

# Sample Size Estimates for Avocado Yield Experiments

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**Abstract.** Fruit number and weight per tree were recorded for 3 years for 2 avocado (*Persea americana* M.) cultivars—'Booth 8' and 'Peterson'. Sample variances were used to determine the number of years per experiment and trees per treatment required to detect differences in yield among treatments at the 5% and 10% significance levels for each cultivar. Yearly variability was greater than variability among trees for both cultivars. Yearly variability for total fruit weight was greater for 'Booth 8' than for 'Peterson'. Fifteen trees per treatment were required to detect a 10-20% difference in total fruit weight per treatment at the 5% level of significance. Each additional tree per treatment decreased the percentage of detectable difference only slightly. Increasing the number of years per experiment decreased the percentage of detectable difference. However, after 3 years, additional years decreased the percentage of detectable difference only slightly for both an alternate- and a nonalternate-bearing cultivar. Efficient designs for avocado yield experiments for the cultivars tested should consist of 10 to 15 trees per treatment and should be conducted for at least 3 years.

There is often considerable variability among years and among trees of the same cultivar in yield experiments with avocado trees. Jones et al. (2) observed that fruit yields among avocado plots were more variable than leaf composition or fruit quality. There have been a few studies to estimate sample size requirements for yield experiments with tree fruit crops (1-3, 6-8). These studies, however, generally have not included yearly variability as a variance component. Yearly variability often is greater than variation among trees within a year. This variation is one reason that it is often necessary to collect yield data for at least 2 years when conducting fruit tree experiments.

Avocado yield can vary considerably among years, since many cultivars are alternate fruit bearers. Alternate bearing is often synchronous within a grove. Thus, years can be deemed either "on" years or "off" years with regard to fruiting (5). The inclusion of yearly variation as a variance component for sample size estimates would, therefore, be extremely useful for establishing experimental designs for avocado yield studies. This experiment was designed to estimate sample size requirements for avocado yield studies, taking into consideration the effect of yearly and among-tree variation.

## Materials and Methods

Two avocado cultivars, 'Booth 8' (common alternate bearer) and 'Peterson' (occasional alternate bearer) planted at the Univ. of Florida's Tropical Research and Education Center, Homestead, were used in this experiment. All trees were on 'Waldin' rootstocks and were 8-years-old at the beginning of the experiment. Trees had been bearing fruit for 3 years prior to this study. Beginning in 1983, fruit number and total fruit weight were recorded for each of 16 randomly selected trees per cultivar for 3 consecutive years. Thus, year (Y) and trees (T) were random variables, whereas cultivar (C) was a fixed variable. Although the experiment was conducted over 3 consecutive years,

Y was a random variable because independent factors that affect fruit yield during a given year are random. An analysis of variance (ANOVA) was performed to determine variability among Y, T, and C and to test for possible interactions. The only significant interaction was Y × C. There was also a significant difference between cultivars. Sample size estimates were calculated separately for each cultivar, since only 2 cultivars, each with different fruit bearing habits, were tested in this study. Variance components were calculated for Y and T, and the least significant difference procedure (3, 4, 9) was used to estimate the percentage of detectable difference between 2 treatments at the 5% and 10% levels of significance, varying the number of years (up to 5 years) and trees (up to 32 trees per treatment) allotted for future experiments. The least significant difference was calculated as:

$$LSD = t \sqrt{2 \left( \frac{S_{t(y)}^2}{n_{t(y)}n_y} + \frac{S_y^2}{n_y} \right)^{1/2}}$$

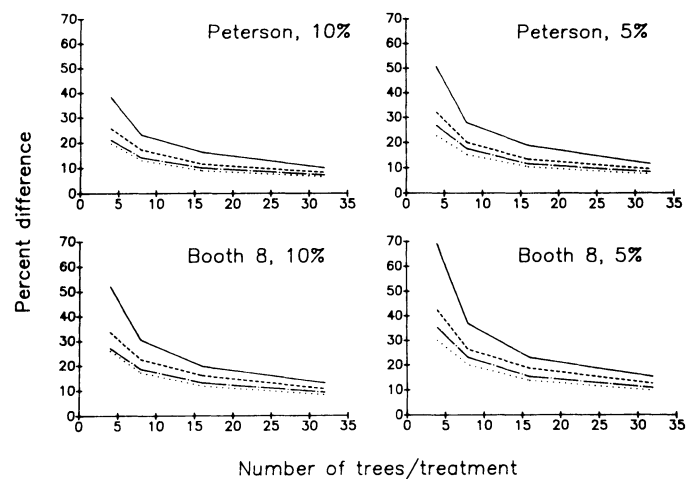


Fig. 1. Estimate of the percentage of difference in total fruit weight (kg) detectable at the 5% and 10% level of significance for 'Peterson' and 'Booth 8' avocado cultivars when varying numbers of years per experiment and trees per treatment are sampled. 2 years = —, 3 years = - - -, 4 years = - · - ·, 5 years = · · · ·.

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Table 1. Partial analysis of variance tables, including sources of interest for total fruit weight and fruit number for 'Booth 8' and 'Peterson' avocado cultivars.

Cultivar	Source of variation	Total fruit wt		Fruit no	
		df	Mean square	df	Mean square
Booth 8	(Y) Year	2	1881.2	2	8,612.2
Booth 8	(T) Tree	15	422.6	15	2,503.0
Peterson	(Y) Year	2	1085.5	2	16,993.6
Peterson	(T) Tree	15	201.4	15	1,205.0

Table 2. Fruit number and fruit weight sample parameters for 'Peterson' and 'Booth 8' avocado cultivars for 1983, 1984, and 1985.

	Data pooled by year		Data pooled by tree (rep.) <sup>2</sup>	
	Fruit no.	Fruit wt (kg)	Fruit no.	Fruit wt (kg)
<i>Peterson</i>				
Mean	1,247.3	438.7	79.8	26.5
Variance	189,144.9	9,543.2	2447.4	243.9
Maximum	1,211.0	520.0	235.0	59.4
Minimum	698.0	264.5	3.0	1.5
<i>Booth 8</i>				
Mean	1,028.7	434.2	67.1	28.1
Variance	51,862.9	14,994.1	1856.6	311.1
Maximum	1,842.0	575.7	170.0	71.3
Minimum	814.0	354.6	14.0	8.0

<sup>2</sup>Data pooled to estimate tree variability. There was no significant year × tree interaction.

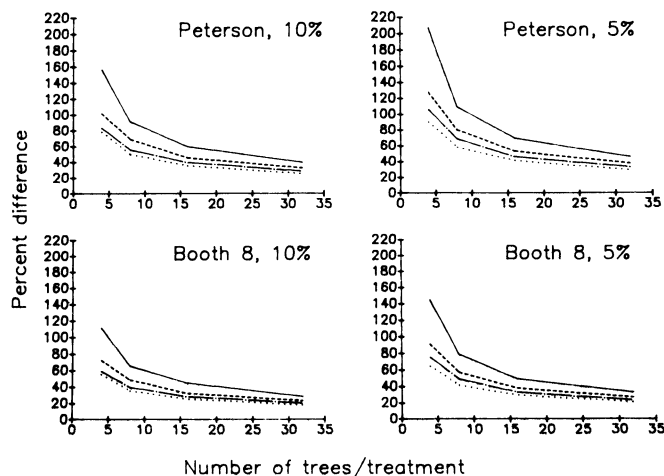


Fig. 2. Estimate of the percentage of difference in fruit number detectable at the 5% and 10% level of significance for 'Peterson' and 'Booth 8' avocado cultivars when varying numbers of years per experiment and trees per year are sampled. 2 years = —, 3 years = - - -, 4 years = - . - . , 5 years = . . . . .

where  $t$  is the Student's  $t$  value for the degrees of freedom associated with  $S_{t(y)}^2$  and  $S_y^2$  at a given significance level,  $n_{t(y)}$  is the number of trees per treatment per year,  $n_y$  is the number of years,  $S_{t(y)}^2$  is the sample variance for trees in years (T mean square - year mean square),  $S_y^2$  is the sample variance for years [Y mean square - T (year) mean square/ $n_{t(y)}$ ]. Mean square

values were obtained from ANOVA and are shown in Table 1. It was assumed that all data were normally distributed with homogeneous variances and that variance estimates from these sample populations will be similar in future experiments.

## Results and Discussion

Fruit number per tree was more variable for a given year than fruit weight (Table 2). Therefore, at the 5% and 10% significance levels for each cultivar, the percentage of detectable difference for a given number of trees was greater for fruit number than fruit yield (Figs. 1 and 2). The percentage of detectable difference was obviously lower at the 10% than the 5% significance level. Although calculations for sample size estimates were determined for only a few levels of  $n_{t(y)}$  for each year, the relationship between the number of trees ( $n_{t(y)}$ ) and the percentage of detectable difference would be represented by an asymptotic line if infinite levels of  $n_{t(y)}$  were plotted (Figs. 1 and 2). The percentage of detectable difference decreased as the number of trees increased. However, as the number of trees increased, the slope of the line decreased. Therefore, the percentage of detectable difference decreased only slightly when the number of trees per treatment exceeded 15 for each cultivar (Figs. 1 and 2). As the number of years per experiment increased, the percentage of detectable difference for total fruit weight for a given number of trees per treatment decreased (Fig. 1). Yearly variability was greater for 'Booth 8' than 'Peterson' for fruit number (Table 2). The opposite was true for fruit weight. As the number of years per experiment increased, the percentage

of detectable difference at a given number of trees per treatment became similar for the 2 cultivars (Figs. 1 and 2).

There was considerable variation in avocado fruit yield among trees. A similar observation was made by Jones et al. (2), who attributed this variation to variability among seedling rootstocks. Trees used in the present study were on seedling rootstocks of the same cultivar. Therefore, variation among trees is probably not a result of rootstock variability. The greater yearly variability for total fruit weight for 'Booth 8' compared to 'Peterson' was presumably due to differences in fruit-bearing habits between cultivars. 'Booth 8' is a stronger alternate bearer than 'Peterson' and therefore exhibits greater year-to-year variation in fruit yield.

Increasing the number of trees per treatment to 15 was effective in decreasing the percentage of detectable difference for a 3-year experiment at the 5% significance level to between 10% and 20% for fruit weight and 50% to 60% for fruit number. Increasing the number of trees above 15 decreased the percentage of detectable difference only slightly. Thus, it would be inadvisable to select more than 15 trees per treatment for future avocado yield experiments unless small differences are biologically or economically important to determine with accuracy. The additional precision gained by using more than 15 trees would probably not warrant the added time and expense of harvesting additional trees. As more trees were sampled, the percentage of detectable difference increased sharply when up to 8 trees per treatment were sampled. Therefore, between 10 and 15 trees per treatment would be advisable for future yield experiments. The percentage of detectable difference was much less for fruit weight than for fruit number. Therefore, fruit weight is the more accurate index of total yield.

As the number of years per experiment increased, the percentage of detectable difference at a given number of trees decreased. After 3 years, additional years increased the percentage of detectable difference only slightly. Therefore, 3 years is probably adequate for yield studies with the 2 avocado cultivars tested. Since alternate bearing within a grove tends to be synchronous (5), increasing the number of years per study to 4 would allow a minimum of 2 bearing years regardless of whether the experiment was started on an "on" year or an "off" year.

Further studies with additional cultivars would be required to determine if these results apply to all alternate- and nonalternate-bearing avocado cultivars.

Fewer trees per treatment were required to detect the same differences at the 10% compared to the 5% significance level. Consistent with previous recommendations by Jones et al. (2) and Marini (3), it may be advisable to test equality of means at the 10% or higher level of significance for tree fruit yield studies. The routinely accepted 5% level may require too many trees per treatment to detect relevant yield differences for fruit trees. Increasing the significance level would allow for the detection of smaller differences using fewer trees per treatment, thus saving researchers considerable time and effort.

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