit size can be measured at any time but to reliably estimate size distribution at harvest, measurements need to done after the end of natural drop. **To determine predicted fruit size at harvest the measurements can be done from January onwards for navel oranges.**

The number of fruit that need to be measured depends on the variability or spread of fruit sizes on the tree. A larger number of fruit will need to be measured on trees showing a wide variation in fruit size.

A sample of 50 fruit per tree from 4 trees of 14-year old Washington navels carrying 500-700 fruit has given a satisfactory estimate of average fruit size distribution. A larger sample would improve precision and a sample of 75-100 fruit per tree would be needed on bigger trees or trees carrying larger crops

At this stage for other citrus varieties we don't have any data on the number of fruit to measure, nor do we have a fruit size model for which to make comparisons. Recent experience from fruit size measurement trials on Imperial mandarins in Queensland suggests that a much larger fruit sample (between 20-25% of the crop load) would need to be measured on monitoring trees to adequately predict an average fruit size.

Measuring equipment

Fruit size can be measured using:

- **Digital vernier callipers:** these are the quickest and easiest to use however they do not operate in wet/damp conditions;
- **Dial vernier callipers:** these are nearly as fast to operate as digital vernier callipers and they work in all conditions;
- **Standard graduated scale vernier callipers:** these are slow to use;
- **A Cranston gauge:** also slow to use.

For measuring fruit size digital vernier callipers are quick and easy to use, but do not operate in damp/wet conditions.

How to measure fruit size

- **Number of monitoring trees**
  As a guide choose 4-6 representative trees (per 1 ha block) to use for monitoring fruit size. These trees should be the same variety/rootstock combination and age. The trees you use need to be representative of the typical crop load within the block to get the most accurate measurements. For blocks bigger than 1 hectare increase the number of monitoring trees.
- **Number and selection of fruit to measure**
  You need to measure at least 50 fruit per tree. You must try and choose a representative sample and not be biased when choosing the fruit to measure (ie. don't always choose the biggest fruit). You need to select fruit from all sides of the tree canopy.
- **Recording the measurements**
  Record the fruit diameter measurement in millimetres (mm) for all fruit measured on all monitoring trees.
- **Calculating fruit size distribution for navel oranges**
  For fruit diameter measurements taken in January or February an estimate of the proportion of the crop likely to achieve a diameter of 75 mm by early June can be calculated for Washington navel oranges from the information in Table 3.

Table 3. Predicted minimum fruit diameter during January and February for Washington navel oranges to attain specified size ranges at harvest in early June.

Measurement date	Size range at harvest		
	69-72 mm	**75-77 mm**	**> 77 mm**
01 January	41	44	47
15 January	44	**48**	50
01 February	50	54	56
15 February	53	57	60

For example: *In mid-January 50 fruit were measured on 6 Washington navel trees (this would be a total of 300 individual fruit measurements). Using Table 3 fruit need to be > 48 mm in mid-January (15 January) to achieve a diameter of 75-77mm at harvest. If 175 fruit out of the total number measured had a diameter > 48 mm then the proportion of fruit likely to achieve a diameter of 75 mm at harvest is 58% (175 ÷ 300 x 100).*

If you want to get even more detailed information on the fruit size distribution within your Washington navel orange crop you can use the information shown below in Table 4. Table 4 shows the predicted average growth increment from the beginning of each month through until harvest in early June. However to use this information requires a lot of calculations and is more easily undertaken using an electronic spreadsheet. You simply need to add the average fruit growth increment (for the specified measurement date) to each fruit size measurement undertaken. If you would like to receive (by email) a copy of an Excel spreadsheet to use for your own measurements contact Ken Bevington or Tahir Khurshid at NSW Agriculture, Dareton.

Table 4. Predicted growth increments for Washington navel oranges for different time intervals between January and harvest in early June.

Measurement date	Predicted diameter growth increment (mm) to harvest in early June	
	Average	**Range**
01 January	29.0	28.1 - 29.9
01 February	**19.9**	19.4 - 20.5
01 March	12.7	12.4 - 13.0
01 April	6.6	6.1 - 7.0
01 May	2.6	2.2 - 3.0

For example: *If you measured the diameter of 300 fruit in early February, then the average growth increment of 19.9 mm would need to be added to each individual fruit size measurement to obtain the predicted final fruit size. You could then sort all these predicted final fruit size measurements into different size counts to determine the proportion of fruit in each size range.*

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