South African Avocado Growers' Association Yearbook 1993. 16:90-95

ANALYSIS OF 'PINKERTON' AVOCADO FRUIT GROWTH

A.D. SIPPEL, M.A. HOLMES[1], N.J.F. CLAASSENS[2] AND VALERIE CLAASSENS
Agricultural Research Council (ARC), Institute for Tropical and Subtropical Crops (ITSC), Private Bag X11208, Nelspruit 1200, RSA ARC, Institute for Soil, Water and Climate, stationed at ITSC, Private Bag X11208, Nelspruit 1200, RSA[1] South African Avocado Growers' Association, P.O. Box 866, Tzaneen 0850, RSA[2]

ABSTRACT

Fruit size, growth rate and fruit fall of the 'Pinkerton' avocado was monitored for two seasons in different climatic areas. The results show that fruit set date had a marked effect on final fruit size. Fruit which set late (mid-September to mid-October) had a much faster growth rate than early set fruit (July August), and on average has the potential to be 40 mm longer (larger), at the end of the season. Fruit size and growth rate figures for the various fruit set periods and for the different tree quadrants are presented, and coupled to on-site meteorological data.

At both mid-season and harvesting stages, three trees were harvested in order to determine total fruit size distribution. Correlations between fruit length, width, mass and volume are presented. The best correlation was found to be between fruit mass and volume. These data are used to calculate on-tree fruit sizes and thus with only a few non-destructive measurements, final fruit size can be predicted.

INTRODUCTION

Why a study of the growth kinetics of the 'Pinkerton' avocado fruit and what does it involve? Firstly, the fruit is the product the producer markets and therefore his most important source of income. Secondly, for both the producer and the researcher it is important to understand the growth processes involved in fruit development to be able to apply manipulation techniques to the crop. Thirdly, fruit growth is also sometimes used as an evaluation method in different trials, for instance to determine the effect of different irrigation treatments. Fruit growth was also used as an indicator to fruit maturity (Lee & Young, 1983).

The maturity of avocado fruit is a problem that was studied intensively for years. However, choosing the correct picking time is still one of the avocado producer's nightmares, with a destructive technique as his only help for determining the beginning of picking time. Oil determinations has been used since 1925 in California as a norm for maturity, and avocado fruit there may only be marketed if the oil content is more than 8%. In Florida the palatability of the fruit is being used. Each cultivar has a specific date when the fruits are of a specific minimum size at which it can be picked. In South Africa the producers make use of water content (correlated to oil content), and palatability indicators such as time of the year, fruit size and other measures like colour changes,

shininess, corkiness, etc. Different cultivars have different margins at which they are considered mature.

With the 'Pinkerton' avocado under South African subtropical conditions, the trees flower over a long period. This results in a long fruitset period, giving rise to fruit of different ages on the same tree. It poses the problem whether this unevenness in age and size of the fruit has an effect on growth rates, fruit fall and eventual quality. Whether or not these fruit will be able to reach its full potential, depends on the ability thereof to effectively compete with other metabolic sinks for the available reserves.

With the view of investigating the effect of different fruit set periods on fruit growth rate, fruit size and fruit fall, a study was initiated in different climatic areas. Initial results showed that different fruit set periods can result in differences in fruit size at the end of the season due to differences in growth rates (Sippel, *et al*., 1992).

This article reports on further data obtained from the Kiepersol site after two seasons in the field. A detailed discussion on fruit sizes and growth rates for different quadrants of the tree are presented and coupled to on-site meteorological data. Correlations between different fruit parameters are also given and discussed.

MATERIAL AND METHODS

During the first year producer orchards were obtained in three localities, namely Schagen, Heidelberg and Kiepersol in the south eastern Transvaal Lowveld. These sites represent different climatic conditions. During the first year (1990/91) a total of 100 fruits per size were marked at a specific date. Length measurements were taken on these fruits until just before harvesting.

The second year (1991/92) only two sites (Heidelberg and Kiepersol) were used due to a hailstorm at the Schagen site. This time 100 fruits of similar size were marked at different time periods. These fruits were selected from 25 trees with a fruit in a specific wind direction. Length and width measurements were taken and fruit fall was determined from missing values.

At both mid-season (November) and at harvesting stage (May) three trees were fully stripped of all fruit in order to determine total fruit size distribution. All the fruits were then weighed, length and width on two planes determined, and every fifth fruit's volume and seed mass were determined.

RESULTS

From the tagging dates it is evident that climatic differences between the different sites have an influence on flowering and fruit set. At both Schagen and Kiepersol tagging commenced from August to October during 1990/91 whilst Heidelberg fruit could only be tagged from October onwards. During the second year (1991/ 92) fruit could be tagged from early September to late October at the two sites monitored. However, the aim was not to show differences between the sites but to show on an individual basis for each orchard that fruit growth of different sets can be a problem regarding period of fruit set. This past season we even had a fruit set during December.

a) Fruit size

For the purpose of this part we will concentrate on the Kiepersol data. The overall effect of different fruit set periods on fruit size was already discussed previously (Figs. 1 & 2) by Sippel, *et al*., (1992). Even though there was a 40 day difference in first set and last set date, the later set had the potential to be as much as 40 mm longer than the first set at the end of the season (1990/91). During the 1991/92 season the differences between sets were less severe than that of the first season. This does, however, still present a problem regarding the maturity status of the fruit.

If we now take a closer look at final fruit sizes of the different sets on the different quadrants of the tree at Kiepersol (Table 1), we find that the western side produced the largest fruit whilst the northern side had the smallest fruit. From this table the size difference between the first and the last set can also be noticed as was already mentioned.

TABLE 1 'Pinkerton' avocado fruit size distribution of the different sets at Kiepersol according to the different quadrants of the tree for the 1991/92 season.

KIEPERSOL	SET1	SET2	SET3	AVERAGE
NORTH	116.1	117.0	119.2	117.4
EAST	119.1	117.9	127.9	121.6
SOUTH	123.0	121.0	120.9	121.6
WEST	125.8	109.2	151.7	128.9
AVERAGE	121.0	116.3	129.9	122.4

Table 2 presents the fruit size distribution according to quadrants of the tree from the correlation data. Looking at fruit length we found that the western side of the tree again produced the largest fruit. Looking at yield, much less fruit were harvested on the southern side of the tree, both in number and in mass. Compared to the northern and western sides it was as much as 50% less. Individual mass of fruit on the southern side of the tree was less than that on the other sides during November, but it changed around to being about the most during May.

TABLE 2 Total amount harvested, total mass, average fruit mass and average fruit length of 'Pinkerton' avocado fruit at Kiepersol sampled from three trees from different quadrants of the tree during two different time periods.

NOVEMBER 1991				
QUADRANT	**AMOUNT HARVESTED**	**TOTAL MASS (Kg)**	**AV. FRUIT MASS (g)**	**AV. FRUIT LENGTH (mm)**
NORTH	446	33.8	74.6	69.6
EAST	449	33.1	74.4	69.9
SOUTH	254	15.8	66.5	67.6
WEST	356	27.4	75.3	71.1
MAY 1992				
NORTH	203	58.3	289.5	119.0
EAST	141	41.6	294.5	116.7
SOUTH	103	31.3	305.5	118.6
WEST	162	49.0	305.7	121.9

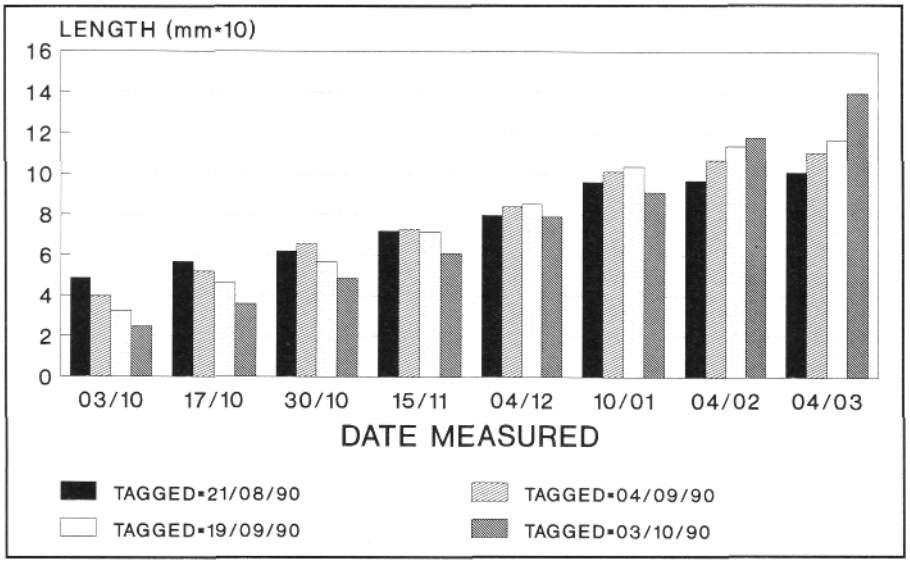

FIG. 1 Fruit growth of 'Pinkerton' Avocado at Kiepersol according to date of fruitset (1990/91).

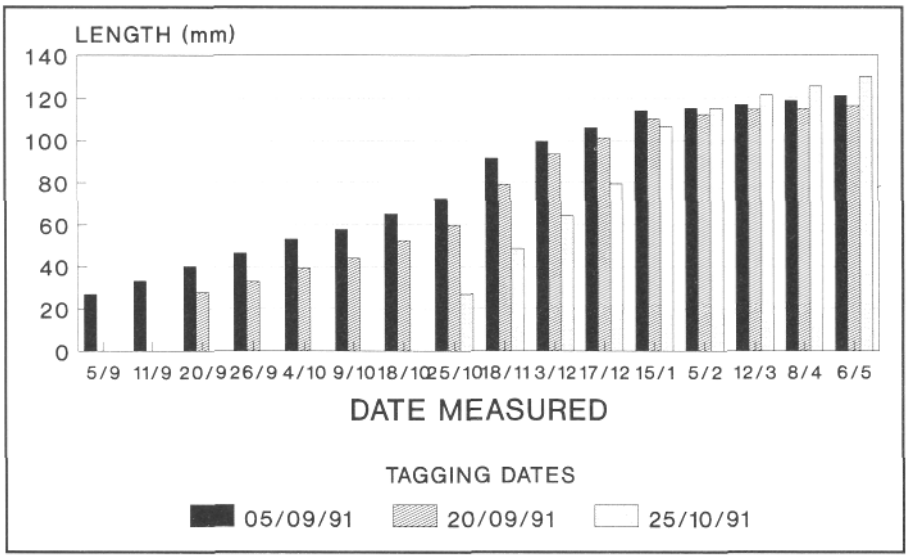

FIG. 2 Fruit growth of different sets of 'Pinkerton' avocado at Kiepersol (1991/92).

The fruit size distribution on the tree can be seen from Fig. 3. The first graph presents the mid-season fruit whilst the second graph presents the end of the season fruit on the tree. Fruit sizes from the November sampling differ between 10 mm and 115 mm, thus 105 mm between the smallest and the largest fruit. At harvesting period fruit sizes were between 70 and 155 mm, an 85 mm difference. This indicates a small improvement in the size difference of the fruit towards the end of the season. However, this improvement still does not solve the problem of mature and immature fruit on the tree at harvesting time. Analyzing the data accumulated we found that fruit size distribution were as follows: during November 68,7% of the fruit were between 60 and 90 mm, with the median being 73,2 mm. During May 74% of the fruit were between 100 and 130mm with the median at 119,1 mm.

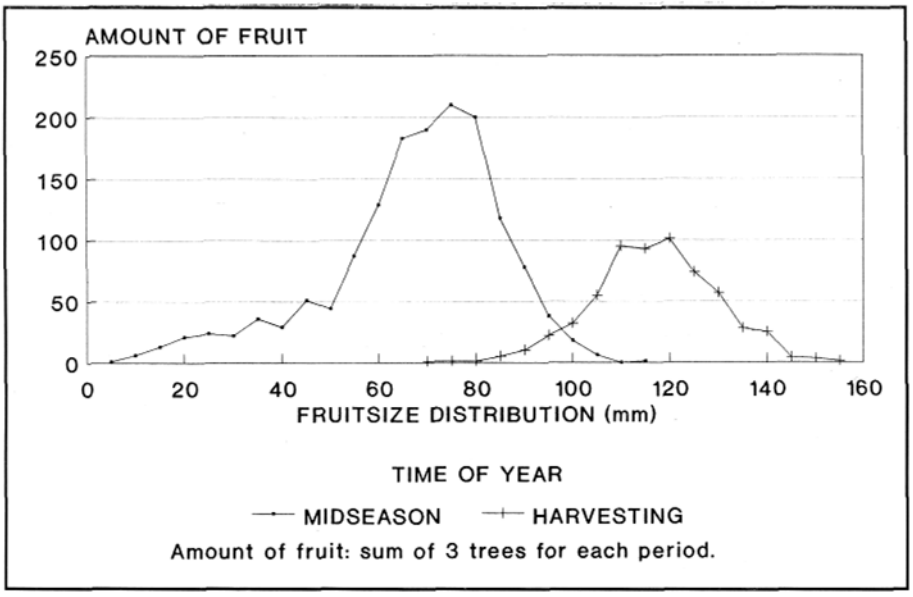

FIG. 3 Fruit size distribution at midseason and at harvesting for the 'Pinkerton' avocado.

Table 3 gives us the averages of the calculated parameters at the two periods of sampling. Interesting to note is the amount of fruit harvested at each period and the total mass of the fruit on the tree. The mass increased from 109,8 kg to 180,1 kg with a decrease in the amount of fruit.

TABLE 3 Average fruit parameters for the 'Pinkerton' avocado sampled from three trees during November and three trees during May at Kiepersol.

CRITERIA	AVERAGES	
	NOVEMBER 1991	MAY 1992
Median size	73.2 mm	119.1 mm
Mass	64.5 g	283.9 g
Length	60.4 mm	114.9 mm
Diameter 1	37.5 mm	69.3 mm
Diameter 2	37.3 mm	69.0 mm
D1/D2	1.007	1.002
L/D1	1.53	1.65
Total mass harvested	109.8 kg	180.1 kg
Total amount harvested	1 502	609

b) Fruit growth rates (FGR) and climatic aspects

The average fruit growth rates of all three set periods at Kiepersol are presented in Fig. 4. It is interesting to note from the figure that the average growth rate did not exceed 3 cm^3 day^{-1}, even for set 3. When the growth rates on different sides of the tree were

studied, we found that growth rate only exceeded the 3 cm^3 day^{-1} mark on the western side (where the biggest fruit was produced) of the tree, reaching a figure as high as 4.36 cm^3 day^{-1}. The average FGR during set 3 (1.34) is greater than set 1 (1.18) or 2 (1.00) during the period of study.

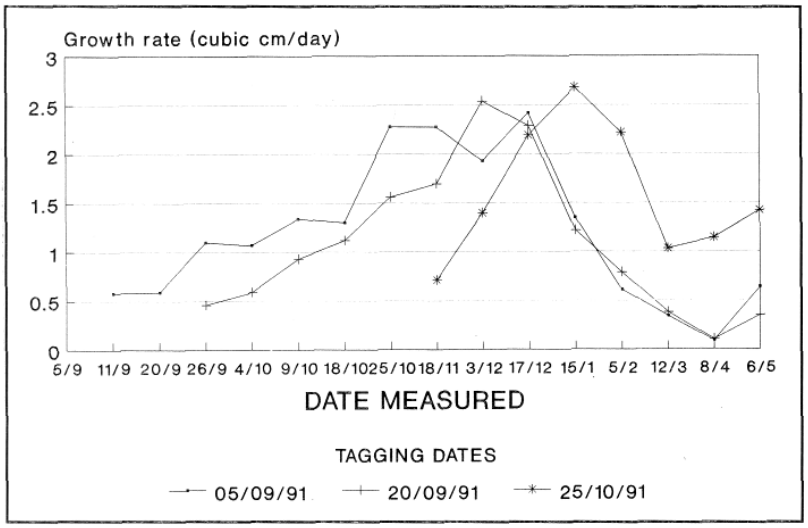

FIG. 4 Fruit growth rates of the different sets of 'Pinkerton' avocado at Kiepersol (1991/92).

Both sets 1 & 2 show clearly defined fruit growth phases viz. I, II & III (Fig. 5). Set 3 only has two fruit growth phases viz I & II, possibly because the fruit were harvested before they reached their full potential. The final fruit volumes increases from 265.52 cm^3 for set 1 to 305.3 cm^3 for set 3.

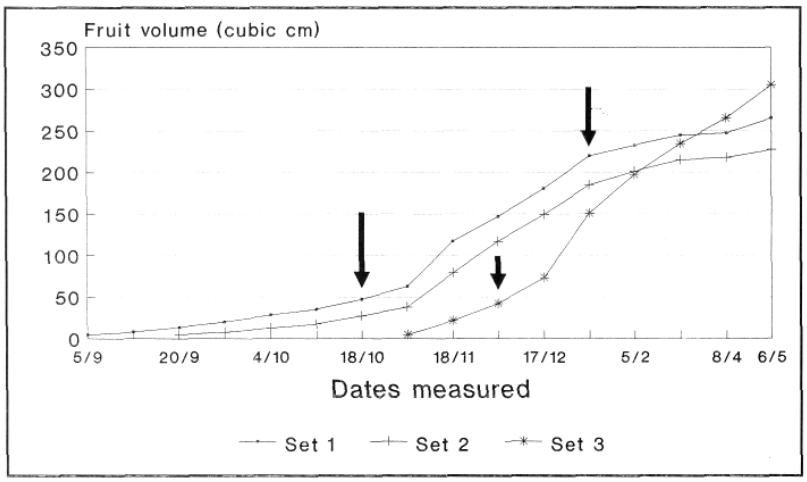

FIG. 5 Fruit growth of different sets of 'Pinkerton' avocado at Kiepersol (1991/92).

During both fruit growth phases, I & II, and throughout all three sets, the maximum air temperature was approximately 1.4°C greater at Heidelberg than at Kiepersol, whilst the minimum air temperature was approximately 0.9°C higher at Kiepersol than Heidelberg (Table 4). Average air temperature never differed more than 0.5°C between the two sites with Heidelberg marginally warmer than Kiepersol than Heidelberg (table 4) Average air temperature never differed more than 0.5°C between the two sites with Heidelberg marginally warmer than Kiepersol.

TABLE 4 Summary of MAX °T, MIN °T and fruit growth rate (FGR) between Kiepersol and Heidelberg for the different fruit growth phases.

		SET 1		SET 3	
		KIEPERSOL	HEIDELBERG	KIEPERSOL	HEIDELBERG
PHASE 1	MAX °T	23,6	25,6	26,0	27,7
	MIN °T	13,2	12,4	15,6	14,2
	PERIOD	11/9 - 17/10	20/9 - 17/10	18/10 - 2/12	18/10 - 2/12
	F.G.R.	1,08	0,77	0,9	0,76
PHASE 2	MAX °T	25,8	26,6	27,6	28,8
	MIN °T	15,8	14,7	17,4	16,3
	PERIOD	18/10 - 14/1	18/10 - 14/1	3/12 - 11/3	3/12 - 11/3
	F.G.R.	2,05	1,82	2,03	1,88
PHASE 3	MAX °T	29,6	30,8		
	MIN °T	18,6	17,3		
	PERIOD	15/1 - 11/3	15/1 - 11/3		
	F.G.R.	0,48	0,54		

The fruit growth rates were interesting in that even a 2,0°C higher temperature at Heidelberg did not achieve a higher FGR during phase I at this site. In fact, Kiepersol average 1,08 cm^3 day^{-1} for set 1 against the 0,77 at Heidelberg. During phase II Kiepersol again had a greater FGR of 2,05 cm^3 against the 1,82 of Heidelberg. For set 3 phase I Heidelberg again had a greater temperature (1,7°C) but Kiepersol showed the higher FGR of 0,9 cm^3 day^{-1} against 0,76. Phase II showed the same tendency with Kiepersol at 2,03 cm^3 day^{-1} and Heidelberg at 1,88 cm^3 day with the temperature 1,2°C in favour of Heidelberg.

c) Spatial shape determinations

It was found by Zilkah & Klein (1987) that the spatial shape of the avocado could be evaluated by a factor (M) which has been calculated from the ratio of the fruit's volume

to its circumferential cylinder volume. If this M-factor is known for a specific cultivar, then the volume can be determined from a formula. The formula is the following:

$$Vf = M\ Pi/4\ LD^2$$

Thus, by measuring non-destructively length and diameter of the fruit, and using a constant, we can calculate volume. This gives us the opportunity to predict fruit size on the tree without destroying the fruit.

Thus, the next step was to determine the M-value (Table 5) and for this purpose we used the trees harvested during November and during May. Fruit data taken at the two sampling periods consisted of length, diameter on two planes, weight, volume, seed mass and seed volume. From the ratio between fruit volume and the circumferential cilinder volume (using length and diameter measurements) the M-value was calculated.

The average for the Pinkerton differs from small fruit (0,47) to large fruit (0,62) with a working average of 0,545. We then used the constantto calculate fruit volume (Table 5). Thus, working out the volume by means of the formula, and using the correlation data (Table 6), we can now determine fruit mass on the tree without removing the fruit. The correlation between fruit volume and fruit mass were excellent for both periods of sampling. Using this knowledge, we can now predict final fruit mass non-destructively by measuring a few fruit for a limited time of growth.

TABLE 5 M-values and calculated volumes compared to real fruit volumes for different fruit sizes of the 'Pinkerton' avocado at Kiepersol from two sampling periods.

NOVEMBER 1991				
FRUIT SIZE	AMOUNT	FRUIT VOLUME	CALC. VOLUME	M-VALUE
20 - 30	4	2 125	3 249	0.37
30 - 40	8	9 750	9 375	0.52
40 - 50	14	16 500	19 321	0.40
50 - 60	24	28 375	32 352	0.43
60 - 70	68	43 294	44 067	0.47
70 - 80	96	65 421	63 680	0.49
80 - 90	60	84 008	79 653	0.50
90 - 100	21	112 619	104 134	0.52
100 +	3	150 333	129 334	0.56
AVERAGE	298	56 936	53 907	0.47
MAY 1992				
90 - 100	3	181 667	166 126	0.67
100 - 110	10	229 000	226 412	0.62
110 - 120	43	268 023	267 743	0.61
120 - 130	35	331 000	326 927	0.62
130 - 140	17	376 176	389 580	0.59
140 +	6	468 333	487 706	0.61
AVERAGE	114	309 033	310 749	0.62

TABLE 6 A Pearson correlation analysis of the 'Pinkerton' avocado fruit parameters sampled during two sampling periods at Kiepersol. (Prob > 0001).

		MAY 1992						
NOVEMBER 1991		MASS	LENGTH	DIAM 1	DIAM 2	F-VOLUME	SEED VOL	SEED MASS
	MASS	-	0.843	0.946	0.941	0.994	-	0.842
	LENGTH	0.954	-	0.734	0.710	0.828	-	0.655
	DIAM1	0.94	0.93	-	0.967	0.945	-	0.794
	DIAM2	0.95	0.937	0.978	-	0.942	-	0.806
	F-VOLUME	0.975	0.916	0.898	0.912	-	-	0.835
	SEED VOL	0.742	0.683	0.704	0.711	0.723	-	-
	SEED MASS	0.765	0.711	0.712	0.721	0.749	0.941	-

DISCUSSION

a) Fruit size

Although we have determined that picking according to fruit size alone is not the recommended method, due to the fact that the later set fruit tends to become larger than early set fruit and they haven't reached picking maturity yet, this method is still being used. We previously found that these later sets also caused postharvest quality problems. No quality problems were observed during the past season

b) Fruit growth rates (FOR) and climatic aspects

The influence of climate on fruit growth, with regard to the three fruit set periods, is not clear. The possible influence of climate on FGR within a given phase, for a given set, should be investigated.

c) Spatial shape determination

The availability of a formula through which, by only taking a few growth measurements, the producer can determine final fruit mass will assist management planning. The advantage of the system is that it is a non-destructive technique.

ACKNOWLEDGEMENTS

The authors wish to thank Messrs Garden, Pienaar & Vos for provision of orchards for the purpose of this trial and also Miss Mariet Christie for technical assistance.

REFERENCES

LEE, S.K. & YOUNG, R.E. 1983. Growth measurement as an indication of avocado maturity. *Journal of American Society for Horticultural Science* 108, 3: 395 - 397.

SIPPEL, A.D., CONRADIE, W. & CLAASSENS, N.J.F. 1992. Growth rates of 'Pinkerton' avocado fruit. *South African Avocado Growers' Association Yearbook* 15: 72 - 74.

ZILKAH, S. & KLEIN, I. 1987. Growth kinetics and determination of shape and size of small and large avocado fruits cultivar Hass on the tree. *Scientia Horticulturae* 32: 195 – 202