FRUIT SIZE AND CROP LOAD PREDICTION

1 Introduction

Fruit size is a very important factor determining market returns. A lot of factors influence eventual fruit size, such as tree health, nutrition, rootstock, irrigation, soil type, quality of the bearing wood, the history of the orchard and seasonal differences due to climate or crop load. Citrus fruit growth has been described for Valencia oranges and grapefruit and follows a sigmoid growth curve, with 3 distinct growth stages: Stage I of cell division, Stage II of cell enlargement and Stage III of fruit maturation (Fig.1). Climatic conditions during Stage II of fruit growth are very important, but adverse climatic conditions during Stage I will also have a negative impact on fruit size. For a more complete summary of the factors influencing fruit size and for the different fruit size management strategies refer to the part on fruit size improvement (5-2).

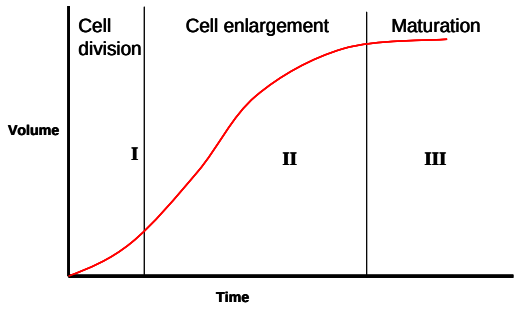

Fig.1. Citrus fruit growth (Bain, 1958).

2 Why is fruit size prediction necessary?

The objective of fruit size prediction is to accurately predict final fruit size at harvest time early in the season; as early as January, but after the physiological fruit drop period at the start of Stage II of rapid fruit growth, or the cell enlargement stage. Estimating final fruit size and crop load is very useful to plan harvesting and packing and to obtain specific markets for the fruit due to the fact that some markets pay more for fruit in a specific size category. By accurately predicting final fruit size at any time of fruit development, one can establish:

1. the final fruit size distribution at harvest per tree and therefore per orchard, therefore how much fruit would be in a specific fruit size category. These data can be used to predict final crop load (kg/tree).
2. what the size of fruit on a tree should be at a specific time to meet the export size requirements. If these requirements are not met, certain manipulations and adjustments to the management programme can be done to increase the number of fruit meeting the requirements or changes in the marketing programme may be an option.

Although it is too late in January to apply synthetic auxins for thinning and/or fruit size improvement, hand thinning is still an option. Hand thinning at this stage may result in larger fruit, but the major advantage would be the reduction in the number of fruit to reduce the incidence of alternate bearing if there is a history thereof in the orchard. Previous work on fruit size prediction was aimed at establishing mathematical models to predict final fruit size and the fruit size distribution of Valencia and navel oranges. In contrast to the growth of oranges and grapefruit, research shows that Satsuma and Clementine mandarins normally grow linearly after physiological fruit drop, during Stage II, until harvest at 0.33 and 0.26 mm/day on average, respectively, without flattening off of the growth curve during Stage III of maturation. Large fruit remain large and small fruit remain small. In this case, the equation $y = ax + b$ can be used for fruit size prediction of mandarins where y = eventual size (predicted), a = no. of days to expected harvest, b = fruit size at time of measurement and x = the growth gradient. However, from Table 1 it can be seen that a flattening off of the growth curve towards harvest time may occur even for mandarins.

3 Measuring fruit size for fruit size prediction

Fruit size is determined by the number of cells, of which most are formed during Stage I of cell division, as well as cell size. Cell enlargement normally occurs during Stage II of fruit growth. Therefore, optimal conditions during both Stages I and II are very important for potential fruit size at harvest. Although the majority of fruit growth occurs during Stage II, normally little growth occurs in oranges and grapefruit during Stage III of maturation just before harvest.

- Fruit size prediction can be done after the physiological fruit drop period by measuring fruit diameter of a representative sample of 50-150 fruit from 2-5 representative trees bearing a typical crop load in order to measure at least 500 fruit per block or growing unit. Measure fruit diameter with a calliper, preferably a digital one. Logging devices for direct download of fruit size measurements on a computer are also available. The same tagged fruit should be measured, weekly, bi-weekly or monthly from after physiological fruit drop until harvest to build up a database of long term mean fruit growth rates to be used for future fruit size prediction. Long term mean fruit growth rates are also useful to determine the fruit size increment the last few weeks before harvest. Before physiological fruit drop, fruit growth rates are variable and not all fruit has dropped making measuring very difficult. If the sample used for fruit size determination is not representative of the block the fruit size predictions would not be accurate.

- An even more representative way of fruit size measurement is to measure all fruit on one or more representative trees in a block or unit. The size of these fruit at the measured date is used to predict the fruit size distribution of trees in a block at the time of harvest based on historic (long term) mean fruit growth rates and the number of fruit can be used to calculate crop load. Final fruit size at harvest for each fruit is calculated by adding the predicted growth increment until harvest based on the predicted harvest date to the measured fruit size at a specific date. The fruit size distribution at harvest time is used together with the fruit number per tree to predict the yield or crop load per tree or per ha or orchard.

4 Fruit number per tree estimation

The number of fruit per tree is another important parameter for yield or crop load prediction. The number of fruit per tree at harvest is determined by both flower intensity and the fruit set achieved. Fruit number estimation should only be done after the physiological fruit drop period. A large proportion of fruit drops after physiological fruit drop until harvest, especially for navel orange trees, called the Summer-Fall fruit drop period. There are different ways to determine the number of fruit per tree:

1. Counting the number of fruit per tree for one or more representative trees per orchard or unit by using stickers and sticking on and removing them from fruit. The number of stickers used per tree is counted.
2. Total fruit removal from one or more representative trees after the physiological fruit drop period. These fruit are counted, fruit diameter is determined and the fruit size distribution calculated. Based on the % fruit in each category and the mean fruit weight (g) of fruit in each category at harvest, crop load (kg/tree and ton/ha) can be predicted.

5 Yield or crop load prediction

The prediction of yield or crop load (kg/tree) is essential in managing fruit size. Yield (crop load) is determined by both the number of fruit per tree as well as the size of the fruit. Larger crops result in smaller fruit and if identified early in the season, fruit number reduction strategies like hand thinning can be done. Although a lot of factors influence fruit size, yield (crop load) plays a major role. Not only may crop reduction at this stage result in larger fruit, but may reduce the incidence of alternate bearing. Thirty to 38% of fruit on navel orange trees can be culled from after the physiological fruit drop period until harvest due to the Summer-Fall fruit drop period, but the amount of fruit drop during this period for other cultivars is not well documented. Historical fruit drop records for each block are important to estimate the size of the Summer-Fall drop.

6 Fruit size and crop load prediction under South African conditions

In South Africa there are many growing areas with distinct climatic conditions and it is impossible to provide fruit growth models for all the cultivars in all the areas. Therefore, it is difficult to provide an overall or general guide to fruit size prediction. Using historical long term means of weekly, bi-weekly or monthly fruit diameter measurements for specific orchards or units, mean daily, weekly, bi-weekly or monthly growth rates until harvest can be calculated. The assumption is made that small and large fruit have the same growth gradient, for a specific season, therefore a mean fruit growth rate is

used for all fruit size categories. These long term mean growth rates are merely guidelines and the refinement and implementation of fruit size and crop load prediction should be done on the farm itself. Although these mean growth rates are fairly stable, they may differ with seasonal differences in crop load and climate, humidity, moisture stress etc. Fruit from individual orchards may also differ in growth rate, due to differences in tree age, rootstock, nutrition, irrigation, crop load, fruit number and tree health. Not only would the growth gradient be lower or higher due to such factors, but the growth curve may flatten off earlier or later as well, even for mandarins.

For instance, a representative Washington navel orange tree in Citrusdal at a spacing of 5 x 3 m (667 trees/ha) has 500 fruit (counted by one of the two methods mentioned) on 15 January. Therefore, all fruit will grow approximately 26.35 mm until harvest according to the fruit growth increments in Table 1 for Citrusdal and the predicted harvest date, based on historical data from 3 consecutive years. Yield or crop load, tree health or full bloom date were not taken into account in these calculations. To calculate the final fruit size at harvest, the growth increment is added to the measured fruit size. Therefore, minimum diameter on 15 Jan (column 4, Table 2) is determined by subtracting 26.35 mm from the minimum diameter of each fruit size category (column 2). Only 100 fruit were measured in this case (column 5), but all the fruit on a tree would be more representative. Fruit diameter of the 100 fruit measured are sorted into the different size categories (column 5). Based on the total number of fruit per tree (500) and the representative fruit size distribution on 15 Jan. (columns 5 and 6), the kg per tree in each category at harvest time can be determined. These calculations can easily be done on an Excel spreadsheet. Assuming 30% of fruit are culled from physiological fruit drop until harvest due to the Summer-Fall fruit drop period, only 350 fruit out of the 500 will be harvested. Therefore, the historical cull percentage during this time for a specific orchard should be documented and subtracted, assuming the same percentage will be culled from each fruit size category. Mean fruit weight for each fruit size category (column 3) is multiplied by the number of fruit in each size category after subtracting the Summer-Fall drop fruit (column 7) to obtain the kg fruit in each fruit size category (column 8). Therefore, yield or crop load would be 74.8 kg per tree and 49.9 ton/ha.

Growers are encouraged to take their own fruit growth measurements and to send them to Stephan Verreynne at sv@cri.co.za in order to build up a database of long-term fruit growth data for different cultivars in different climatic areas throughout the country, for more accurate fruit size prediction.

Additionally, monthly fruit growth increments for Swellendam (Table 3), Tshipise (Table 4) and Swaziland (Table 5) are also provided.

7 Literature

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Table 1. Monthly fruit growth increments in **Citrusdal** based on historical data from 3 consecutive years. Navel and Valencia in bold represent the means of all Navel or Valencia cultivars, respectively.

	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
	----------mm fruit diameter increments per month----------								
Mihowase Satsuma	**9.5**	**10.1**	**7.4**	**8.2**	**2.6**				
Nules Clementine		**5.0**	**7.5**	**7.6**	**5.5**	**3.3**			
Eureka Lemon		**4.4**	**5.2**	**7.2**	**5.5**	**3.4**	**2.4**	**1.6**	
Navel (mean)		**4.8**	**7.3**	**7.8**	**4.5**	**3.9**	**1.5**	**0.5**	
Bahianinha		6.1	7.0	8.0	4.0	3.7	1.4		
Palmer		3.1	7.8	8.3	5.4	2.9	1.6		
Robyn		5.3	6.6	7.5	3.9	5.3	1.7	0.7	
Washington		3.9	7.8	7.4	4.7	3.8	0.7		
Valencia (mean)		**4.5**	**6.0**	**7.6**	**5.4**	**4.3**	**2.8**	**1.7**	**0.9**
Delta		4.4	5.7	7.6	5.1	4.4	3.0	1.4	0.9
Midknight		5.3	6.3	7.8	6.2	4.4	2.4	1.7	0.6
Valencia		3.8	6.2	7.6	4.8	4.3	2.9	1.9	1.2

Table 2. Fruit size categories for oranges. Representative fruit size measurements are used to determine fruit size distribution and kg/tree.

Fruit/15 kg carton	Min. diameter (mm)	Mean fruit weigh (g)	Minimum diameter on 15 Jan	% by number on 15 Jan.	No. of fruit in category/ tree	After Summer-Fall drop	Kg per tree
32	99	468	72.65	0	0	0	0
36	95	417	68.65	0	0	0	0
40	90	375	63.65	0	0	0	0
48	86	313	59.65	5	25	17.5	5.5
56	82	267	55.65	15	75	52.5	14.0
64	78	234	51.65	30	150	105	24.6
72	73	208	46.65	20	100	70	14.6
88	69	171	42.65	15	75	52.5	9.0
105	65	143	38.65	10	50	35	5.0
125	62	120	35.65	5	25	17.5	2.1
		15 kg/no. of fruit /carton	Min. diameter-26.35 mm	out of 100 fruit measured	out of 500 per tree	minus 30%	Fruit weight x no. of fruit after S-F drop

Table 3. Monthly fruit growth increments in the **Swellendam** area based on historical data from 3 consecutive years.

	Feb	Mar	Apr	May
	--mm fruit diameter increments per month--			
Miho Wase	**6.9**	**6.1**	**3.3**	
Nules	**6.5**	**7.9**	**7.9**	**1.3**
Marisol	**6.5**	**7.9**	**5.8**	**2.0**
Oroval	**8.2**	**9.6**	**7.1**	**2.0**
SRA	**7.7**	**7.1**	**6.0**	**1.2**
Nova	**6.6**	**7.4**	**9.5**	**1.8**

Table 4. Monthly fruit growth increments in **Tshipise** based on historical data from 5 consecutive years. Valencia in bold represents the means of all Valencia cultivars.

	Feb	Mar	Apr	May	Jun
	--mm fruit diameter increments per month--				
Marsh	**1.4**	**1.0**	**2.4**		
Tomango	**5.2**	**3.8**	**3.1**	**1.3**	**0.4**
Valencia (mean)	**6.2**	**4.9**	**4.8**	**3.1**	**1.4**
Delta	6.7	5.0	5.5	3.2	1.5
Valencia	5.6	4.7	4.1	2.9	1.4

Table 5. Monthly fruit growth increments in **Swaziland** based on historical data from 5 consecutive years. Grapefruit and Valencia in bold represents the means of all Grapefruit or Valencia cultivars, respectively.

	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
	----------mm fruit diameter increments per month----------							
Nawel	**10.0**	**6.9**	**5.0**	**3.3**	**2.8**			
Pummelo	**15.1**	**18.1**	**15.3**	**7.4**	**1.6**			
Grapefruit (mean)	**12.3**	**9.3**	**5.2**	**3.9**	**2.2**	**2.3**	**0.5**	
Marsh	11.1	10.4	6.1	3.5	3.5			
Ray Red	12.4	8.1	5.2	3.5	1.7	3.3		
Rio Red	11.6	8.1	4.3	4.5	1.3	2.5	0.5	
Rose	13.5	8.9	4.6	4.1	2.4	2.7	0.5	
Star Ruby	13.1	11.0	5.6	4.1	2.1	0.8		
Minneola	**13.1**	**11.3**	**5.3**	**6.9**	**4.8**	**5.0**		
Tambor	**11.3**	**10.7**	**6.3**	**5.0**	**4.5**	**4.7**	**1.6**	**2.4**
Temple	**11.5**	**11.3**	**5.0**	**5.6**	**5.3**	**3.1**	**1.1**	**3.3**
Valencia (mean)	**10.3**	**8.0**	**5.7**	**4.2**	**3.5**	**3.8**	**0.5**	**1.2**
Delta	10.6	7.7	5.7	4.9	3.5	3.5	0.5	1.7
Valencia	10.0	8.2	5.8	3.6	3.5	4.1	0.5	0.6