CHARACTERIZATION OF THE VEGETATIVE DEVELOPMENT AND ITS RELATIONSHIP WITH FRUITING AND PRODUCTION OF ORANGE TREES [*Citrus sinensis* (L.) OSBECK]

Guillermo R. Almenares Garlobo¹, María del C. Pérez Hernández², Walfredo Torres de la Noval², Mario Varela Nualles² and María I. Pavón Rosales²

**ABSTRACT.** A characterization of the vegetative development of *Valencia Late* and *Washington Navel* orange cultivars was done and the relationship between vegetative development, fruiting, production and efficiency of the fruiting and production was determined. A plot from each cultivar was selected and during every year’s flushing period, the number of leaves per canopy surface, tree dimensions and average foliar surface were evaluated; accumulated rainfall was recorded. Variables like vegetative development, foliar area per tree, foliar area per canopy volume and the foliar area index were estimated. From each variable data, a simple classification analysis of variance was performed every year. Variables as fruiting, production and efficiency of the fruiting and production were calculated and their relationship with those of vegetative development was determined through an Analysis of Canonic Correlations. The results showed that the vegetative development corresponds to the behavior of accumulated annual rainfall, as they increase, the vegetative development is higher. The foliar area was directly related to fruiting and production of both cultivars. Increased foliar area per tree and foliar area reduction per canopy volume mainly contributed to an increased fruiting (number of fruits per tree) and production (kg of fruits per tree).

Key words: *Citrus sinensis*, leaf area, fruiting, plant production

**INTRODUCTION**

Citrus fruits have a high importance from an economic and nutritional standpoint. In the world 8,7 million hectares are dedicated to its cultivation and production amount to 122,3 million tones, of which 56,4 % are oranges.

---

¹ Instituto de Investigaciones en Fruticultura Tropical, La Habana, Cuba.
² Instituto Nacional de Ciencias Agrícolas (INCA), gaveta postal 1, San José de las Lajas, Mayabeque, Cuba, CP 32700.

guillermo@inca.edu.cu; guillermo@enet.cu
In Cuba, citrus occupy 29.3 thousand hectares, with a production of 203.7 thousand tons, mainly oranges (46.1 %)\(^3\). Although the cultivated area and production have grown in recent years for different causes, mainly pest and disease impact, researches are continuing to develop the scientific and technical basis under new circumstances of the sector.

In this context, the study of vegetative development, behavior and yield components factors involved in them is important for the differentiated handling of cultivars by the application of appropriate planting, nutrition, phytosanitary defense, watering and pruning technologies in different edaphoclimatic conditions.

It is known that edaphoclimate conditions influence the development of citrus trees. For example, the issuance of vegetative flows, plantations without irrigation is regulated by the occurrence of wet and dry periods (1, 2, 3). These flows vegetative growth or sprouting, are responsible for branch growth and increased leaf area of trees (4).

Therefore, the behavior of vegetative budding play a key role in maintaining an adequate balance between vegetative and reproductive structures, very important aspect for producing fruits and growth (5). Leaves produce and export photosynthates to the rest of the tree and are known as sources, while non-photosynthetic organs (fruits and roots) are known as sinkholes (6). The leaf-fruit ratio is dependent on many factors such as species, variety, phytotechnical practices and soil and climate conditions (7, 8).

To compare the potential productivity of the top in citrus plantation systems, they were used vegetative development variables as the leaf area per tree and the leaf area index (LAI). The latter is defined as ratio of a leaf area and the soil surface area occupied by a tree\(^4\). Also it is used to model plant processes (9) and as an indicator of photosynthetic activity, by its relation to the sunlight interception (7). LAI also combined with climatic variables, has been used to calculate daily volumes of water needed to irrigate the crop in some agroecosystems (10).

However, little information exists about interrelationship studies between groups of vegetative and reproductive development variables in citrus. Vegetative growth behavior and its relationship with fruiting processes, production and efficiency in oranges grown in Contramaestre citrus agroecosystem in the eastern region of Cuba, it is not known.

The study aim is to characterize the vegetative development of Valencia Late’ and ‘Washington Navel’ orange cultivars and determine the relationship of vegetative development to fruiting and production besides, production and fruiting efficiency.

**MATERIALS AND METHODS**

The experience was developed in the period 2000-2002, sweet orange trees were used \([Citrus sinensis\ (L.) Osbeck], ‘Valencia Late’ (VL) and ‘Washington Navel’ cultivars (W.N.), 30-33 years age, grafted on sour orange \([Citrus aurantium\ L.]\) and planted at a distance of 4 x 8 m.

The experimental plots are located at 20° 18’56” North Latitude; 76° 16’22” West Longitude (VL), and 20° 19’56” North Latitude; 76° 17’32” West Longitude (W.N.), in production areas without irrigation, belonging to the Citrus Company “América Libre” municipality Contramaestre, Santiago de Cuba province.

The soil is classified as calcific fluffy brown soil (11). The agronomic management of plantations was made according to the technological scheme of the company during this period and accumulated precipitation \((Pr; mm)\) were recorded in pluviometers located 300 m of the experimental plots.

**CHARACTERIZATION OF VEGETATIVE DEVELOPMENT**

The vegetative development was characterized in the four central trees of a selected plot in each cultivar and constituted by 16 trees (four per row). During each of the three budding waves per year, leaf number were evaluated per the surface top, dimensions of trees and vegetative development variables (12) were estimated.

Leaf number per top surface was recorded \([Ln; leaves \ (m^2 \ top)^{-1}]\) through a frame of 0.25 m placed to 1.5 m of the tree height by cardinal points of the top and the five leaves leaf surface was determined \((cm^2 \ leaf)^{-1}\) for each top cardinal point, using a digital planimeter Delta T-Device (UK).

Moreover, tree height dimensions \((TH; m)\), height from the ground to the base of the top \((m \ S)\) and top diameter in two directions, North-South \((NS)\) and East-West \((EW)\) were evaluated, which was determined as maximum horizontal diameter \((Dp_{NS})\ and \((Dp_{EW})\) and


horizontal diameter to 1.5 m of tree height (Dm<sub>N-S</sub> and Dm<sub>E-W</sub>) using a ruler in mm and a length of 7 m. Then, the average leaf area (Sp cm<sup>2</sup> leaf<sup>-1</sup>), canopy height (H, m) \( H = AT-S \), the maximum horizontal radius of the top (Rp; m) \( Rp = [(Dp_{N-S} + Dp_{E-W})/2]/2 \), the horizontal radius of the crown to 1.5 m of the tree height (Rm; m) \( Rm = [(Dm_{N-S} + Dm_{E-W})/2]/2 \) and the volume of the top (Vc; m<sup>3</sup>) \( Vc = 2.0944 Rp^2 H \) were estimated.

In each budding wave, vegetative growth variables were estimated: leaf area per tree \( At \) (m<sup>2</sup> top<sup>-1</sup>) \( At = (Vc Sp Nh)/Rm \), leaf area per canopy volume \( (Av, m^2 (m^3 top)^{-1}) Av = (Sp Nh)/Rm \) leaf area per tree; and leaf area index LAI = (0.667 Sp Nh H)/Rm. The outcome in vegetative development variables is the annual cumulative sum of the three sprouting waves.

The data for each variable in each of the years were analyzed by a variance analysis of simple classification (p≤0.05).

**RESULTS AND DISCUSSION**

**CHARACTERIZATION OF VEGETATIVE DEVELOPMENT**

It is noted, generally in each cultivar, correspondence among the magnitudes of vegetative development variables, leaf area per tree (Figure A), leaf area per canopy volume (Figure B) and leaf area index (Figure C) with annual accumulated rainfall (Figure D).

**Behavior of vegetative development variables† (A, B, C) and accumulated rainfall (D) in ‘Valencia Late’ (V. L.) and ‘Washington Navel’ (W. N.) oranges**
These variables showed higher values to the extent that cumulative rainfall was more abundant.

Moreover, the estimated values of LAI average over the three years of study were 1.7 ('Valencia Late') and 2.0 ('Washington Navel'). These values are lower than those reported in Florida, United States (14), which ranged from 3.9 to 5.1 and in Ceiba del Agua, Cuba (15) with values between 2.5 to 3.6; all Citrus sinensis (L.) Osbeck, plantations with similar planting distances but with irrigation.

In effect, informed and estimated IAF values are very different; however, given the average leaf area for both cultivars in the Contramaestre agroecosystem presented some similar values to reports from the above, in Ceiba del Agua and Florida plantations by author. This fact points to the apparent differences between of LAI shown among agroecosystems are mainly due to leaf number per top surface (NL) (data not shown).

Low values of NL quantified in this agroecosystem could be associated to two factors, on one hand, dry land conditions in which the crop is developed and on the other, to the cultural care, especially nutrition made with nitrogen (N), where doses tree 0.25-0.30 kg N yr⁻¹ were lower than the estimated needs, and also with respect to those used in agro comparison.

Both factors are closely related to vegetative growth and probably contributed to the shown variation. In this regard, it has been reported that water stress periods cause effects on vegetative growth of citrus as senescence and abscission of leaves (15), so optimize nutrition with N in citrus trees needed to regulate the vegetative growth (16).

Table I. Canonical Correlation Analysis between vegetative development variables† (x1, x2, x3) and fruition and its efficiency†† (y1, y2, y3), in two orange cultivar [Citrus sinensis (L.) Osbeck]

<table>
<thead>
<tr>
<th></th>
<th>U1 Coefficient</th>
<th>V1 Coefficient</th>
<th>Canonical correlation†</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) ‘Valencia Late’ cultivar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>x1. Leaf area per tree top (At)</td>
<td>-1.69</td>
<td>y1. Number of fruits per tree (Ft)</td>
<td>-1.23</td>
</tr>
<tr>
<td>x2. Leaf area index (LAI)</td>
<td>-1.91</td>
<td>y2. Number of fruits per m² of top tree (Fv)</td>
<td>1.87</td>
</tr>
<tr>
<td>x3. Leaf area per tree top volume (Av)</td>
<td>3.82</td>
<td>y3. m² of leaf per fruit (Rhf)</td>
<td>-0.18</td>
</tr>
<tr>
<td>B) ‘Washington Navel’ cultivar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>x1. Leaf area per tree top (At)</td>
<td>-1.23</td>
<td>y1. Number of fruit per tree (Ft)</td>
<td>-2.09</td>
</tr>
<tr>
<td>x2. Leaf area index (LAI)</td>
<td>0.25</td>
<td>y2. Number of fruits per m² of top tree (Fv)</td>
<td>2.15</td>
</tr>
<tr>
<td>x3. Leaf area per tree top volume (Av)</td>
<td>0.63</td>
<td>y3. m² of leaf per fruit (Rhf)</td>
<td>-0.30</td>
</tr>
</tbody>
</table>

†§ Signification for p≤0.01; n=12
††† Estimated values when setting fruit period ended of April-May, 2001 and 2002.
Tabla II. Análisis de correlaciones canónicas entre variables de desarrollo vegetativo\(\dagger\) \((x_1, x_2, x_3)\) \(y\) su eficiencia \((z_1, z_2, z_3)\) en dos cultivares de naranjo \([\text{Citrus sinensis (L.) Osbeck}]\).

<table>
<thead>
<tr>
<th>U</th>
<th>Coeficiente</th>
<th>V</th>
<th>Coeficiente</th>
<th>Canonical correlation(\ddagger)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) ‘Valencia Late’ cultivar</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(x_1). Leaf area per tree top ((At))</td>
<td>2,09</td>
<td>(z_1). kg of fruit per tree ((Mt))</td>
<td>1,27</td>
<td></td>
</tr>
<tr>
<td>(x_2). Leaf area index ((LAI))</td>
<td>0,52</td>
<td>(z_2). kg of fruit per m(^2) of tree top ((Mv))</td>
<td>-1,65</td>
<td>0,99**</td>
</tr>
<tr>
<td>(x_3). Leaf area per tree top volume ((Av))</td>
<td>-2,50</td>
<td>(z_3). m(^2) of leaf per kg of fruit ((Rhm))</td>
<td>0,34</td>
<td></td>
</tr>
<tr>
<td>B) ‘Washington Navel’ cultivar</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(x_1). Leaf area per tree top ((At))</td>
<td>1,01</td>
<td>(z_1). kg of fruit per tree ((Mt))</td>
<td>1,70</td>
<td></td>
</tr>
<tr>
<td>(x_2). Leaf area index ((LAI))</td>
<td>0,49</td>
<td>(z_2). kg of fruit per m(^2) of tree top ((Mv))</td>
<td>-1,79</td>
<td>0,97**</td>
</tr>
<tr>
<td>(x_3). Leaf area per tree top volume ((Av))</td>
<td>-1,12</td>
<td>(z_3). m(^2) of leaf per kg of fruit ((Rhm))</td>
<td>0,06</td>
<td></td>
</tr>
</tbody>
</table>

\(\ddagger\) Significación para \(p\leq0,01; n=12\)

\(\dagger\) Annual accumulated values of sproutings in 2000, 2001 and 2002.

\(\ddagger\) Estimated values when the harvest ended in October (‘Washington Navel’) and December (‘Valencia Late’) years 2000, 2001 and 2002.

This dependence was not known in the Contramaestre citrus agroecosystem and shows the specific relationship of leaf area per tree, as well as canopy volume with production and efficiency variables. From a practical standpoint, it can handle agronomic crop aspects such as planting density, pruning and fertilization, influencing vegetative growth variables as \(At\) and \(Av\).

Leaf area is related to the fruition and production in both cultivars. The increase in leaf area per tree and leaf area per canopy volume decrease, mainly contributed to the increase of fruiting (number of fruit per tree) and production (kg of fruit per tree). The direct relationship of leaf area with fruit number and kilograms of fruit (all defined by tree), was associated with the leaf number per surface of the top, to the leaf surface, and the development of the canopy, expressed by volume.

In this regard, leaf area, has a direct relationship with the photosynthetic capacity (18), which affects the supply of photoassimilates (19). In fruit (7, 20) has shown a direct relationship between leaf area per tree and production.

In study conditions in plantations without irrigation, a leaf number decrease of abscission, or other factors could reduce the sunlight interception by the top tree, reducing the amount of photoassimilates produced and consequently the biological and agricultural productivity is affected culture (14, 21).

Moreover, the inverse relationship of leaf area per top volume with the fruit number per tree and kilograms of fruit per tree can be associated with the number of leaves per top surface \((NL)\). An increase of \(NL\) means vegetative growth more detrimental to reproductive, suggesting that bud differentiation was favourable to the vegetative and therefore decreased the amount of produced flowers, setting fruit and yield per tree.

According to the results, the Canonical Correlation Analysis is an appropriate statistical tool for the analysis of multiple variables and facilitates the study of the interrelationships between groups of dependent and independent variables, as has been shown in other studies (22).

**CONCLUSIONS**

♦ The vegetative growth of orange ‘Valencia Late’ and ‘Washington Navel’ in the Contramastre citrus agroecosystem, corresponds to the behavior of the annual accumulated rainfall, when they rise, the vegetative development is superior.

♦ Leaf area is related to the fruition and production in both cultivars. The increase in leaf area per tree and reduced leaf area per canopy volume, mainly contributed to the increase of fruiting (number of fruit per tree) and production (kg of fruit per tree).

**BIBLIOGRAPHY**


Received: October 4th, 2013
Accepted: June 19th, 2014