THE INFLUENCE OF ROOTSTOCKS ON SOME FRUIT AND TREE CHARACTERS OF AVOCADO (*PERSEA AMERICANA* L.)

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I. INTRODUCTION

Avocados have been used as food in Mexico, Central America and South America for many centuries. Commercial production started in the U.S.A. around 1900 in California and Florida and has been expanding ever since, particularly in the former state.

Avocados are not yet in general use by all people because they have usually been considered a luxury and their true food value has not been fully appreciated. When consumers learn about the excellent nutritional qualities of avocados, the fruits are likely to become more popular. Avocado is the only fruit containing all of the basic food elements: carbohydrates, proteins and fat as well as vitamins and minerals. In contrast to most other fruits, they are distinguished by their high oil content and relatively low carbohydrate content (28).

Avocado oil has been found to be a desirable anti-cholesterol agent containing from about 60 to 84 percent unsaturated fatty acids (24, 28). Ninety-five percent of the fatty acids are made up of oleic, palmitic, linoleic and palmitoleic acid. More than 60 percent of the fatty acid content is oleic acid (23).

The percentage of oil in avocado fruits varies widely. Some varieties contain as little as 3 percent oil, while others are reported to have as much as 30 percent oil (31). In Hawaii, avocado fruits tend to have even higher oil contents, and some avocados have been found with up to 40 percent oil.

Tests conducted in California indicate that avocados of a given cultivar are generally more palatable when their oil content is higher (22). Wolfe *et al.* (31), however, reported no positive correlation between high fat content and quality in comparisons between varieties.

High oil content in avocados is nearly always associated with high ash content, but apparently not related to sugar and protein content (31).

Oil content is often used as a criterion of maturity in major avocado producing areas. In California and Israel a minimum percentage of oil is required at picking time to prevent marketing of immature fruit. Avocado fruits harvested while still immature, usually shrivel and/or rot while softening and characteristically lack desirable flavor (12,25).

Within *Persea americana* 3 ecological or horticultural races have been described. These have been referred to as the "Mexican," "Guatemalan" and "West Indian" races (29). The Mexican race is native to the highlands of Mexico, the Guatemalan race originated in the highlands of Central America and the West Indian race is from the lowlands of Central America (29).

It has become increasingly difficult to differentiate between races because of recurrent natural hybridization which takes place between races and their hybrids. Season of maturity and skin thickness seem to be the most reliable indications of racial origin of varieties.[1] Racial origin or identity attributed to commercial cultivars is often a provisional judgment based on the phenotype of the variety.

Rootstocks of different avocado races have been found to have different effects on certain tree characteristics such as sodium and chlorine (chloride) concentration in the plant (8, 13, 14) and disease resistance (15, 16, 17, 32, 33).

[1] Dr. B. O. Bergh, personal communication.

The present study was carried out in an attempt to determine what effects Guatemalan and West Indian rootstocks have on trunk circumference, fruit size, seed size, skin (exocarp) weight, flesh (mesocarp) weight, ratio of seed to flesh, and oil content of the flesh of several avocado cultivars. The effect of 2 different locations on fruit characters studied was also investigated.

II. REVIEW OF LITERATURE

Rootstock effects

Interest in rootstocks has been largely concerned with the search for resistance to the soil fungus *Phytophtora cinnamomi* Rands., commonly referred to as "avocado root rot." To date no compatible rootstock has been found which possesses adequate field resistance to this important disease. 'Duke,' a Mexican race rootstock has, however, been reported to have some degree of resistance or field tolerance (33). Certain other *Persea* species, which are highly resistant to avocado root rot, are unfortunately not graft compatible with *P. americana* (33).

Avocado rootstocks from the 3 different races have been studied in regard to effects on a number of fruit and tree characters. Embleton *et al.* (8) studied the influence of race and variety of rootstock on concentration of chlorine (chloride) and other elements (ions) in leaves of the avocado. Trees on Guatemalan race rootstocks showed significantly lower chlorine (chloride) concentrations in avocado leaves than those on Mexican race rootstocks. There was, however, some overlap of effects on varieties with the different races of rootstocks used. In other experiments by Haas (13), West Indian race rootstocks tolerated higher chlorine (chloride) concentrations than either Guatemalan or Mexican race rootstocks. Haas (14) also observed that root systems of Mexican race rootstocks permitted more sodium to pass into leaves, causing leaf injury, than did Guatemalan rootstocks. This suggests that in saline areas Guatemalan rootstocks should be used in preference to those of Mexican race.

Zentmyer *et al.* (32) found that Guatemalan rootstocks were generally more susceptible to *Verticillium* wilt than Mexican rootstocks. Halma and Zentmyer (17) reported on the relative susceptibility of Guatemalan and Mexican avocado varieties to *Dothiorella* canker. They found Guatemalan cultivars to be more susceptible than Mexican. Halma and White (15) and Halma and Goodall (16) found that a type of chlorosis of young avocado trees in California, probably caused by excess calcium, was largely confined to trees on Guatemalan rootstocks. Trees on Mexican or West Indian rootstocks seemed immune or only slightly affected by this disorder.

Oppenheimer (27) conducted a stock-scion trial in Israel for 6 years with 4 varieties: 'Fuerte,' 'Anaheim,' 'Benik' and 'Nabal' and 5 rootstocks: 'Duke' and 'Northrop' of the Mexican race, 'Benik' and 'Nabal,' both Guatemalan race, and 'Fuerte,' which is considered to be of hybrid Guatemalan/Mexican parentage. Effects of rootstock on tree size, yield and mean fruit weight were examined in this experiment. Mean differences in tree size which could be attributed to rootstocks used were small and not significant. Trees budded on 'Nabal' seedling rootstocks gave appreciably, but not statistically significantly higher average yields. Mean fruit weight did not appear to be affected by the rootstocks used.

<u>Oil content in relation to maturation and ripening</u>

Depending upon race and cultivar, avocado fruits reach maturity from about 6 to 12 months after fruit set (29). During fruit development, oil content increases at a uniform rate as the fruit approaches maturity. After maturity has been reached the percentage of oil remains constant or increases only slightly until the fruit is ripe. Moisture content on the other hand decreases at a uniform rate until maturity, and then remains more or less constant (1, 18). Davenport and Ellis (7) believe that during fruit development oil takes the place of water in the vacuoles of the cells of the mesocarp. The refractive index of the oil in 'Fuerte' avocados was found to be constant throughout the season (1).

It has been reported that fruits of most avocado varieties grown in California stay firm as long as they remain attached to the tree by a healthy stem (9). In Florida, however, avocados may eventually ripen on the tree (5). After avocados have been picked, the ripening process begins unless they are refrigerated. The rate of respiration begins at a minimum and then rises to a maximum climacteric peak. Duration of this rise depends on external conditions and stage of maturity of the fruit. The avocado fruit does not utilize fat or sugar for CO_2 production during climacteric activity. Biale (3) considered that CO_2 is probably derived from hemicelluloses and pectins during respiration. If avocados are kept at temperatures below 5°C or above 30°C for an extended period of time, they fail to ripen properly, the flesh darkens and the fruits become inedible (4).

The composition of avocados varies at maturity, but usually they contain between 3 and 30 percent fat, from 1 to 3 percent protein and less than 1 percent carbohydrates (3, 31).

It is important that avocados attain maturity before picking in order to become attractive and palatable after softening. It is, however, somewhat difficult to judge maturity visually without considerable experience. Formation of a waxy coat or "bloom" on the surface of the fruit is usually indicative of approaching maturity (6). Erickson and

and Porter (11) also found a positive correlation between amount of cuticle wax and oil content.

Other criteria of maturity include filling out of the fruit, yellowing of the stem joint and formation of small rusty specks around the distal end of the fruit (6). Thickness and color of seed coat and condition of the seed (10, 25) as well as corking of the lenticels on the skin (21) are also useful indications of stage of maturity. Number of days required for fruit to soften and loss of weight during softening have also been studied as possible indices of avocado maturity (21).

Most visual or physical tests of fruit maturity are of limited value compared to laboratory determination of oil content. Percent of oil in the flesh was chosen as a criterion of maturity because it is closely correlated with fruit development (9). California regulations stipulate that "all avocados, at the time of picking and at all times thereafter, shall contain not less than 8 percent of oil, by weight of the avocado excluding the seed and skin" (25). In Israel regulations specify a different minimum oil content for different commercial cultivars (12). In Florida palatability of avocados was found to be correlated with season of maturity rather than with oil content. Each cultivar is, therefore, assigned an arbitrary date on which fruit of a designated minimum size may be picked for marketing (9).

Although non-destructive tests, such as specific gravity of the fruit (18, 21), pressure tests (18) and other rather complicated tests described by Bean (2) are of interest, they have the common shortcoming that physical properties of the fruit change more rapidly during ripening after maturity than during maturation on the tree. An essential requirement for a practical maturity standard is that it can be applied at any time after harvesting (9).

Tests conducted by Hatton *et al.* (19) in Florida with 'Lula' avocados indicated that fruit picked from the upper half of the tree usually contained a higher percentage of oil than fruit from the lower half. Fruit harvested from the 4 quadrants of the tree failed to show significant differences in oil content.

Harkness (18) found considerable variation in oil content within fruits. Flesh nearest the skin often had lower oil content than flesh nearest the seed. The part of the mesocarp with the deepest yellow color had the highest oil content. There was no significant difference in oil content between stem and blossom ends of fruits.

Gazit and Spodheim (12) and Hatton *et al.* (20) found no consistent correlation between oil content and fruit weight.

Variation in oil content between fruits from the same tree may be partly accounted for by the relatively long period of blossoming and fruit set. Because of this, it is possible that avocados which look similar may be in different stages of physiological development (1, 9). Harkness (18), however, stated that the range of oil content in fruits from the same tree appears due to a natural random variation, since as much as 3 percent difference in oil content was found between fruits of the same size, set at the same time, located within 1 m. of each other on the same tree.

Two different methods are used in determining oil content of avocados. One involves extraction of oil with a volatile solvent, evaporating the solvent, and weighing the oil (24,26). The second consists of extraction with a relatively non-volatile solvent with a high refractive index such a 1-chloronaphthalene, commonly known as Halowax oil. Oil content is then measured indirectly by determining the refractive index of the mixture of solvent and oil (25).

III. MATERIALS AND METHODS

Rootstocks

The experimental trees were located adjacent to each other in pairs in the same row with each clone grafted on 2 different rootstocks. One tree of each pair was grafted on a 'Nabal' seedling rootstock of the Guatemalan race and the other on an 'Ashikawa' seedling rootstock of the West Indian race.

Locations

Data were taken at 2 locations. One experimental planting was located on the Haleakala Experimental Farm on Maui and the other on the Malama Ki Experimental Farm on Hawaii. Elevation, temperature and rainfall data of both locations are given in Table 1.

Table 1. -- Elevation and weather data from the Haleakala and Malama Ki Experimental Farms [a]

Location	Elevation (m.)	Mean annual temperature (°C) Max.	Min.	Mean annual rainfall (mm.)
Haleakala	640	23.5	15.2	2304
Malama Ki	100	26.3	19.2	3459

[a] weather data from March 1966 through February 1971

Varieties

Pairs of trees of 9 avocado varieties were used to study the influence of rootstock on trunk circumference. Both trees of each pair were of the same age. The experimental trees were located at the Haleakala Experimental Farm. They are listed as follows along with their age and probable racial origin. Racial origin is indicated by G for Guatemalan, M for Mexican and WI for West Indian:

1. Allmeat (G x M) - 8 years and 2 months
2. Chrones (G x WI) - 8 years and 2 months
3. Monge (WI) - 8 years and 2 months
4. Fujikawa (G) - 6 years and 8 months
5. Kaguah (G) - 6 years and 7 months
6. Yamagata (G) - 6 years and 3 months
7. Tsutsumi (G) - 6 years and 3 months
8. Beardslee (G x WI) - 6 years and 3 months
9. CRC 151-2 (G x M) - 6 years and 2 months

Fruit samples from 14 pairs of trees were studied, 8 pairs from Haleakala and 6 from Malama Ki. Varieties from which fruits were sampled at both locations are listed as follows together with their most probable racial origin:

Haleakala			Malama Ki		
1.	Fuerte	(G x M)	1.	Fuerte	(G x M)
2.	Sharwil	(G x M)	2.	Sharwil	(G x M)
3.	Allmeat	(G x M)	3.	Rincon	(G x M)
4.	HAES 7315	(G)	4.	HAES 7315	(G)
5.	Elsie	(G)	5.	Wahiawa	(G)
6.	Ilialu	(G)	6.	Guatemala	(WI)
7.	Hass	(G)			
8.	Kahaluu	(G x WI)			

One pair of trees of each cultivar was available at each location. Three cultivars, 'Fuerte,' 'Sharwil' and 'HAES 7315,' were common to both locations.

Chemicals

For the oil content determination method the following chemical materials were used:

1-chloronaphthalene (Halowax oil)

'Hy-flo Supercell,' a diatomaceous earth filteraid

Equipment

The following equipment was used for the determination of oil in avocados:

Mettler balance, Model K5T

Waring blendor

Abbe 3L Bausch and Lomb refractometer

Carver hydraulic press

Tree characters studied

One tree character was studied: trunk circumference, measured to the nearest cm., approximately 8 cm. above the graft union. Comparisons were made between trees of the same variety grafted on the 2 different rootstocks.

Fruit characters studied

1. Fruit weight in grams, to the nearest gram.
2. Seed weight in grams, to the nearest gram, and as percentage of total fruit weight.
3. Skin weight in grams, to the nearest gram, and as percentage of total fruit weight.
4. Flesh weight in grams, to the nearest gram, and as percentage of total fruit weight.

5. Ratio of seed to flesh.

6. Oil content of the flesh in percent by weight, to the nearest tenth of a percent.

Influence of rootstocks on these characteristics was studied by comparing fruits from trees of the same variety, grown on 2 different rootstocks. Data from the 3 varieties available at both locations were analyzed in an attempt to determine the influence of locations and rootstocks on the fruit characters.

Laboratory methods

Samples for analysis were collected from the experimental trees by picking fruits at random from near ground level up to about 2 m. Fruit samples were examined upon arrival at the laboratory to select sound fruits which were then allowed to ripen at approximately 23°C. When the avocados had ripened, the stem was removed and fruits weighed to the nearest gram. Stage of ripeness was determined by hand pressure aided by color judgment in the case of fruits which turn purple as they ripen.

Ripe fruits were cut in half, the seed removed and then weighed to the nearest gram. The flesh of the fruit was carefully scooped out of the skin, weighed and then transferred to a Waring blendor. In large fruits with too much flesh for the blendor cup, alternate eighths of the fruit were used instead of the entire fruit. The skin was weighed and flesh weight obtained by subtracting the weight of seed and skin from total fruit weight. The seed/flesh ratio was calculated by dividing seed weight by flesh weight.

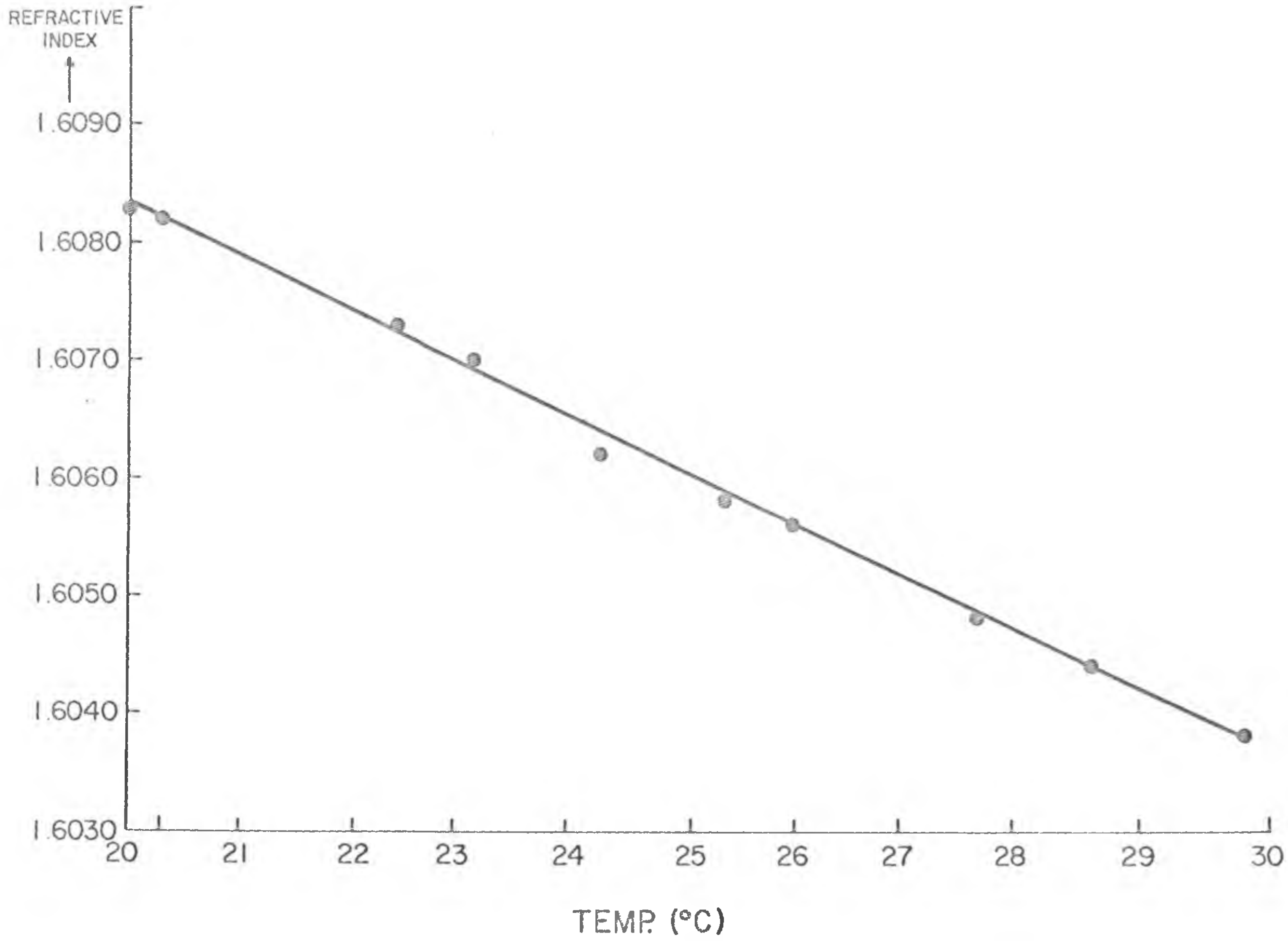
A volume of distilled water, having the same weight as the flesh in the blendor, was added to the blendor cup. Flesh and water were then blended for 2 minutes into a puree. Ten ± 0.1 gram of this puree was weighed into a 25 cc screw cap vial and the remainder discarded. Five ± 0.01 cc Halowax oil was added to the avocado-water mixture in the vial with a 5 cc pipet. The lid was screwed tightly on the vial and the mixture of avocado flesh, water and Halowax shaken manually for 2 minutes. The resulting emulsion was stored in a freezer with a temperature range of -20°C to -23°C. The vial and contents were kept in the freezer at least 2 hours until the emulsion was frozen solid. The vial was removed from the freezer and left at approximately 23°C 2 hours or more until the mixture had completely thawed. The vial and contents were again shaken for 1.5 minutes and replaced in the freezer. This thawing-shaking-freezing cycle was repeated 3 times.

The vial was then removed from the freezer and a drop of avocado oil-Halowax mixture transferred from the frozen emulsion in the vial onto the prism of an Abbe 3L Bausch and Lomb refractometer. Refractive index readings of the oil mixture were made to the fourth decimal place. After the contents of the vial had thawed, they were shaken for 1 minute and replaced in the freezer. This procedure was repeated until the difference between 3 consecutive readings from the same sample was less than 0.0001. The last 3 readings were averaged and the refractive index thus obtained was used in determining oil content of individual fruits.

A linear regression of refractive index on temperature was found to exist. This relation is shown in figure 1. An arbitrary standard temperature of 27°C was adopted and refractometer readings made at other temperatures converted to the corresponding refractive index at 27°C.

Four 500 gram lots of 1-chloronaphthalene were utilized. The refractive index of the first 2 lots was 1.6299 at 27°C, but that of the

Fig. 1. Regression of refractive index of a mixture of avocado oil and Halowax oil on temperature.



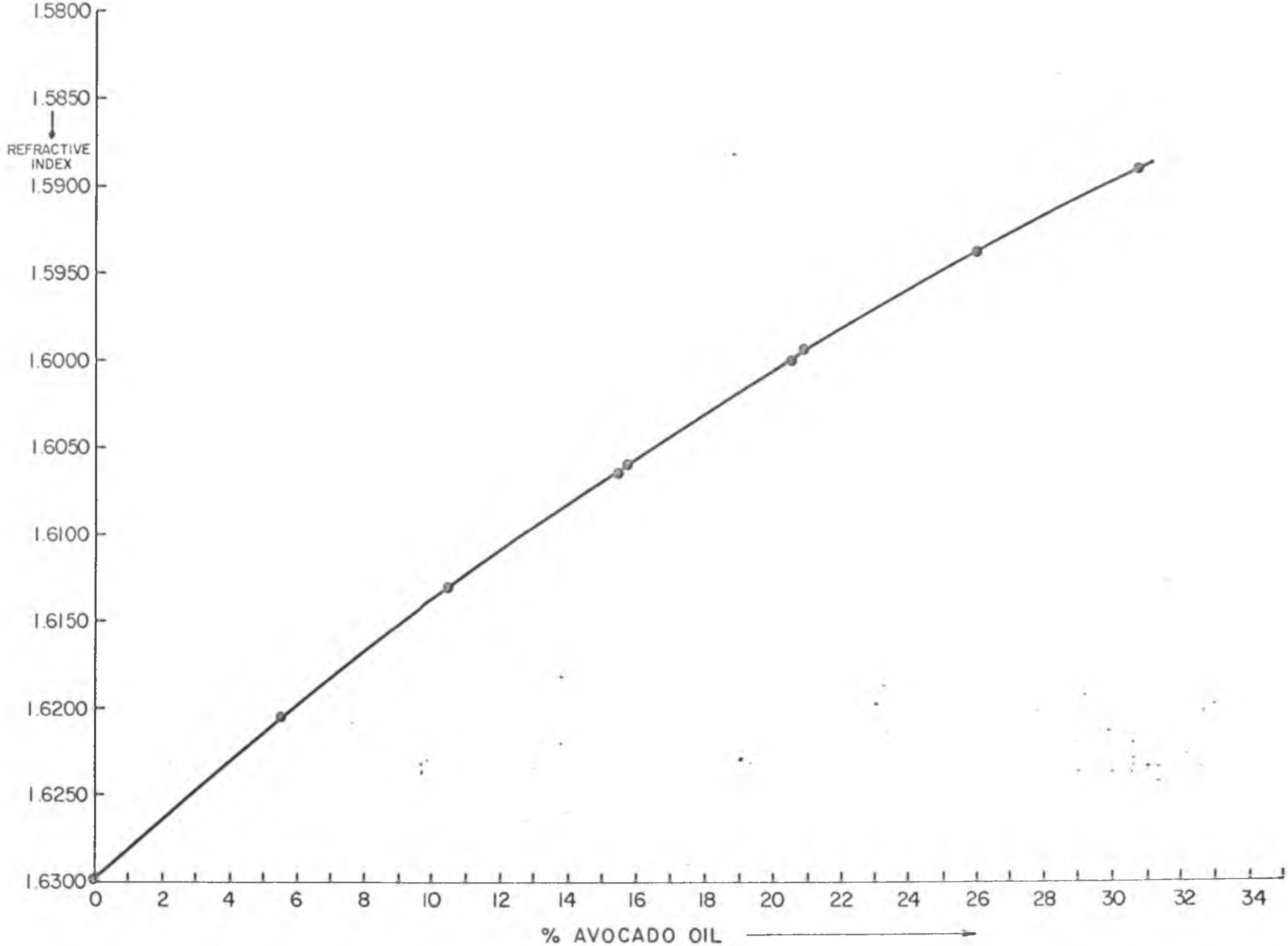
REFRACTIVE INDEX
1.6090
1.6080
1.6070
1.6060
1.6050
1.6040
1.6030
20
21
22
23
24
25
26
27
28
29
30
TEMP. (°C)

third lot was 0.0006 higher. The fourth lot had a refractive index of 1.6298, slightly lower than that of the first 2 lots. The refractive index of the first 2 lots was arbitrarily chosen as a standard and readings obtained with the third and fourth lots corrected by subtracting 0.0006 and adding 0.0001 respectively. The validity of this correction was confirmed by testing the different avocado oil-Halowax solutions and comparing refractive indices obtained.

In converting refractive indices of the avocado oil-Halowax mixture into percentage of oil in avocado flesh, the relation between oil content and refractive index was established and expressed as a curve (figure 2). This curve was obtained by mixing known quantities of avocado oil and Halowax and determining the refractive indices of resulting mixtures. The avocado oil used as a standard for this experiment was extracted from fruits of 2 standard varieties, 'Itzamna' and 'Yamagata.' The oil extraction method used was as follows: Five fruits were peeled and the flesh heated to approximately 75°C in a pan over a hot water bath. A diatomaceous earth filteraid in the amount of 2% of the weight of flesh was added to the material in the pan to facilitate breakdown of the oil/water emulsion in the flesh. After 15 minutes the flesh was transferred into a nylon bag and the liquid portion squeezed out in a Carver hydraulic press. The solution obtained was left overnight and the following day the oily top layer was filtered through Whatman no. 4 filter paper until the oil was clarified.

The correlation curve of refractive index and oil content established with 'Itzamna' oil was identical to that obtained with 'Yamagata' oil. The 2 curves were therefore superimposed and the resulting curve

Fig. 2. Correlation between refractive index readings and the known oil content of mixtures of Halowax oil and avocado oil.


1.5800
1.5850
REFRACTIVE INDEX
1.5900
1.5950
1.6000
1.6050
1.6100
1.6150
1.6200
1.6250
1.6300
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
% AVOCADO OIL

utilized as the standard curve for determining oil content of fruit samples tested.

The following testing methods were used to verify the accuracy of the oil content determination method.

The effect of water on refractive index readings was examined by adding water to the oil on the prism. Addition of water failed to change the refractive index of the oil.

A decrease in refractive index was usually observed in the first few tests of each sample examined. This may have been due to the fact that after each cycle of freezing, thawing and shaking additional small amounts of avocado oil were extracted from the puree into the solvent, thus resulting in a lower refractive index. No significant change in refractive index was found in a mixture of avocado oil and Halowax stored for several months. It was therefore concluded that the above assumption is correct. This test also indicated that at least 3 freeze-thaw cycles were required for complete extraction of oil.

A recovery test was also conducted. Six vials were filled with avocado flesh-water puree and Halowax as in the oil determination method. A known weight of avocado oil was added to 3 of these vials. All 6 vials were subjected to the standard freezing, thawing, shaking treatment. The refractive indices were determined and converted into oil content. Differences in oil content between the samples with added avocado oil and the samples without oil added were compared and percent recovery calculated. The procedure was repeated with flesh from another avocado. The mean recovery of both tests was 97.9%. This recovery was considered adequate for the oil content determination method to be valid for purposes of this study. In both tests the difference between the refractive indices of the 3 samples without avocado oil added was not larger than 0.0001.

Statistical methods

The number of fruits to be sampled from each tree was computed by using the formula: $n = \frac{(Z_\alpha + Z_\beta)^2 \cdot 2\sigma^2}{\delta^2}$. The variance σ^2 was obtained by testing an arbitrary sample size of 14 fruits of the 'Guatemala' variety. The value of δ, arbitrarily set at 1.5% oil, represents the difference desired between the mean oil content of samples. The multiplier $(Z_\alpha + Z_\beta)^2$ was taken from Table 4.13.1 (30) to give 90% probability of detecting a difference of 1.5% oil between population means at the 5% significance level. After correction for degrees of freedom, the required sample size was determined to be 8.

Tree trunk circumference data were analyzed by means of a t-test of paired data from trees of the same variety on 2 different rootstocks.

T-tests of independent data were made to test the null hypothesis of no difference between mean fruit weights, mean seed weights, mean skin weights, mean flesh weights, mean seed/flesh ratios and mean oil contents of fruits from trees of each variety grown on 'Nabal and 'Ashikawa' seedling rootstocks. T-tests of paired data were also made on the means of fruit characteristics studied.

Where possible and applicable, analyses of variance were carried out of factorials with rootstocks, locations and varieties as factors.

Tests were also made for correlation between fruit characters studied.

Statistical methods used were derived from Snedecor and Cochran (30).

IV. EXPERIMENTAL RESULTS

Tree data

Trunk circumference measurements on 9 pairs of trees at the Haleakala Experimental Farm are summarized in Table 2.

Table 2. -- Avocado trunk circumference in cm., 8 cm. above the graft union of trees on 'Nabal' (G) and 'Ashikawa' (WI) rootstocks

Variety	Racial Origin	Age	Rootstock Nabal	Rootstock Ashikawa
Allmeat	G x M	8 yrs, 2 mo.	128	72
Chrones	G x WI	8 yrs, 2 mo.	116	130
Monge	WI	8 yrs, 2 mo.	89	84
Fujikawa	G	6 yrs, 8 mo.	65	68
Kaguah	G	6 yrs, 7 mo.	65	42
Yamagata	G	6 yrs, 3 mo.	87	69
Tsutsumi	G	6 yrs, 3 mo.	62	50
Beardslee	G x WI	6 yrs, 3 mo.	49	46
CRC 151-2	G x M	6 yrs, 2 mo.	52	42
Average trunk diameter			79	67

Circumference of trees grown on 'Nabal' was compared with that of trees grown on 'Ashikawa' by means of a t-test of paired data. In many cases trees on 'Nabal' tended to have thicker trunks than those on 'Ashikawa' rootstocks, but these apparent differences were not statistically significant. When the 4 Guatemalan race cultivars were tested, no significant difference in trunk circumference was found between trees grafted on the different rootstocks.

A possible explanation of the tendency of trees on Guatemalan rootstocks to have thicker trunks may be that this experiment was conducted at the Haleakala Experimental Farm at an elevation of about 640 m. At this climate and elevation, Guatemalan race avocados, native to Central American highlands, appear to be better adapted than West Indian avocados.

Only 1 out of 9 cultivars was of the West Indian race and it is therefore not possible to determine whether or not racial ancestry of the scion variety influenced trunk circumference.

In a stock-scion trial of 5 rootstocks, Oppenheimer (27) failed to find significant differences in tree size which could be attributed to the rootstocks used. Rootstocks utilized were seedlings of 2 Mexican varieties, 2 Guatemalan varieties and 1 Guatemalan x Mexican hybrid. In Oppenheimer's rootstock experiment, trunk diameter was considered one of the components of tree size.

Fruit data

When the avocados arrived at the laboratory, outward appearance of fruits picked from trees grown on 'Nabal' was compared to that of fruits from trees on 'Ashikawa.' In most cases there was little apparent difference between the 2 samples except for fruit size. The fruits of 'Elsie' and 'Hass' from Haleakala and 'Sharwil' from Malama Ki generally appeared to have somewhat rougher skin when grown on 'Ashikawa' rootstocks, though differences in skin texture between the 2 samples were not consistent. 'Fuerte' fruits from Haleakala, when grown on 'Nabal,' were generally rounder in shape than fruits from the tree on 'Ashikawa' rootstock, which appeared to be more pyriform. Differences in skin texture and fruit shape were not pronounced and did not occur consistently enough to positively decide whether or not rootstocks had any identifiable influence on external appearance of fruit.

The fruit data are presented in the following sections. Unless otherwise indicated, each entry in the tables is the mean of 8 fruits in a sample from each tree.

Fruit weight

Mean fruit weight of avocados from 14 pairs of trees on 'Nabal' and 'Ashikawa' rootstocks at the Haleakala and Malama Ki Experimental Farms is listed in Table 3. Mean fruit weights of 'Fuerte' and 'Rincon' at Malama Ki are given, although rotting had already started in some fruits during ripening. Results of t-tests between paired samples are given in the right hand column of the table. A t-test of paired data was also made using mean fruit weights of the 14 cultivars in the experiment. Results of this test are also shown in Table 3.

Table 3. -- Mean fruit weight in grams of avocados from trees grown on 'Nabal (G) and 'Ashikawa' (WI) rootstocks at the Haleakala and Malama Ki Experimental Farms

Location	Variety	Racial origin	Rootstock Nabal	Ashikawa	t-test results
	Fuerte	G x M	279	346	*
	Sharwil	G x M	295	268	n.s.
	Allmeat	G x M	384	433	n.s.
Haleakala	HAES 7315	G	264	273	n.s.
	Elsie	G	466	390	**
	Iliahi	G	300 a)	280	n.s.
	Hass	G	209 a)	261 a)	**
	Kahaluu	G x WI	414	445	n.s.
	Fuerte	G x M	344	363	n.s.
	Sharwil	G x M	346	338	n.s.
Malama Ki	Rincon	G x M	330	330	n.s.
	HAES 7315	G	317	283	n.s.
	Wahiawa	G	497	600	**
	Guatemala	WI	636 b)	575 b)	n.s.
Average fruit weight			363	370	n.s.

* = significant difference at 5% level
** = significant difference at 1% level
n.s. = no significant difference

a) sample size = 7
b) sample size = 14

'Fuerte,' 'Elsie' and 'Hass' at Haleakala Experimental Farm and 'Wahiawa' at Malama Ki Experimental Farm showed significant differences in mean fruit weight associated with the 2 rootstocks. The result of the t-test of paired data, however, suggests no consistent influence of rootstocks on fruit size. This is in agreement with observations of Oppenheimer (27) in his stock-scion trial. He found that mean fruit weight did not appear to be affected by the rootstock used.

An analysis of variance of a 3-factor experiment, involving 3 varieties, 2 rootstocks and 2 locations was done with fruit weight data. Data used were from 'Fuerte,' 'Sharwil' and 'HAES 7315' which were available at both locations. Results of the analysis of variance are shown in Table 4.

Table 4. -- Analysis of variance of 3-factor experiment for fruit weight

Source of variation	d.f.	Mean square
Rootstocks (R)	1	490.5
Locations (L)	1	47,215.0 **
Varieties (V)	2	18,998.1 **
R x L	1	3,325.3
R x V	2	9,046.0 **
L x V	2	1,800.6
R x L x V	2	2,762.5
Error	84	1,712.6

** = significant at 1% level

Highly significant Location and Variety effects were found as well as a significant interaction between Rootstocks and Varieties. This indicates that fruits of these varieties from the Malama Ki Experimental Farm averaged larger than those from the Haleakala Experimental Farm. Higher temperatures and higher rainfall at Malama Ki are factors which could logically influence fruit size resulting in larger fruit than at Haleakala which is cooler and drier. Apparently, rootstocks have a different effect on some varieties than on others in relation to fruit weight. This is suggested by the highly significant interaction between Rootstocks and Varieties. The interaction appears due to the fact that fruits of 'Sharwil' were larger than those of 'Fuerte' when grown on 'Nabal' rootstock, but smaller than 'Fuerte' when 'Ashikawa' was the rootstock source.

Seed Weight

Table 5 gives the mean seed weight for each tree in both grams and percentage of mean fruit weight. T-test results are also listed in Table 5.

Table 5. -- Mean seed weight in grams and in percent of mean fruit weight of avocados from trees grown on 'Nabal' (G) and 'Ashikawa' (WI) rootstocks at the Haleakala and Malama Ki Experimental Farms

Location	Variety	Racial Origin	Rootstock Nabal g	Nabal %	Ashikawa g	Ashikawa %	t-test results
	Fuerte	G x M	68	24.3	69	20.0	n.s.
	Sharwil	G x M	35	11.8	26	9.7	**
	Allmeat	G x M	37	9.5	41	9.5	n.s.
Haleakala	HAES 7315	G	40	15.0	42	15.3	n.s.
	Elsie	G	74	15.9	68	17.5	n.s.
	Ilialu	G	77	25.9 a)	76	27.0	n.s.
	Hass	G	42	20.3 a)	43	16.6 a)	n.s.
	Kahaluu	G x WI	65	15.8	64	14.3	n.s.
	Fuerte	G x M	--	----	--	----	----
	Sharwil	G x M	48	13.9	48	14.2	n.s.
Malama Ki	Rincon	G x M	89	27.0	72	21.8	n.s.
	HAES 7315	G	55	17.4	36	12.5	**
	Wahiawa	G	95	19.2	98	16.4	n.s.
	Guatemala	WI	86	13.5 b)	88	15.3 b)	n.s.
Average seed weight			62	17.7	59	16.2	n.s.

** = significant difference at 1% level
n.s. = no significant difference

a) sample size = 7
b) sample size = 14

Some fruits of 'Elsie,' 'Rincon' and 'Guatemala' appeared to be overmature and in some instances the seeds had begun to germinate in the fruit. Differences in mean seed weight of fruit from the 2 trees in each variety at the same location were significant at the 1% level for 'Sharwil' at Haleakala and 'HAES 7315' at Malama Ki. Mean seed weights of 'Sharwil' at Malama Ki and 'HAES 7315' at Haleakala were not, however, significantly different. Because the t-test of paired data did not indicate a significant difference between mean seed weights, it is suggested that there were probably no important differences in seed weight attributable to the rootstocks used.

For 'Sharwil,' seed weight was higher at Malama Ki than at Haleakala. For 'HAES 7315,' it was higher at Malama Ki when 'Nabal' was the rootstock source, but lower when 'Ashikawa' was used as rootstock. It is possible that location may influence seed weight, but the information obtained from these data was not sufficient to be conclusive.

Skin weight

Mean skin weight of fruit in grams and in percent of mean fruit weight is shown in Table 6. Results of t-tests are listed in the right hand column. Skin weights of 'Fuerte' and 'Rincon' at Malama Ki were not included in Table 6 because decomposition had already begun which might have affected the accuracy of the data. Significant differences at the 5% level in mean skin weight were found for 'Fuerte,' 'Sharwil,' 'Ilialu' and 'HAES 7315' at Haleakala. The outcome of the t-test on paired data of skin weight, however, suggests that rootstocks probably had no significant effect on skin weight of cultivars studied.

In comparing the skin weights of 'Sharwil' and 'HAES 7315' at both locations, skins of 'Sharwil' avocados produced at Malama Ki appeared to be slightly heavier than those at Haleakala. Skins of 'HAES 7315' fruits when grown on 'Ashikawa' were heavier at Haleakala than at Malama Ki, but weighed more at Malama Ki when grown on 'Nabal.' There did not, however, appear to be any important difference in percent of skin weight to fruit weight at the 2 locations.

Table 6. -- Mean skin weight in grams and in percent of mean fruit weight of avocados from trees grown on 'Nabal' (G) and 'Ashikawa' (WI) rootstocks at the Haleakala and Malama Ki Experimental Farms

Location	Variety	Racial Origin	Rootstock Nabal g	Nabal %	Ashikawa g	Ashikawa %	t-test results
	Fuerte	G x M	24	8.4	29	8.3	*
	Sharwil	G x M	36	12.3	32	11.8	*
	Allmeat	G x M	24	6.2	27	6.3	n.s.
Haleakala	HAES 7315	G	59	22.3	68	24.8	*
	Elsie	G	33	7.1	32	8.3	n.s.
	Ilialu	G	52	17.3 a)	45	15.9	*
	Hass	G	36	17.3 a)	37	14.1 a)	n.s.
	Kahaluu	G x WI	55	13.4	58	13.0	n.s.
	Fuerte	G x M	--	----	--	----	----
	Sharwil	G x M	39	11.3	38	11.2	n.s.
Malama Ki	Rincon	G x M	--	----	--	----	----
	HAES 7315	G	69	21.8	64	23.0	n.s.
	Wahiawa	G	85	17.1	95	15.8	n.s.
	Guatemala	WI	48	7.5 b)	49	8.5 b)	n.s.
Average skin weight			46	13.5	49	13.4	n.s.

* = significant difference at 5% level
n.s. = no significant difference

a) sample size = 7
b) sample size = 14

There appeared to be a relationship between fruit weight and skin weight within cultivars: skin weight increased as the fruit got larger. This correlation did not, however, exist between cultivars.

The Guatemalan cultivars had the highest skin percentage with the exception of 'Elsie,' which had a relatively low percentage of skin for a variety with Guatemalan race characteristics.

Flesh weight

Mean flesh weights in grams and in percent of mean fruit weight are summarized in Table 7 together with results of t-tests. Data for 'Fuerte' and 'Rincon' are missing because some decomposition of the flesh was evident in the samples on arrival.

For 'Fuerte,' 'Elsie' and 'Hass' at Haleakala and 'Wahiawa' at Malama Ki, significant differences were found between mean flesh weights of avocados produced by trees grafted on the 2 different rootstocks. The same cultivars also showed significant differences in mean fruit weight due to rootstock influence. This relationship between fruit weight and flesh weight is verified by a positive correlation of 0.963

Table 7. -- Mean flesh weight in grams and in percent of mean fruit weight of avocados from trees grown on 'Nabal' (G) and 'Ashikawa' (WI) rootstocks at the Haleakala and Malama Ki Experimental Farms

Location	Variety	Racial origin	Rootstock Nabal g	Nabal %	Ashikawa g	Ashikawa %	t-test results
	Fuerte	G x M	188	67.3	248	71.7	**
	Sharwil	G x M	224	75.9	210	78.5	n.s.
	Allmeat	G x M	324	84.3	365	84.2	n.s.
Haleakala	HAES 7315	G	166	62.7	164	59.9	n.s.
	Elsie	G	359	77.0	290	74.2	**
	Ilialu	G	170	56.7 a)	160	57.1	n.s.
	Hass	G	131	62.4 a)	181	69.3 a)	**
	Kahaluu	G x WI	293	70.8	323	72.7	n.s.
	Fuerte	G x M	---	----	---	----	----
	Sharwil	G x M	259	74.8	252	74.6	n.s.
Malama Ki	Rincon	G x M	---	----	---	----	----
	HAES 7315	G	193	60.8	183	64.5	n.s.
	Wahiawa	G	317	63.7	407	67.8	**
	Guatemala	WI	502	79.0 b)	438	76.2 b)	n.s.
Average flesh weight			261	69.6	268	70.9	n.s.

** = significant difference at 1% level
n.s. = no significant difference
a) sample size = 7
b) sample size = 14

found between these characters. The results of the t-test of paired data suggest that there was no influence on flesh weight due to rootstocks.

Mean flesh weight of 'Sharwil' and 'HAES 7315' fruits was higher at Malama Ki than at Haleakala, but the percent of flesh weight to fruit weight did not appear to be affected by location. Both mean fruit weight and mean flesh weight were higher at Malama Ki than at Haleakala.

Ratio of seed to flesh

The seed/flesh ratio was calculated by dividing seed weight by flesh weight. A low ratio is preferred because fruits with lower ratios contain a higher proportion of flesh. The ratios of seed to flesh are summarized in Table 8 together with t-test results. Flesh and seed weight data of 'Fuerte' and flesh weight data of 'Rincon' were not available from Malama Ki and therefore seed/flesh ratios could not be calculated for these varieties.

The seed/flesh ratios range from 0.11 to 0.48. Significant differences in seed/flesh ratio due to rootstock influence were found for 'Fuerte,' 'Sharwil' and 'Hass' at Haleakala and for 'HAES 7315' and 'Wahiawa' at Malama Ki. In instances where significant differences were found, the higher ratio of seed to flesh was associated with the 'Nabal' rootstock. The result of the t-test of paired mean ratios does not, however, suggest important effects on seed/flesh ratio due to the rootstocks used. Seed/flesh ratio for 'Sharwil' was higher at Malama Ki than at Haleakala. The ratio for 'HAES 7315' was higher at Malama Ki, when the tree was grafted on 'Nabal,' but lower when grafted on 'Ashikawa.' Some location effect on ratio of seed to flesh is possible, but the data do not provide sufficient information for definite conclusions.

Table 8. -- Mean seed/flesh ratio of avocados from trees grown on 'Nabal' (G) and 'Ashikawa' (WI) rootstocks at the Haleakala and Malama Ki Experimental Farms

Location	Variety	Racial origin	Rootstock Nabal	Rootstock Ashikawa	t-test results
Haleakala	Fuerte	G x M	0.36	0.28	*
	Sharwil	G x M	0.16	0.13	**
	Allmeat	G x M	0.12	0.11	n.s.
	HAES 7315	G	0.24	0.26	n.s.
	Elsie	G	0.21	0.24	n.s.
	Iliialu	G	0.47 a)	0.48	n.s.
	Hass	G	0.33 a)	0.24 a)	**
	Kahaluu	G x WI	0.23	0.20	n.s.
Malama Ki	Fuerte	G x M	----	----	----
	Sharwil	G x M	0.19	0.19	n.s.
	Rincon	G x M	----	----	----
	HAES 7315	G	0.29	0.20	**
	Wahiawa	G	0.31	0.25	*
	Guatemala	WI	0.17 b)	0.20 b)	n.s.
Average seed/flesh ratio			0.26	0.23	n.s.

* = significant difference at 5% level
** = significant difference at 1% level
n.s. = no significant difference

a) sample size = 7
b) sample size = 14

Oil content of the flesh

The mean oil content of fruit samples computed as percent of flesh weight is presented in Table 9. Results of t-tests are also given in the table.

Significant differences between mean oil contents of fruits grown on different rootstocks were found in 'Allmeat,' 'Elsie' and 'Kahaluu' at Haleakala and 'Sharwil,' 'Rincon' and 'Guatemala' at Malama Ki. For 6 out of 8 varieties at Haleakala the oil content was higher in fruits from trees on 'Nabal' rootstocks than in those from tress on 'Ashikawa' rootstocks. At Malama Ki, however, 5 out of 6 varieties had a higher oil content when grown on 'Ashikawa.' Although not all of these differences were significant, both location and rootstocks appear to have an effect on oil content. At Haleakala, trees on 'Nabal' had a tendency to produce avocados with higher oil content than trees on 'Ashikawa.' At the lower elevation Malama Ki location, avocados from trees grown on 'Ashikawa' rootstocks tended to have higher oil contents than those from trees on 'Nabal.' T-tests of paired data from each location did not, however, indicate significant differences in mean oil content of fruits due to rootstocks used. The data are not conclusive, but it is possible

Table 9. -- Mean oil content in percent of the flesh weight of avocados from trees grown on 'Nabal' (G) and 'Ashikawa' (WI) rootstocks at the Haleakala and Malama Ki Experimental Farms

Location	Variety	Racial origin	Rootstock Nabal	Rootstock Ashikawa	t-test results
	Fuerte	G x M	29.3	29.0	n.s.
	Sharwil	G x M	20.9	20.1	n.s.
	Allmeat	G x M	18.6	21.1	**
Haleakala	HAES 7315	G	15.2	16.3	n.s.
	Elsie	G	20.9	14.7	**
	Ilialu	G	19.0 a)	17.1	n.s.
	Hass	G	24.3 a)	21.3 a)	n.s.
	Kahaluu	G x WI	21.7	16.2	**
	Fuerte	G x M	17.5 b)	18.7 a)	n.s.
	Sharwil	G x M	16.1	18.0	**
Malama Ki	Rincon	G x M	16.9	19.9	**
	HAES 7315	G	14.6	14.9	n.s.
	Wahiawa	G	19.3	18.7	n.s.
	Guatemala	WI	8.8 c)	9.7 d)	**
Average oil content Haleakala			21.2	19.5	n.s.
Average oil content Malama Ki			15.5	16.7	n.s.
Overall average oil content			18.8	18.3	n.s.

** = significant difference at 1% level
n.s. = no significant difference

a) sample size = 7
b) sample size = 6
c) sample size = 13
d) sample size = 14

that better adaptation of the Guatemalan rootstocks to higher elevations is related to higher oil content at Haleakala. Similarly better adaptation of West Indian rootstocks to lower elevation might logically be associated with higher oil content obtained on those rootstocks at Malama Ki.

Analysis of variance of data on oil content from fruits of 4 Guatemalan varieties on the 2 different rootstocks at Haleakala gave highly significant Rootstock and Variety effects as well as a highly significant interaction between Rootstocks and Varieties (Table 10). The interaction noted between Rootstocks and Varieties appears due to the fact that the oil content in fruits of 'Elsie' was the lowest of the 4 varieties when the rootstock source was 'Ashikawa,' but it was the second highest when 'Nabal' was used as rootstock. In addition, fruits of 'HAES 7315' on an 'Ashikawa' seedling rootstock had a higher oil content than those grown on 'Nabal.'

Table 10. -- Analysis of variance of 2-factor experiment for oil content

Source of variation	d.f.	Mean square
Rootstocks (R)	1	97.14 **
Varieties (V)	3	130.21 **
R x V	3	36.31 **
Error	53	2.69

** = significant at 1% level

Because of the interaction noted between Rootstocks and Varieties, caution must be exercised in drawing conclusions concerning behavior of rootstocks and varieties. If the interaction is used as an Error term for the main effects, the F-values obtained are not significant. They are however, sufficiently large to suggest a possible effect of rootstocks on oil content.

Analysis of variance of data on oil content of 'Fuerte,' 'Sharwil' and 'HAES 7315' on 2 rootstocks at 2 locations is summarized in Table 11. This table shows Location and Variety effects on oil content which are highly significant at odds of 99 to 1. There is also a significant interaction between Locations and Varieties indicating that the behavior of certain varieties is different from that of other varieties at a given location. The mean square for Locations is large, strongly suggesting an influence of location on oil content, although the F-value is not significant when Location effects are tested using the interaction between Locations and Varieties as an Error term. For the 3 cultivars common to both locations oil content is higher at the Haleakala Experimental Farm than at the Malama Ki Experimental Farm. In the case of 'Fuerte' the difference in oil content between locations is large, amounting to 11.8% for fruits from trees grown on 'Nabal' and 10.3% for fruits from trees on 'Ashikawa.'

Table 11. -- Analysis of variance of 3-factor experiment for oil content

Source of variation	d.f.	Mean square
Rootstocks (R)	1	7.63
Locations (L)	1	650.73 **
Varieties (V)	2	609.16 **
R x L	1	5.19
R x V	2	1.64
L x V	2	167.11 **
R x L x V	2	5.61
Error	81	2.70

** = significant at 1% level

Fruit size of the 3 cultivars found at both locations was larger at Malama Ki than at Haleakala. The oil content of a given quantity of avocado flesh was higher at Haleakala than at Malama Ki, although the absolute amount of oil per fruit might not differ greatly from location to location because there was more flesh per fruit at Malama Ki.

V. DISCUSSION

In the experiment conducted, fruit data were gathered from 14 pairs of trees at 2 locations. Trees of each pair were grafted on 2 different rootstocks, each pair representing a single variety. There was no replication of varieties on the same rootstock at a given location.

Varieties of a similar racial origin could be grouped together and considered replications within a race or racial combination, but differences between varieties were generally larger than differences between rootstocks.

When the racial origin of a cultivar is given, it means that the characteristics of the cultivar most resemble those of the indicated race or races. For example, if a variety is said to be of G x M racial origin, this means that the cultivar has recognizable Guatemalan and Mexican characters. It does not, however, mean that it is a hybrid between pure Guatemalan and pure Mexican trees. In avocados usually only the female parent is known because cross pollination is characteristic of avocado flowers.

When pairs of trees of the same variety are compared at both locations, Location effect is larger than Rootstock effect. Although certain general tendencies in rootstock influence were noted, a more elaborate and detailed experimental set up would be needed to make generalization possible concerning the Rootstock effects on characteristics studied. The strong interaction between Locations and Varieties suggests that at a given location there is a different effect on characteristics studied in some varieties than in others.

Both 'Nabal' and 'Ashikawa' rootstocks were propagated from seed and because there is a high percentage of cross pollination in avocado varieties, considerable genetic variability can be expected to occur among rootstocks grown from seed of these varieties.

Variability found between fruits on the same tree has been previously discussed (18). A fruit sample size of 8 was computed to be the minimum number of fruits needed to reduce sampling error to the level required.

Coefficients of variation were computed to provide an indication of within sample variation in relation to the mean values of characters studied. These coefficients of variation are listed in Table 12. A study of the coefficients shows that oil content was the least variable characteristic studied, while seed weight was the most variable.

Data on fruit characters were taken after the fruits had ripened. It was not possible to process all the fruits at exactly the same stage of ripeness, but an attempt was made to assess characters at as near the same stage as possible based on judgment of softening and color. Fruit weight and flesh weight are somewhat affected by moisture loss and resulting decrease in weight which occurs during ripening. Actual oil content remains relatively constant after maturity has been attained, but the percentage of oil in the flesh is influenced by decrease in weight of flesh.

The oil content determination method used was developed by Mr. J. E. Brekke of the Hawaii Fruit Laboratory of the U.S.D.A. and the author for the purpose of comparison only. All fruits were tested objectively by the same method and the results of oil determinations are directly

Table 12. -- Coefficients of variation for fruit characters studied

Location	Variety	Racial origin	Root-stock	Fruit wt.	Seed wt.	Skin wt.	Flesh wt.	Sd/fl ratio	Oil cont.
Hale-akala	Fuerte	G x M	(Nabal	13.1	25.9	11.6	13.4	25.3	9.0
			(Ashik.	16.7	25.9	18.5	16.7	21.1	10.6
	Sharwil	G x M	(Nabal	7.0	11.1	8.4	7.9	12.5	6.2
			(Ashik.	15.5	9.3	13.6	17.3	10.8	8.5
	Allmeat	G x M	(Nabal	15.1	23.2	14.7	15.0	11.7	9.4
			(Ashik.	10.6	15.6	16.9	11.0	12.7	5.8
	HAES 7315	G	(Nabal	7.3	17.1	9.4	9.6	17.5	8.6
			(Ashik.	14.2	12.3	9.3	17.7	12.7	6.9
	Elsie	G	(Nabal	12.5	15.9	10.0	13.9	16.7	6.1
			(Ashik.	8.0	13.4	9.8	9.4	15.4	6.9
	Ilialu	G	(Nabal	12.8	9.1	14.0	17.9	17.2	9.9
			(Ashik.	11.1	16.4	9.5	12.7	13.3	10.2
	Hass	G	(Nabal	10.9	13.4	12.5	13.0	16.1	9.8
			(Ashik.	10.8	18.9	9.6	11.6	17.5	10.0
	Kahaluu	G x WI	(Nabal	8.8	18.7	12.7	8.8	17.4	16.0
			(Ashik.	11.9	17.6	9.7	12.8	15.0	10.5
Malama Ki	Fuerte	G x M	(Nabal	14.9	----	----	----	----	9.4
			(Ashik.	8.6	----	----	----	----	4.2
	Sharwil	G x M	(Nabal	6.3	10.4	6.1	6.8	8.9	8.7
			(Ashik.	15.5	17.0	11.2	17.6	17.4	3.8
	Rincon	G x M	(Nabal	14.1	17.5	----	----	----	6.1
			(Ashik.	13.8	22.1	----	----	----	7.1
	HAES 7315	G	(Nabal	13.7	19.9	11.5	16.3	21.4	10.5
			(Ashik.	19.8	15.0	17.1	22.3	11.0	4.4
	Wahiawa	G	(Nabal	11.9	18.2	9.8	14.8	19.4	4.1
			(Ashik.	12.4	10.5	13.5	15.2	15.2	5.0
	Guatemala	WI	(Nabal	17.8	28.4	16.9	17.4	22.9	9.1
			(Ashik.	12.2	19.8	10.5	12.9	16.5	6.0

comparable. The assumption was made that all fruits contain oil with a refractive index identical to that of 'Itzamna' and 'Yamagata.' These were the varieties used for establishing the standard relation between refractive index and oil content.

For each fruit characteristic studied, significant Rootstock effects were generally found for a few of the cultivars, but most varieties did not show a significant rootstock influence. It is therefore suggested that rootstocks may have significant effects on fruit characteristics in certain specific, but not all, rootstock-scion combinations.

VI. SUMMARY AND CONCLUSIONS

Influence of rootstocks on tree trunk circumference, fruit weight, seed weight, skin weight, flesh weight, ratio of seed to flesh and oil content of the flesh of avocados was studied in this experiment. Influence of location on fruit characters studied was also examined.

Trunk circumference was studied on 9 pairs of trees at the Haleakala Experimental Farm, Maui. One tree of each pair was grafted on a 'Nabal' seedling rootstock and the other on an 'Ashikawa' seedling rootstock. The 'Nabal' variety is considered to be of Guatemalan racial origin and 'Ashikawa' of West Indian parentage.

Fruit samples were taken at 2 locations from 14 pairs of trees, grown on 'Nabal' and 'Ashikawa' seedling rootstocks. Eight pairs of trees were growing at the Haleakala Experimental Farm at 640 m. elevation and the other 6 pairs at the Malama Ki Experimental Farm on Hawaii at 100 m. elevation. Data from only 1 pair of trees of a given variety were available at each location. Random samples of 8 fruits per tree were used in obtaining fruit data. Three of the cultivars studied were available at both locations.

An oil content determination method, employing refractometer testing of samples, was developed to compare the oil contents of fruit samples.

Rootstocks of a given variety did not have similar effects on all cultivars tested. Rootstocks also had no consistent effect on fruit characters of the same variety at different locations.

There was a tendency for trees grafted on 'Nabal' seedlings at Haleakala to have greater trunk circumference than when grafted on

'Ashikawa,' but the difference was not statistically significant.

Rootstocks failed to show positive effects on fruit weight, seed weight, skin weight, flesh weight and seed/flesh ratio.

The oil content of the flesh had a tendency to be slightly higher in fruits from trees grown on 'Nabal' seedling rootstocks at the Haleakala Experimental Farm at 640 m. elevation. The oil content was, however, higher in fruits from trees grown on 'Ashikawa' seedling rootstocks at the Malama Ki Experimental Farm, located at 100 m. elevation.

Fruits of varieties available from both locations were larger at Malama Ki than at Haleakala.

Flesh weight also showed a tendency to be greater at Malama Ki than at Haleakala, but there was not much difference in percent of flesh weight to fruit weight between the 2 locations.

Differences in seed weight, skin weight and seed/flesh ratio between locations were not consistent or conclusive.

Oil content of varieties grown at both locations was higher at Haleakala than at Malama Ki.

A positive correlation was found between fruit weight and flesh weight. There was no correlation between fruit weight and oil content.

Of the fruit characteristics studied, oil content appeared to be the most consistent and the seed weight the most variable.

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