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EFFECT OF SIZE AND HEIGHT OF FRUIT WITHIN THE TREE ON CONTENT OF OIL IN HASS AND FUERTE AVOCADOS (*Persea americana* Mill.)

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In the present test, the effect of height and size of the fruit on maturity was determined. To do this, Hass and Fuerte fruits of "large" (220 g) and "small" size (average 140 g) were harvested every 14 days, at 2 heights: below 2 m and above 3 m. The sampling periods were from July 19th to November 8th 2005 for Hass cultivar, and from June 14th to October 4th 2005 for Fuerte. In each sampling date, parameters of fresh weight, equatorial diameter, moisture content and oil content were evaluated. Regarding Fuerte cultivar, size is related to maturity; larger fruits have higher oil content, whereas this is not the case for Hass. There were no effects of height ($p \leq 0.05$) on maturity in both cultivars. The equatorial diameter is highly related to weight, but not to oil percentage, in Hass and Fuerte cultivars.

Key Words: Maturity, Quality, Harvest, Fruit weight.

EFECTO DEL CALIBRE Y LA ALTURA DEL FRUTO DENTRO DEL ÁRBOL SOBRE EL CONTENIDO DE ACEITE, EN PALTA (*Persea americana* Mill.) CVS. HASS Y FUERTE

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En el presente ensayo, se determinó el efecto de la altura y el calibre de la fruta sobre la madurez. Para esto se cosecharon cada 14 días frutos cvs. Hass y Fuerte, de calibre "grande" (220 g) y calibre "pequeño" (promedio 140 g) en 2 alturas dentro del árbol, bajo 2 m y sobre 3 m. Los períodos de muestreo fueron desde el 19 de julio hasta el 8 de noviembre del 2005 para el cv. Hass y desde el 14 de junio hasta el 4 de octubre del 2005 para el cv. Fuerte. En cada fecha de muestreo fueron evaluados los parámetros peso fresco, diámetro ecuatorial, contenido de humedad y contenido de aceite. En el cv. Fuerte el calibre tiene relación con la madurez, frutos más grandes poseen más contenido de aceite, no así para el cv. Hass. No hubo efecto de la altura ($p \leq 0{,}05$) sobre la madurez, en ambos cultivares. El diámetro ecuatorial está muy relacionado con el peso, no así con el porcentaje de aceite, en los cvs. Hass y Fuerte.

Palabras claves: madurez, calidad, cosecha, peso de frutos

1. Introduction

According to Gámez (2004), information from FAO and USDA states that the world area of avocado trees keeps growing and currently exceeds 380,000 hectares, representing a significant increase over the last ten years. The main producing countries are Mexico (102,000 ha, 30%), followed by the United States (26,000 ha, 7%) and Chile (23,500 ha, 6%).

Regarding the national production, 80% corresponds to Hass avocado, from which 70% is exported and the remaining 30% is destined to the local market. In Chile, the main varieties planted correspond to Hass with 67% and Fuerte with 8% of the area (Sitec, 2003).

The size of the avocado is strongly affected by the competence of photoassimilates where the shortage of carbohydrates affects the potential size of the fruit (Wolstenholme and Whiley, 1990). In trees with biennial production, in an "off" year, the lower competence of the fruits, the tree will produce larger sizes. When reducing the competence with the vegetative growth, the location of dry matter increases, producing higher yields and a larger size of the fruit. This is demonstrated when applying growth inhibitors in spring (Whiley and Saranah, 1992).

In this context, Gardiazábal (2004) mentions that the size is mainly affected by the quantity of the tree harvest. Size may be increased reducing the risk intervals and increasing the volume of water applied, within certain limits. According to Saavedra (2000), strong water restrictions do not drastically affect the production regarding volume, but they do reduce sizes, especially in the last period of growth and ripening (Whiley, 1990).

The intensity of light and temperature affect the development of the fruit. In the north side of the tree, the fruit has a greater size than the fruit in south side (Bertling and Cowan, 1998). According to Muñoz (2004), among the different locations of the fruits in the tree, there is only one difference in the maturity level with regard to its height, without differences in the geographical location for both Hass and Fuerte. This maturity difference caused by height occurs because of the greater quantity of hours of radiation daily received by the higher part of the tree, in comparison with lower parts.

When the fruit ripens, the oil content increases, moisture reduces and palatability rises (Martínez, 1984). Belmar (1996), who work on Edranol and Bacon varieties in different locations, indicates the same. The content of moisture or dry matter becomes the best indicator of the oil content in the fruit.

In Chile, the Hass fruits should be harvested above 26% of dry matter (11% oil). The qualification "very pleasant" by the judges from the sensory panel is reached with 32% of dry matter, which is equal to approximately 14.5% of oil (Esteban, 1993). With regard to Fuerte, according to the trial conducted by Latorre (1994), for the zone of Quillota, the minimum level of dry matter to harvest fruits should

be above 22.14% (10.5% oil) in order to have palatability at least “acceptable.” The level “very pleasant” in that trial corresponds to 16.05% oil in fruits. If the small fruit is riper than the large, the latter must be sampled to ensure that the entire fruit has the minimum level required for harvest. In addition, a proper quantity of samples must be sampled, at least 10 fruits per sector, one per tree to avoid mistakes produced when a high variation is detected in dry matter of close fruits (Hofman and Jobin-Décor, 1997).

In the present trial, the effect of height and size of the fruit on the oil content of Hass and Fuerte avocados was determined.

2. Materials and methods

Hass and Fuerte avocado fruits were collected from 6 trees previously tagged, from the Experimental Station La Palma of the Faculty of Agricultural Sciences, Pontificia Universidad Catolica de Valparaiso, located in Quillota (Latitude 32° 49’ S, Longitude 71° 16’W). The fruits were harvested in both varieties, every 14 days, of “large” size (average 220g) and “small” (average 140 g) in 2 heights in the tree, below 2 m and above 3 m. The sampling periods went from July 19th to November 8th 2005 for Hass and from June 14th to October 4th 2005 for Fuerte.

The study included 2 trials:

- Trial 1: Hass variety was used and the fruit of the north half of the tree was sampled in the external part of the tree
- Trial 2: Fuerte variety was used and the fruit of the north half of the tree was sampled in the internal part of the tree

For both trials, the sample unit was one fruit, with six replications.

Subsequently, the fruits were taken to Post-Harvest Laboratory, evaluating in each sampling date: fresh weight (digital balance Precisa 3100C), equatorial diameter (manual vernier caliper), moisture content (difference between fresh weight and dry weight, obtained after reaching constant weight in heater at 100°C) and oil content (Soxhlet).

A multifactorial completely randomized design was used, with 2 factors and each with 2 levels. Regarding the height factor, the levels were high and low, and for size factor were large and small. The data were analysed through an analysis of variance (ANOVA) and, subsequently, the means were separated using the Tukey test with 5% of significance.

In addition, with the data obtained in the research, two simple linear regressions were conducted, making in every case a variance analysis to verify the representativity of the model, through Fischer test, and also prove the existence of the gradient through T-Student test, both with 5% significance.

3. Results and discussion

It was determined in both varieties that no interaction was observed between the factors height and size on maturity. In Hass, only a size effect on the oil content was detected in the last sampling date (8/11) (Table 1 and 2). In addition, it was determined that there was no effect of the area where the fruit in the tree is sampled, in any of the nine dates. Therefore, obtaining the fruit from the high part is the same when obtaining it from the low part. Additionally, in Fuerte, from the 9 samplings conducted, size had an effect on the oil content of fruits in 5 dates. However, it was determined that height had an effect on the maturity level (Table 3, 4 and 5) in only one sampling date (20/9).

Table 1: Effect of fruit height in the tree and size on the oil content in Hass avocados

Variation source	P value	Date	Difference
Height (Factor A)	0.4244		N.S
Size (Factor B)	0.3680	19-Jul	N.S
Interaction (A*B)	0.3333		N.S
Height (Factor A)	0.1717		N.S
Size (Factor B)	0.1348	02-Aug	N.S
Interaction (A*B)	0.7299		N.S
Height (Factor A)	0.4321		N.S
Size (Factor B)	0.2699	16-Aug	N.S
Interaction (A*B)	0.6504		N.S
Height (Factor A)	0.1106		N.S
Size (Factor B)	0.0626	30- Aug	N.S
Interaction (A*B)	0.1445		N.S
Height (Factor A)	0.8743		N.S
Size (Factor B)	0.2085	13-Sep	N.S
Interaction (A*B)	0.7591		N.S
Height (Factor A)	0.2158		N.S
Size (Factor B)	0.0862	27-Sep	N.S
Interaction (A*B)	0.6373		N.S
Height (Factor A)	0.8213		N.S
Size (Factor B)	0.0687	11-Oct	N.S
Interaction (A*B)	0.8842		N.S
Height (Factor A)	0.3713		N.S
Size (Factor B)	0.1691	25-Oct	N.S
Interaction (A*B)	0.6356		N.S
Height (Factor A)	0.2341		N.S
Size (Factor B)	**0.0098**	08-Nov	**Significant**
Interaction (A*B)	0.3700		N.S

Significant differences when P value is smaller than 0.05 according to Fischer test with 5% of significance.

Table 2: Mean separation of oil percentage for the size factor in Hass avocado

Levels	Means of Hass oils	Sampling date
Small	12.22 a	8-Nov

Large	13.63 b	

Table 3: Effect of fruit height in the tree and size on the oil content in Fuerte avocado.

Variation source	P Value	Date	Diferencia
Height (Factor A)	0.2048		N.S
Size (Factor B)	0.0638	14-Jun	N.S
Interaction (A*B)	0.3625		N.S
Height (Factor A)	0.5327		N.S
Size (Factor B)	0.1618	28-Jun	N.S
Interaction (A*B)	0.8292		N.S
Height (Factor A)	0.4236		N.S
Size (Factor B)	**0.0011**	12-Jul	**Significant**
Interaction (A*B)	0.6185		N.S
Height (Factor A)	0.2253		N.S
Size (Factor B)	**0.0116**	26-Jul	**Significant**
Interaction (A*B)	0.4007		N.S
Height (Factor A)	0.7789		N.S
Size (Factor B)	0.0871	03-Aug	N.S
Interaction (A*B)	0.8000		N.S
Height (Factor A)	0.8044		N.S
Size (Factor B)	**0.0126**	26-Aug	**Significant**
Interaction (A*B)	0.9649		N.S
Height (Factor A)	0.3517		N.S
Size (Factor B)	**0.0002**	06-Sep	**Significant**
Interaction (A*B)	0.3223		N.S
Height (Factor A)	**0.0176**		**Significant**
Size (Factor B)	**0.0051**	20-Sep	**Significant**
Interaction (A*B)	0.1811		N.S
Height (Factor A)	0.4499		N.S
Size (Factor B)	0.0857	04-Oct	N.S
Interaction (A*B)	0.6618		N.S

Differences when P value is below 0.05, according to Fische test, with 5% of significance

Table 4: Mean separation of oil percentage for the size factor in Fuerte.

Levels	Means of Fuerte oil	Sampling date
Large	13.19 b	12-jul
Small	9.79 a	
Large	14.00 b	26-jul
Small	11.51 a	
Large	17.36 b	23-ago
Small	14.79 a	
Large	19.15 b	06-sep
Small	15.69 a	
Large	20.88 b	20-sep
Small	17.97 a	

Table 5: Mean separation of oil percentage for the height factor in Fuerte

Levels	Means of Fuerte oil	Sampling date
High	18.23 a	20-sep
Low	20.62 b	

In both varieties, the height is not a determining factor in the maturity level of the fruits measured in oil percentage, if the zones sampled show similar exposure to solar radiation. In Hass variety, the fruit was only obtained from the external part and the north half, without "ambush" between adjoining trees. In the case of Fuerte variety, the fruit was sampled from the internal part of very large trees, with high level of leaves of low photosynthetic degree because of the great shade inside the tree. Therefore, when having a good light interception, the leaves are photosynthetically active, so the photosynthates would not affect the production of dry matter in the fruits (Castro, 2000).

Muñoz's research (2004) states that a difference is only detected in the maturity level of the fruits concerning the height of the tree, regardless its cardinal position. The fruit located in the high zone contains a higher level of oil than the fruits located in lower areas. This would be caused by greater exposure to solar radiation of the high zone of the plant.

In this sense, Muñoz (2004), Gil (2000) and Vera (1997) mention that, regardless the height of the tree, the fruit of the external part has a higher level of maturity because of the greater availability of carbohydrates, caused by a greater photosynthetic activity of the leaves in that zone.

With regard to size, unlike the situation in Hass, there is a clear tendency of the largest fruits to have a higher level of maturity in Fuerte variety. This could be provoked by the "ambushed" status of the orchard, by the old and less vigorous trees. In this case the competence would be greater by photsynthates, with some fruits ripening before others.

The largest fruits had a greater maturity in Fuerte variety. This could be explained by the growth conditions of the fruit. Muñoz (2004) states the fruits have higher level of maturity when exposed to solar radiation. Additionally, Sippel *et al.* (1992) mention that cell division is greater with higher temperatures, increasing the size of the fruits. In this way, the largest fruits would have more oil.

Bertling and Cowan (1998) indicate that fruits located in a zone of higher exposure to solar radiation are larger than those exposed to less light. Therefore, a higher level of solar radiation produces riper and larger fruits. In short, largest avocados should also have higher level of maturity.

The results of trials conducted by Hofman and Jobin-Dëcor (1997) in Hass in Australia and by Sippel *et al.* (1992) in Pinkerton in South Africa indicate that the smallest fruits would have more dry matter. However, they conclude that the

variability is very wide among close fruits inside trees and between trees; therefore, the size is not always related to maturity. With this result, it may be mentioned that, to some degree, maturity is influenced by size in Fuerte avocado trees, but it does not have a significant effect in Hass. Therefore, the importance of the variety is fundamental when associating the size with the maturity of the avocado fruits.

According to the simple linear regression analysis, the relation between equatorial diameter and oil percentage of Hass and Fuerte fruits was insignificant (Table 6) (Figure 1).

Table 6: Relation between equatorial diameter and oil percentage in Hass and Fuerte varieties

Variety	**Regression equation**	**Coefficient of determination**
Hass	Diameter (mm) = 2.6027 – 0.1130 Oil (%)	R^2 = 0.063
Fuerte	Diameter (mm) = 0.7135 – 0.2534 Oil (%)	R^2 = 0.075

Valdevenito (1981) mentions that no correlation is observed between the size of the fruit measured in weight on the oil content, which is confirmed by Saavedra (1995), who determined that physical parameters, including equatorial diameter, do not show a relation with the maturity in the fruits which allows using them as valid indicators in the oil content.

The small relation is demonstrated in fruits having similar equatorial diameter that have different level of oil during the several sampling dates.

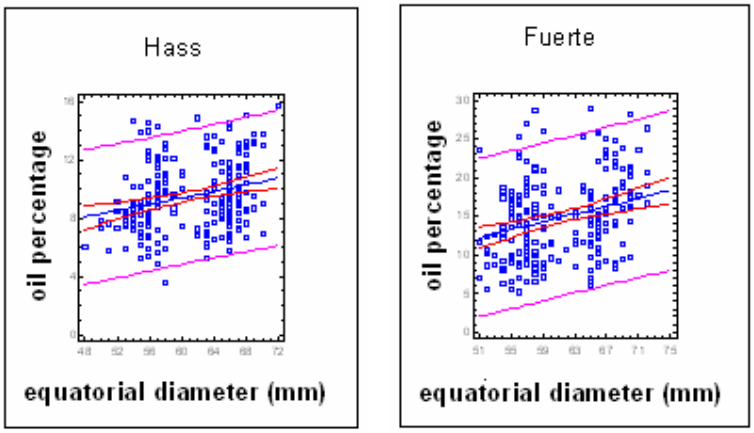

Figure 1: Curve between equatorial diameter and oil percentage in Hass and Fuerte

The relation between the equatorial diameter and fruit weight in Hass and Fuerte was high, according to the simple linear regression analysis (Table 7) (Figure 2).

Table 7: Relation between equatorial diameter and fruit weight in Hass and Fuerte

Variety	**Regression equation**	**Coefficient of determination**
Hass	Diameter (mm) = -278.8260 + 7.5311 Weight (g)	$R^2 = 0.91$
Fuerte	Diameter (mm) = -267.5340 + 7.4065 Weight (g)	$R^2 = 0.83$

The developing fruit increases its volume; therefore, it gains more diameter and weight.

Martínez (1984) and Caro (1998), established a high correlation among volume, weight and equatorial diameter

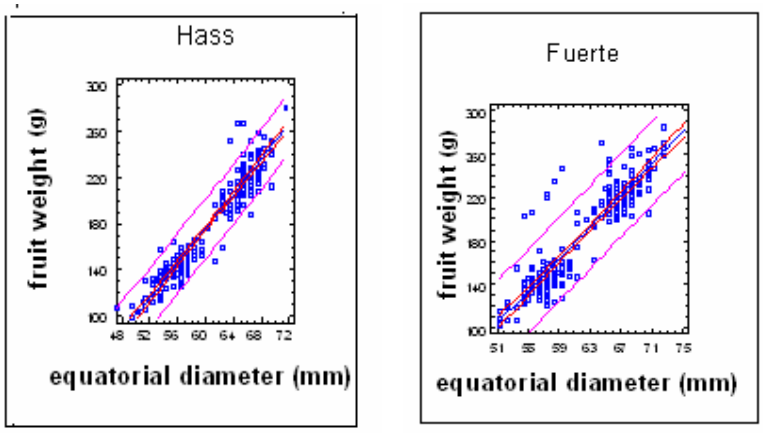

Figure 2: Curve between equatorial diameter and fruit weight in Hass and Fuerte

4. Conclusions

No effects of height are detected on the maturity of Hass and Fuerte avocados, in the north area of the tree, in both the high and low parts.

In Fuerte, the size is related to maturity, larger fruits have higher oil content, unlike Hass variety.

No combined effect of size and height of fruit inside the tree are noticed on the maturity measured as oil percentage, for both Hass and Fuerte.

The equatorial diameter is highly related to weight, but not with oil percentage, in Hass and Fuerte varieties.

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