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NON-DESTRUCTIVE METHODS AND OPTIMUM HARVESTING TIME OF 'SEMIL 34' AVOCADO (*Persea americana* Mill.) IN THE DOMINICAN REPUBLIC

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Dominican avocado exports face serious problems by quality heterogeneity due to inadequate pre and post harvest management. A research was conducted to explore a non-destructive method to determine the optimum harvesting time. Independent experiments were conducted in two of the main producing areas. Fruits were harvested for eight weeks in a commercial farm in each area. Chlorophyll fluorescence was used as a fast non-destructive method to determine fruit maturity rate. It has been also used as a marker of photosynthesis reaction to verify the physiological condition in other crops. The oil and dry matter contents were evaluated as quality variables. This method has been previously used as an indicator of *in vivo* photosynthetic reaction and environmental stress on various crop plants. Oil and dry matter content of fruits were evaluated as quality indicators. Phenological and ripening quality analyses as well as of organoleptic fruit attributes were also used as quality indicators. There is no significant correlation ($r=0.02$, $p= 0.92$) between chlorophyll fluorescence and oil content to establish an optimum harvesting time. Under the conditions of this study, based on fruit oil and dry matter contents, optimum harvesting times were determined in 24 weeks after inflorescence appearance for one region and 26 weeks for the other region. Organoleptic fruit quality was good for both areas.

Key words: fluorescence, oil, dry matter, fruit quality

MÉTODOS NO DESTRUCTIVOS Y MOMENTO ÓPTIMO DE COSECHA DEL AGUACATE (P*ersea americana* Mill.) 'SEMIL 34' EN REPÚBLICA DOMINICANA

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El aguacate dominicano de exportación, enfrenta problemas críticos por la heterogeneidad de la calidad, debido principalmente a la pre y poscosecha. Esta investigación se realizó con el fin de explorar un método no destructivo y de calidad de fruta para determinar momento óptimo de cosecha. Se condujeron experimentos independientes, en las dos principales zonas productoras del país. Se hicieron ocho cosechas semanales, en una finca comercial en cada localidad. La fluorescencia de la clorofila fue utilizada como método no destructivo y rápido para la determinación del índice de madurez de la fruta. Ésta se ha utilizado como indicador de la reacción de la fotosíntesis para comprobar la condición

fisiológica en otros cultivos. El contenido de aceite y materia seca, fueron evaluados como variables de calidad. Análisis fenológicos, de calidad de maduración y de los atributos organolépticos de la fruta, fueron también usados como indicadores. No existe una correlación significativa (r = 0,02 y P =0,92), entre la fluorescencia y el contenido de aceite, para establecer el momento óptimo de cosecha. Bajo las condiciones del estudio, basado en el contenido de aceite y materia seca, los momentos óptimos de cosecha fueron determinados como 24 semanas después de la floración para una zona y 26 semanas para la otra zona. Organolépticamente los frutos resultaron de buena calidad para ambas zonas estudiadas.

Palabras claves: fluorescencia, aceite, materia seca, calidad de fruta.

I. Introduction

The avocado is a high value crop that promotes the protection of the environment and the social and economic development of the population in the Dominican Republic. These is demonstrated by the 100% growth that has occured between 2002 and 2006.

For the production of high quality fruit the national producers require of precise techniques that facilitate the determination of the optimal time for harvesting the fruits. The knowledge of these techniques is necessary due to the great variability of ecologic and soil conditons among other genetic differences in the same avocado fruit varieties, these factors present an obstacle to a homogeneus treatment and prediction of harvest time that will help to organize a high quality production system that will reinforce the regional economy along with Chile and Mexico.
The United States and Puerto Rico are the principal consumers of the Dominican Avocado, these markets have very specific rules about size, cropping dates for variety and locality. In the Dominican Republic harvest time is selected based on the experience of the producers whom check two main factors, color and size, both of which can be deceptive according to Coajuste *et al.* (1994). This results in a broad variability of the quality of the fruit and its commercial value, weakening the commercialization system.

The reinforcement measures are each time more demanding, with the extra rule that explains that EE. UU. would not aloud the entrance of fruit after october 17th (Severino 2005), moment at which the Dominican avocado has reached the necessary maturity point.

The No. 422 Californian law, created on 1925, deals with the standarization of the oil content, set the minimum oil content of the fresh fruits at 8%. Even though is currently known that the oil content varies depending on the variety and the weather conditions. This is confirmed by several authors (Lee 1981) whom has been cited by (Lopez 1998 and Mortons 1987).

Several authors confirmed that a good ripening indicator is the dry matter. This and the oil content varies acording to the harvest period. Besides, there is a correlation between the oil content and dry matter. Based on the Mexican experience the fruit reaches a good taste and has low calories when has a minimum oil content of 8% and a dry matter of 21% (Mortons 1987) and the average of dry matter is 22% and the minimum is 20% (Dorantes *et al.* 2004). About this Kader and Arpaia (2000), mention that the requirements of dry matter for the ripening index are between 19 and 25%, depending on the cultivar.

The determination of harvest time is done based on the dry matter and oil content percentage, these test could be very complicated and take to many samples. Because of this we will explore the use of clorophyll fluorescense, as a fast non destructive method. This method had been used in Bananas, (*Musa* AAB Simmonds), apples (*Pyrus malus*), squash (*Cucurbita pepo* L.) and green pepers (*Capsicum annuum* L.), as an indicator of the physiological state of the surface of the fruits. (Mir *et al.* 1998). The measure of fluorescence of the clorophyll is a primary process of the photosynthesis used as a non destructive indicator of the in vivo reactions and stress in several crops.

To make the measurements, a low light emition is taken, this catches almost all the energy and we obtain the minimum fluorescense called Fo (Mir *et al*., 1998). When its applied faster at a higher light level and it catches relatively few energy it reaches the maximum fluorescence called Fm. The difference between the maximum and minumun fluorescence (Fo – Fm) is called the variable of fluorescence Fv. The relation Fv/Fm is the fotochemical eficiency, where we obtein the energy eficiency in the transformation process and the cloroplast activity (Mir *et al*. 1998).

*General objective***:** Explore non destructive methods for quality and fenotipic aspects that could help determine the optimal harvest time for the avocado variety 'Semil 34' in two localities in the North and South of the Dominican Republic (Moca and Cambita).

Specific objectives

- Determine the correlation between fluorometry and the oil content in `Semil 34´ varieties.
- Validate the determination of the optimal time of the `Semil 34´ avocado , through the quality indicators.

2. Materials and Methods

The material object of this study is the variety `Semil 34´, because this represents the 63.9% of the planted surface of the country. Two localities where selected because they are the major producers and exporters been North region (Moca, Espaillat province) and the South region (Cambita, San Cristóbal province). The research done in each locality are considered independent, not related with each other. The field work was done at harvest time, 2006 – 2007.

This research was an exploratory without a preestablished desing. In each area a farm was selected based on the premise that its production was going to be used in exportation.

The variables measured**:** a) Fluorometry (fotochemical eficiency= Fv/Fm) b) Weather: temperature, rain, altitud. c) Physico – chemical charcteristics of the soil (micro and macro nutrients, pH, salinity, texture and foliage). d) crop management (fertilization, pruning, weed control, sanitation, age, and plantation framework, among others). e) Quality attributes: physico – chemical (% fat, % dry matter, carbohydrates, weight, length and diameter), quality of maturation (time of maturation, peeling and seed, uniformity of ripening) organoleptic (flavor, texture, color of the pulp, fibers, herbal).

Management of the Experiment**:** a single farm was selected from each geographic area, inside the farm a plot of 629 m^2 was marked with 10 trees of perfect competence, from wich we will get exporting quality fruits.

Taking into account the producers criteria about the estimated harvesting time, we pick up weekly during 8 weeks, every 22 weeks after floration. At the beginning of the 1^{st} week of harvest 130 fruits where marked, this where distributed in the previous 10 trees selected per station. Of the chousen fruits we harvest 13 per week and 5 were used for the physico-chemical and fluviometry tests.

The soil and foliage tests were done as well as the GPS reference of the stations. The management data was collected throught interview at the moment were the trees were marked. The fluviometry was taken in 10 different points of the avocado.
Eight avocados were stored to analyze their maturation quality at room temperature, between 25 to 27°C. according to Eaks (1991), the optimal temperature for high quality ripening fruit is between entre 21 to 27°C.

The ripening test was confirm by touch. When the fruit riped other measures where taken as, weight loss, uniformity, pulp state, maturation days, peeling and pulp seed (a scale was used from 1 to 5, 5 been the best peeling and pulp state) was documented also the presence of vivible fibers. The organoleptic tests where carried out by a group of 6 no trained individuals.

The statistical analysis include a correlacion coeficient of Spearman, to stablish the correlation between fluorescen and oil content. This test was also used to correlate the chemical variables analyzed. For the quantitative variables we used regresion models for the harvest time and to estimate the equation that better fits. For the quantitative variables, we use the non-parametric tests of Kruskal-Wallis and the separation of the range. The analysis was done by the InfoStat program 2004 edition.

3. Results and discussion by locality

3.1 North (MOCA)

3.1.1 Description of the farm: The farm has a total extention of 2.63 ha, the soil is lime stone in steep located between the 19° 26`00" Latitud North and 70° 29`00" Longitud West and a altitude of 335 msnm. The age of the plantation is 5 years and is intercroped with plantain, (*Musa paradisiaca,* L), yuca (*Manihot esculenta* Crantz), Squash (*Cucurbita pepo* L.) and lemon (*Citrus limon* L.). the avocado plantation is compose by hibrids (`Gualtemanteco´ x `Antillanos´). The 80% belongs to the variety `Semil 34`, 10% veriety ´Choquete` and 10% `Pola´. The crop framework is of 6 x 7 m, the density of the plantation is of 238 plants/ ha.

The agronomical management, this include no irrigation and fertilization 3 time a year using organic and chemical compounds and a foliar fertilizer. The weed control was carried out when was required by weeding the field and by chemical control. Pest and disease control is done with chemical insecticides. Soil conservacion practices include digging furrows at the hill base and planting live barriers as recommended by other authors (SEA 2000, INFOAGRO s/f).

3.1.2 The fluorescence effect: to determine the fluorescent unity we use the fluorescence efficiency test, this is equal to the relation of Fv/Fm (Fv = Fm – Fo, Fo minimum measure, Fm maximum measure). To test the harvest index for avocado, independently from its variety, the oil content was used to compare with the clorophyll fluorescence to stablish the correlation. For Moca the results where:

	Fv/Fm	GT
Fv/Fm	1.00	0.92
GT	0.02	1.00

Spearman correlation test: coeficients\probabili´ties

The correlation coeficient is very low (r = 0.02 y P = 0.92) so for this study the fluorescence coeficient is not a good indicator of the harvest time.

3.1.3 Quality parameteres

3.1.3.1 Chemical Variables s

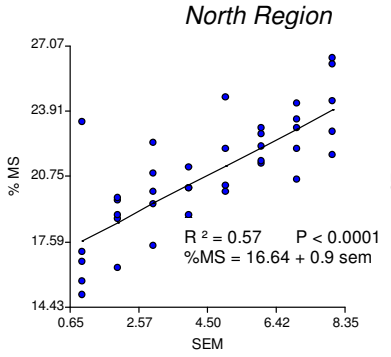

Fig 3.1. Regression of Dry Matter

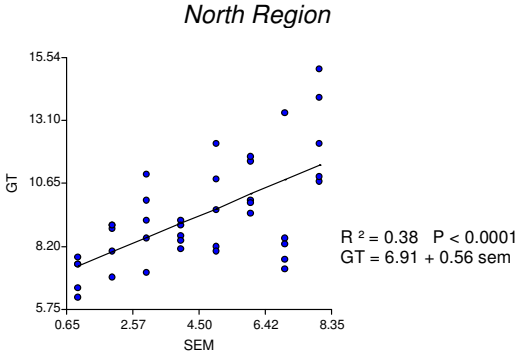

Fig 3.2. Regression of Oil content

(%MS) over time (Sem) of Semil 34 avocado fruits harvested for eight weeks in the north zone

(GT) over time (Sem) of Semil 34 avocado fruits harvested for eight weeks in the north zone

In the figures 3.1 and 3.2, its observed that not only the oil content (GT), and the dry matter (MS), show an ascending tendency correlated to the number of harvest time. This results are similar to another study done in Mexico in 1995, in which was confirmed that the content of MS and GT increase as harvest time increase (Cajuste *et al*. 2001).

The correlation between the %GT and %MS was considered as a determinat factor for the harvest index, and the correlation is good (r = 0.72 P< 0.0001). and its confirmed by other authors (Cajuste *et al.* 2001, Dorantes *et al*. 2004). See Figure 3.3.

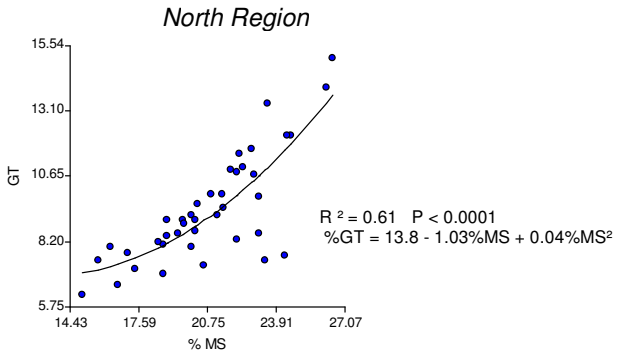

Figura 3.3. Regression analisys of Oil content (GT) over Dry Matter (%MS) in Semil 34 avocado fruits in the north zone

3.1.3.2 Fenotipical Variables

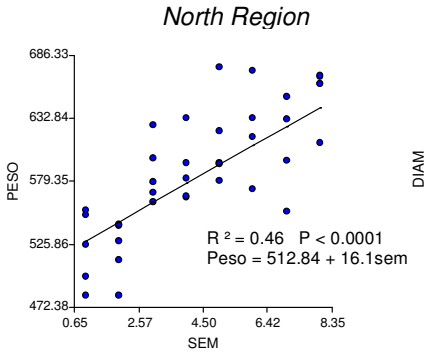

Figura 3.4. Regression of Fruit Fresh Weight at harvest over time (Sem) of Semil 34 avocado fruits in the north zone

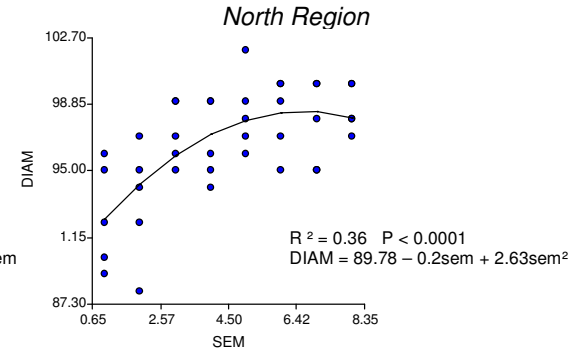

Figura 3.5. Regression of Fruit Diameter at harvest over time (Sem) of Semil 34 avocado fruits in the north zone

Accordingh to several authors the weight of the fruit is not an important indicator at harvest time, this basically because inside the farm are different floration times. (Dorantes *et al*. 2004, Cajuste *et al*. 2001).

3.14.2 Ripening quality

Table 3.1. Probability matrix of fruit quality descriptors of Semil 34 avocado fruits in the northern zone.

DESCRIPTOR	UNIFMAD	DESCAS	CASAD	ESTPULP	ESTFRU
P> 0.05	0.3757	0.1953	0.2139	0.0640	0.4676

Kruskal-Walis non-parametric statistical test
UNIFMAD = ripening uniformity. DESCAS: peeling CASAD: peeling of the seed. ESTPULP: state of the pulp. ESTFRU: state of the fruit.

Table 3.1, shows that there are no significant differences between harvest weeks in none of the variables tested. There was a good skin peeling and a minimum proportion resulted a little difficult. The pulp was between good and excelent while the state of the fruit in general was considered good. The uniformity was not confirmed in many fruits, the 62% where 1/3 riped. Only a 16% of the 60 samples analyzed between the 7^{th} and 8^{th} harvest week had a soft visible fiber content, in none of the cases we found dark pulp.

3.1.5 Organoleptic characteristics: color, appearance and preferences do not show significant differences between harvest weeks. As observed in table 3.2 the aroma, flavor, texture and herb shown significant differences. This characteristics where improving as the harvest time, oil an dry matter content were also increasing.

Table 3.2. Means of organoleptic quality descriptors in Semil 34 avocado fruits harvested for eight weeks in the north zone.

DESCRIPTOR/Harvest week	**Aroma**	**Flavor**	**Texture**	**Herb**
Sem01	5.94	5.50	6.67	5.22
Sem02	6.83	6.95	6.65	6.82
Sem03	7.10	7.15	7.37	6.82
Sem04	7.78	7.26	7.39	7.18
Sem05	6.46	6.38	6.23	6.45
Sem06	7.50	8.00	7.64	7.43
Sem07	7.08	7.58	7.15	7.36
Sem08	6.89	6.78	7.11	7.00
P > 0.05	**0.0001**	**0.0001**	**0.0083**	**0.0003**

Kruskal-Walis non-parametric test

3.2. South Region (Cambita)

3.2.1 *Farm description:* With an extention of 1.25 ha, the farm is located at the 18° 27`01" North and 70° 10`01" West, at 295 m over sea level. The plantation is 4 years old, planted with avocado hibrids of the `Gualtemanteco´ and `Antillanos´

varieties, the 80% is the `Semil 34` variety and the rest of the crop is `Pollock´ and `Popenol´.

The agronomical management does not include irrigation, but the farms are fertilized tree times a year, with chemical and organic compounds. The weed control is done manually and with chemicals. The pests and disease control is done with chemical and biological insecticides and some cultural practices. They have some soil protection practices and pruning two times a year.

3.2.2 *Fluorescence effect:* Lthe results of the correlation analysis of the clorophyll fluorescence (Fv/Fm) and the % of oil content (GT) in the South area was:

	Fv/Fm	GT
FvFm	1.00	0.37
GT	-0.14	1.00

Spearman correlatin test: coeficients\probabilities

As observed, the correlation coeficient is very low as in the north (R = -0.14 y P = 0.37) which confirms that for this area also the fluorescence index is not a harvest indicator.

3.2.3 Quality parameters

3.2.3.1 Chemical Variables

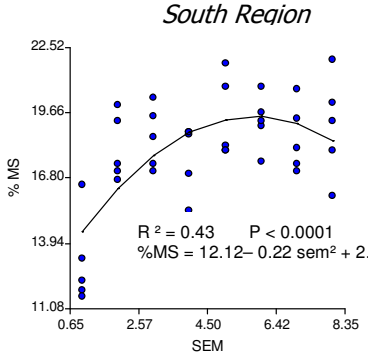

Fig 3.6 Regression of Dry Matter (%MS) over time (Sem) of Semil 34 avocado fruits harvested for eight weeks in the south zone.

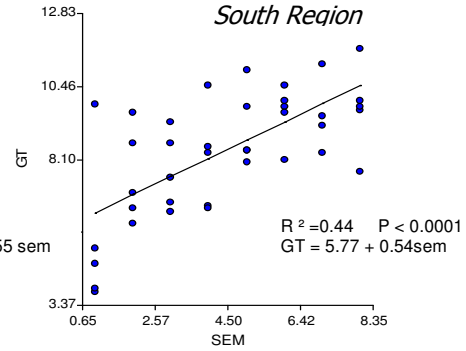

Fig 3.7 Regression of Oil content (GT) over time (Sem) of Semil 34 avocado fruits harvested for eight weeks in the south zone.

In the figures 3.6 and 3.7, similar to the Northern station, the oil content and dry matter show ascending tendency as the harvest week increased.

The correlation between the GT and the MS percentages is good, similar to the North station, see fig. 3.8.

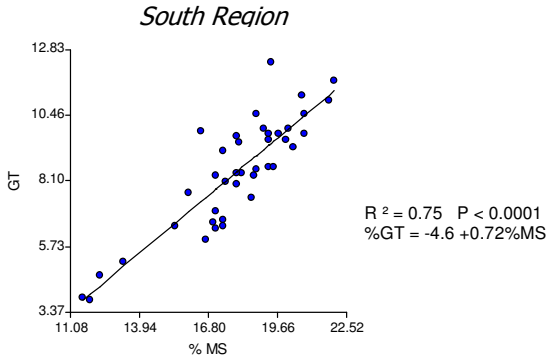

Figura 3.8. Regression of Oil content (GT) over Dry Matter (%MS) in Semil 34 avocado fruits in the south zone

3.2.3.2 Fenoipic Variables

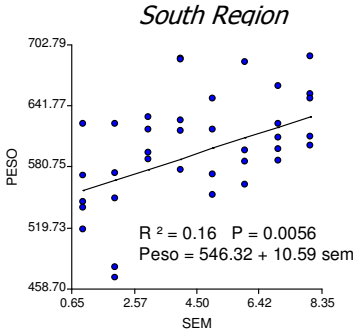

Fig 3.9. Regression of Fruit Fresh Weight at harvest over Time (Sem) of Semil 34 avocado fruits in the south zone

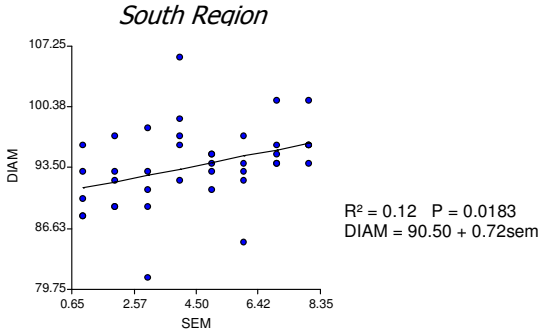

Fig 3.10. Regression of Fruit Diameter at harvest over Time (Sem) of Semil 34 avocado fruits in the south zone

3.2.4 *Maturation quality*

Table 3.3 Probability matrix of fruit quality descriptors of Semil 34 avocado fruits in the south station

DESCRIPTOR	UNIFMAD	DESCAS	CASAD	ESTPULP	ESTFRU
P> 0.05	0.2680	0.4596	0.2964	0.0494	0.1055

Kruskal-Walis non-parametric test

The table 3.3 shows that there where no significant differences among the harvest weeks for the evaluated variables with the exception of the pulp state that had a significant difference.

38% of the fruits riped completely while 41% only riped 1/3 and the rest I a 50%. There was good peeling and a minimum had difficult peeling of the seed. The

state of the fruit was considered good, and the pulp was considered between good and excellent.

At this locality only 38% of the 75 samples had soft visible fibers in the riped fruit. This characteristic was found mainly after week number 4.

3.2.5 *Organoleptic Characteristics:* The characteristics to describe are color, aroma, flavor, herb and preference and among this there was no significant difference, but these characteristics had a noticeable better calification compared to the other station.

During the first weeks the texture had a stickyness problem and during the last weeks the problem where the visible fibers. See table Table 3.4.

Table 3.4 Significantly different means in Semil 34 avocado fruits harvested for eight weeks in the south zone

DESCRIPTOR/Harvest week	Texture	Appearance
Week01	7.00	7.20
Week02	7.53	7.94
Week03	7.31	7.18
Week04	7.90	7.45
Week05	6.94	7.22
Week06	7.21	7.42
Week07	6.94	7.33
Week08	7.88	7.75
P > 0.05	0.0055	0.0427

4. Conclutions and recommendations

The non-destructive flourescence method for green avocados is not informative as an indicator for the harvest time.

Take in consideration the oil content and dry matter correlation test, the `Semil 34` avocado variety in the North region reach the optimal harvest time after the 3rd week (%GT = 9.18 y %MS =20.02). This moment is the 24th week after floration. The South region reaches the harvest optimal time at the 5th week, the 26 week after floration (%GT = 9.12 y %MS =19.3). The quality charcteristics are of general aceptance for the exporting market.

As verified by other authors, was also confirmed that fenotipical characteristics are not reliable to determine the harvest time.

According to the regression curves is necessary to repeat the investigation and increase the number of harvest weeks tested to observe the point of maximum curvature.

Its necessary to continue the research for at least two more harvest periods to ensure the behavoiur of the harvest and conclude cientifically about the harvest index for the avocado variety `Semil 34´ at the study areas.

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