Growth of three color hybrids of sweet paprika under greenhou[illegible] conditi[illegible]

Crecimiento de tres híbridos de pimentón de colores en condiciones de inver[illegible]ero

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ABSTRACT

The color varieties of sweet paprika are conquering the Colombian vegetables markets, not only because of their fancy colors, but also because they are one of the best sources of ascorbic acid and carotenoids as well as phenolic compounds, important in the human diet. Therefore, basic studies related to the growth and development of the available imported varieties under greenhouse conditions on the Bogota Plateau are required. In a completely randomized block design with five replicates, biometric parameters of the hybrids Plinio, Menta RZ and Orangery were evaluated, showing that the latter one was statistically different for leaf area, leaf area index and number of leaves during the 20 study weeks, while the dry matter in the leaves, stems and roots showed no differences between the varieties. Although, 'Orangery' exhibited the highest perce[illegible]t of final allocation of accumulated dry matter in the fruits[illegible] in general, the most promising hybrid for cultivation und[illegible]e research conditions.

Key words: vegetables, Bogota Plateau, lea[illegible]dry matter, fruit color.

RESUMEN

El pimentón de col[illegible] está conquista[illegible]cado de hortalizas colombian[illegible]o solamente por sus [illegible]os colores, sino también por se[illegible]iderado uno de las mejores fuentes de ácido ascórbi[illegible]ca[illegible]ides, como también de compuestos fenólicos importantes e[illegible]ta de los humanos. Por lo tanto se requieren estudios básico[illegible]ionados con el crecimiento y desarrollo de las variedades d[illegible]onibles, importadas, bajo con[illegible]de invernadero en la Sabana de Bogotá. En un di[illegible]o de bloques completamente al azar, con cinco repetici[illegible], se evaluaro[illegible]parámetros biométricos de los híbridos Pli[illegible]enta RZ [illegible]ngery, mostrando que este último se diferen[illegible]dística[illegible]te en los parámetros área foliar, índice del área fo[illegible]o de hojas durante las 20 semanas del estudio, mientras que la materia seca en hojas, tallos y raíces no mostró diferencia entre ellos. Igualmente, 'Orangery' [illegible]tó el mayor porcentaje de distribución final de materia se[illegible]da en los frutos, lo que en general muestra a ese [illegible]ido como el más promisorio para ser cultivado bajo las [illegible]diciones mencionadas.

Palabras clave: hortalizas, Sabana de Bogotá, área foliar, materia seca, color de frutos.

Introduction

Paprika, bell or sweet pep[illegible]varieties of *Capsicum annuum* (L.), grown under [illegible]se conditions, can reach, according to the quality [illegible]d hea[illegible]ices up to five times higher than those of varieties culti[illegible]outdoors, especially if they are [illegible]rketed when the fru[illegible]ave taken the typical variety c[illegible], red, orange, yellow, cream, chocolate or purple (Jo[illegible]n *et al.*, 2004). The "bell cultivar group" shows large, [illegible], not spicy fruits, which, when ripe, can be red, ye[illegible]reen, [illegible]ge, white, purple, blue, or even brown depend[illegible]specific cultivar. In Colomb[illegible]t recently, color[illegible]paprika varieties have been in[illegible]duc[illegible]nd have been marketed profusely in diverse [illegible]ermark[illegible]nly used as decorative ingredients in sa[illegible]p[illegible]ther [illegible]dishes. The main marketed colors are or[illegible]red and green. From a health point of view, the fruits are o[illegible]rtance, as shown by Sun *et al.* (2007) who investigated the antioxidant compounds and activity in four different colored, green, yellow, orange and red, sweet bell peppers, detecting in all of the varieties a high total phenolic content; all of the colored sweet peppers revealed substantial abilities in preventing the oxidation of cholesterol or docosahexaenoic acid. Ghasemnezhad *et al.* (2011) even considered that consumer interest in colored bell peppers is mainly due to the content of bioactive compounds and their importance as dietary antioxidants. Different studies have also demonstrated that, for example, the sweet red pepper is one of the best sources of ascorbic acid and carotenoids as well as phenolic compounds that are important in the human diet (Hallmann and Rembiałkowska, 2012).

Up to now, aspects of the growth and development of the different color varieties have not been studied in Colombia and their management depends only on the instructions

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provided by the seed companies, which are introducing the planting material.

The botanical family Solanaceae is recognized worldwide for including important cultivated vegetables and ample agronomic utility of the species, mainly of the genera *Solanum* and *Capsicum* (SOL, 2004). Colombia, which is situated in the tropics and subtropics, can ensure the continued production of many species of this family, representing promising alternatives with better opportunities to ensure competition in global market scenarios.

Therefore, a growing demand for fruits, for example *Capsicum* species, both sweet and spicy, can be observed in the country, using imported materials for planting. Only recently, a variety of sweet and hot paprika has been cultivated profusely and, in view of its good profitability, production and export possibilities, has started to expand. Currently, production is concentrated in the departments of Santander, Valle del Cauca, Huila and Antioquia with 656, 532, 412 and 349 ha, respectively; corresponding to 79% of the cultivated area nationwide, during the period 2000-2009, the highest production was obtained in [illegible] reaching 54,796 t, grown in 2,480 ha (Casilimas *et al.*, [illegible]).

In the Amazon region, Solanaceae is the most cultivated genus, by the diverse ethnicities, being part of their cultural heritage, which has resulted in va[illegible]dapted to different environments and agricult[illegible]al re[illegible]ements; unfortunately, they have not been ev[illegible]d for [illegible] purposes. The Amazon is considered th[illegible]f origin *C. annuum*, *C. chinense* and *C. frutescens* d[illegible]the morphological, reproductive and [illegible]lecular variatio[illegible]n in the genus *Capsicum* as men[illegible]ed by Melgarejo *et al.* (2004).

Growth, as indicated by Cebula ([illegible]for sweet paprika, is the increase in the size of the total pla[illegible]part of it, which can be expressed [illegible]dry matter or in dime[illegible]ions due to the formation of n[illegible]ells; the growth rate, therefore, is stated as weight, vo[illegible], area [illegible]length increases per unit time.

Generally, the pla[illegible]wth r[illegible]decreases with increasing sizes until it become[illegible]hen it reaches maturity or fina[illegible]sion. According to Daşgan and Abak (2003), d[illegible]lopm[illegible] is an orderly and progressive change, often, more [illegible]d complex stage.

To des[illegible]the growth and development of crops, it is necessary t[illegible]tify phases and stages within the development and predict of each span at different temperatures (Wurr *et al.*, 2002; Soto-Ortiz *et al.*, 2006; Soto-Ortiz and Silvertooth, 2008). For *Capsicum* sp., T[illegible](2009) suggested four phenological phases: eme[illegible]cy, [illegible]h leaf, flowering and maturity; meanwh[illegible]the USDA[illegible]0) identified three specific phases: 50% fr[illegible]nting to t[illegible] ning; 75% from thinning or transplanting[illegible]uit t[illegible]g and 100% from fruit tying to[illegible]rvest or harves[illegible]ng. The flowering period fluct[illegible]s between 70 and 93 d, fruit ripening starts at 85 d in [illegible]most p[illegible]ocious varieties and at 107 d in the more delayed [illegible]lva Filh[illegible]*et al.*, 2004).

Phenology comp[illegible]s the study of t[illegible]al phenomena that are related [illegible]ertain periodic rhythms or phases and their relatio[illegible]p[illegible] the environment where they occur. In their cycles, p[illegible]suffer visible changes that are influenced by the genotyp[illegible]ecosystem and their interaction (Mundarain *et al.*, 2005). From the point of view of en[illegible]ntal supply, climate, temperature, and radiation, a[illegible]ng others, knowledge of the phenology of a specific cr[illegible]importa[illegible]proper management (Soto-Ortiz *et al.*, 20[illegible]to-Ort[illegible]and Silvertooth, 2008); they are the fundamen[illegible]or interpreting changes that occur in the plant and the possible implementation of management [illegible]ns and agricultural practices (Cautín and Agustí, 2005).

M[illegible]tes-Hernández *et al.* (2004) pointed out heat unit [illegible]cumulation during different developmental stages of C[illegible]*icum* sp., showing differences between paprika types and between different degrees of domestication. Agarwal *et al.* (2007) found that, for *C. annuum*, depending on the degree of precision required when the developmental stagesare defined, heat units can be used once each variable and the environment to be evaluated has been defined as well, but noted that it is impractical to handle many developmental phases associated with different stages of the plants development.

Paschold and Zengerle (2000) mentioned three developmental phases for sweet peppers, which are related to dry matter weight per crop in unit area or individual plants in relation to time; this behavior generally corresponds to a sigmoidal curve characterized by a) a logarithmic phase, where size increases exponentially with time, the growth rate is proportional to the size of the organism, the higher the size the faster the growth, and it ranges from germination to the juvenile stage, b) a linear phase, where the vegetative growth continues at a nearly constant rate, having an increased demand for water and nutrients, and c) a constant state phase, where the largest amount of dry matter accumulates, known as physiological maturity; at this stage, the dry matter gain is balanced with the losses.

The objective of this research was to determine the differences in biometric growth parameters, such as foliar area index, foliar area, leaf number, plant height and dry matter, of Plinio (yellow), Menta RZ (green) and Orangery (orange) hybrids under greenhouse conditions, unknown up to now for these cultivars on the Bogota Plateau.

Materials and methods

The research was carried out at the experimental unit "El Remanso" of the Universidad de Ciencias Aplicadas y Ambientales (U.D.C.A), under cover in a greenhouse, chapel-type with straight walls and a side ventilation rate of 40%, located on the Bogota Plateau, 4°35'N and 74°04 W, altitude 2,560 m a.s.l. Hybrid seeds of yellow Plinio (35-702 RZ), green Menta RZ and orange Orangery from the Holland company Rijk Zwaan were employed; the seeds were germinated in a growth chamber at 26°C and 80% relative humidity, within 128 alveoli trays, filled with a mixture of peat, perlite and vermiculite as propagation substrate. The seedlings were transplanted after approximately 3 weeks when well-formed with true leaves and a length between 12 and 15 cm. The research had a total duration of

The treatments, each consisting of a color hybrid, were placed in a compartment of an area with a 6.8 m width and 20.0 m length, arranged in a complete randomized block design with five replicates. The replications corresponded to five beds per area, each 0.80 m wide with a distance between the beds of 0.50 m; in each bed 4 plants were planted, corresponding to 40,000 plants/ha a distance of 50 cm between plants under the triangle system.

The fertigation consisted of a drip system caliber 8000 (RODRIP John Deere Waterline, IL) with a distance between issuers of 0.10 m and a flow rate of 0.80 L h^{-1}, with an irrigation schedule of 4.5 to 6.0 L m^{-2} day, including Cadahía's standard nutritional solution for sweet peppers (Cadahía, 2005).

In order to prevent damage in the branches, 30 d after transplanting (DAT) staking with trellis with polyethylene raffia was initiated, periodically until harvest. The first flower was removed to reduce competition and to achieve fruit uniformity.

The parameters leaf area index (LAI), leaf area (LA), leaf number, plant height and dry matter were estimated. The LAI was determined using a previously established model by De Swart *et al.* (2004), which relates the leaf area obtained with the ground area occupied by the plant. The LA was measured on nine occasions, every 5 d, starting day 0 after transplanting, estimating indirectly the individual leaf area, measured by an integrator (LI-COR, Lincoln, NE). The variables leaf number and plant height were recorded on a weekly basis, starting on week two during the 20 weeks of research. The dry matter was estimated biweekly through destructive sampling of 4 plants per treatment, separating the leaves, stems, roots and fruits, which were dried in an oven at 70°C for 48 h.

Assumptions of variance normality and homogeneity were evaluated using InfoSTAT® software (Cary, NC) (statistical package); data that did not present any result once the SAS run was finished were submitted to a Friedman test for the parameters LA and LAI and Kruskall-Wallis test for variables radiation and dry matter in root and stems. Because of the absence of normality of the data, the non-parametric Kruskall-Wallis test was employed. For the variables number of leaves, height, and leaf dry matter, an ANOVA was applied and the differences between the treatments were determined by a Tukey test ($P \leq 0.05$). The statistical package SAS (Statistical Analysis System) v.9.2, was employed.

Results and discussion

Leaf area (LA):

According to the analysis of variance, significant differences between the treatments related to the leaf area were observed within the three hybrids. Figure 1 shows that the treatment with the highest value was 'Orangery', for which 3,299 cm^2 were recorded, significantly higher than 'Plinio' and 'Menta RZ', which measured 2,802 and 2,503 cm^2, respectively. 'Orangery' presented a significant increase after 75 DAT due to the generation of photosynthetic organs for the growth and development of new tissue. The data are similar and agree partially with those registered by Reséndiz-Melgar *et al.* (2010), who reported an LA of 0.25 m^2 at a density of 4 plants/m^2 in hybrids of the purple bell pepper.

Under the study conditions, 'Orangery' had a higher development, with more leaves and a higher formation of structures such as branches and crosses, and showed an ampler foliar expansion and a defined architecture as compared with the other two hybrids 90 DAT. Usually, the leaf surface area is a good indicator of a crop's ability to intercept radiation and a bigger plant canopy captures more photosynthetically active radiation, which determines the LAI and the light absorption of each stratus (Cabezas and Corchuelo, 2005; Vieira *et al.*, 2009). These positive

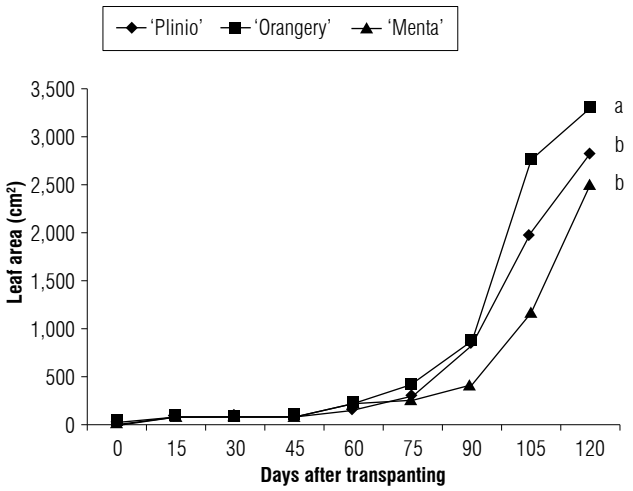

FIGURE 1. Leaf area variation of the three planted paprika hybrids under greenhouse conditions in the Bogota Plateau. Means with different letters indicate significant differences according to the Friedman test ($P \leq 0.05$).

characteristics of the hybrid Orangey, besides its notable color, make it stand out from the other hybrids.

Leaf area index (LAI): This variable showed high nificant differences ($P = 0.0128$) among the three hy Figure 2 illustrates that 'Plinio' and 'Orangery' present a higher LAI, as compared to 'Menta RZ', recording, respectively, values of 3.3, 3.2 and 2.5. Similar results were obtained by Cruz-Huerta *et al.* (2005), imed that the optimum LAI for sweet paprika i twee and 4 in order to achieve maximum growt ues, p t and general performance, a parameter eached the yellow and the orange hybrids.

During the first samples, up to sample n 5, the LAI had a similar behavior performance; fr hen shown in Fig. 2, a significant increase in ' ngey' and io' was noted; this change was attributed existence dichotomous growth and to more leaves a anche these hybrids, unlike the gree Menta RZ', whic ed low bearing, fewer leaves a ittle dichotomous de lop-ment. According to the lts ob ed by Vos and Van der Putten (2001), the size, ion and anopy shape comprise an essential part of a 's ca y to sustain high yields and bi ss production onversion into organisms of ag ltural relevance. Furthermore, the LAI of a crop is c the morpho-physiological characteristic of gr est pr nce in the capture, distribution and utilization of incide radiation. Provides, in addition, parameters to perform y accurate yield estimates and the methodologies for calculating assimilated s ce-demand relationships (DeJong, 1999). Within a c y with a d ed and homogeneous AFI, a correct and p solar r tion distribution is reached, allowing bette f1i , increased photosynthetic efficiency and, hence, hig yields (Lee *et al.*, 2000).

umber: As detected by the ANOVA, significant dif-fe sted between the leaf number developed by the ee hybrids ($P = 0.004$). Figure 3 reveals that 'Orangery' ented a trend of significant increase in this variable over th ther two hybrids, recording an average of 207.2 leaves/plant at 140 DAT; a low average was presented by 'Menta RZ' and 'Plinio', 105.8 and 115 leaves/plant, respectively. These results highlighted the importance of the amount of photosynthetic organs present in a plant, in order to

FIGURE 2. B of the leaf area index for the three color paprika hybrids under gr ouse conditions in the Bogota Plateau. Means with different letters indicate significant differences according to the Friedman test ($P \leq 0.05$).

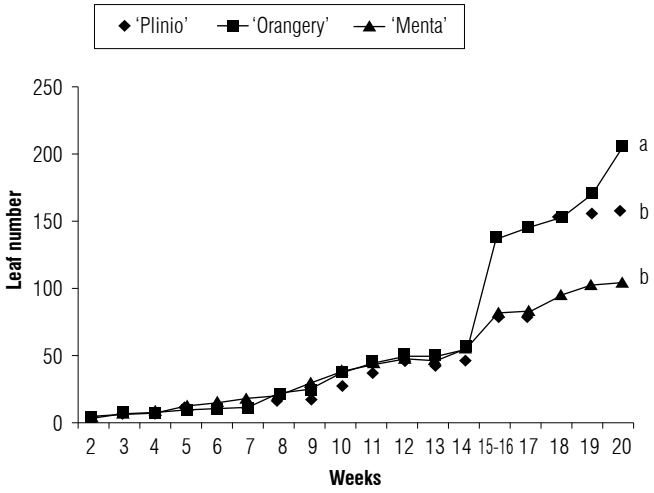

FIGURE 3. Leaf number of the three color paprika hybrids during the 20 week period under greenhouse conditions in the Bogota Plateau. The means with different letters indicate differences according to the Tukey test ($P \leq 0.05$).

potentiate the uptake of sunlight (energy) for the formation and development organs (Vieira *et al.*, 2009). According to Sabater (1977), the higher the energy content, the greater the rate of chemical reactions is.

The hybrid Orangery, of non-determined growth, developed a defined architecture with more leaves, which revealed an inclination for a greater projection of the leaf blade. The inclination, distribution and orientation of the leaf might be important for determining light interception. Cabezas and Corchuelo (2005), noted that, under natural conditions, the amount and quality of light establish continuous production of assimilates, morphogenesis and biological and agronomic performance.

It can be observed that the three hybrids showed a significant increase in leaf production starting with the accumulation of approximately 800 degree-days (°C day) at week 14 (Fig. 3), which coincides with fruit formation and filling. Moreno-Pérez *et al.* (2011) stated that the productivity of plants depends on the physiological activity of the leaves, which is reflected in the fruit filling. Similar results were obtained by Bowen and Frey (2002) when evaluating the effects of staking, drip irrigation frequency and fer... N rate on the dry matter partitioning and yield of bell ... pers, concluding that resources were remobilized from t... leaves to support fruit development.

Height: The statistical analysis indicated ...ant differences between the treatments ($P = 0.0$...). Th... ngation of the stems and branches of the ora... colore... s compared 'Plinio' and 'Menta RZ' (Fi... wed a ... nificant increase from week 14 on, presenti... aximum average height of 60 cm at 140 DAT. 'Pli... and 'Menta RZ' behaved similarly, presenting on... ight of 38.8 and 39.2 cm, respectively. Simi... esults we... nd by Reséndiz-Melgar *et al.* (2010). In th... dy, the aut... reported that bell pepper varieties reach... bserve... this study for 'Orangery', a... verage height ... m/ plant, sown also at a den... of 4 plants/m^2. Ge... rally, increases in plant heigh... icate ... ter competition for light between plants and ... ptake a... d utilization of the available radiation.

Dry matter dis... ution: The behavio... the distribution of assimilate... valuated hybrids can be appreciated in Fig. 5. Th... inal ... tter accumulation in the aerial part of the plants was hig... 'Orangery' (93%), followed by 'Plinio' (91%) and, final... Menta RZ' (90%). High per... indicate greater leaf number, source, and pro... on of photo-assimilates for the filling of demanding o... . The allo... n is regulated within the source leaves, base... control ... nts, which are enzymes, that allow either th... per... n of intermediaries for the Calvin-Benson cycle ... arch synthesis or sucrose synthesis, its division in temporary storage centers, and its transport ... ng distances (Bustan *et al.*, 1996; Thornley and Can... Also, 'Orangery' showed a lower percentage of ... al leaf dry matter, whereas the demanding organs, the ... ts, occupied the highest value, distinguishing again and fa... ing this hybrid.

A similar behavior can be appreciated regarding the final amount of stem dry matter (DM) for the evaluated hybrids (Fig. 5). The opposite occurred in the accumulation of leaf

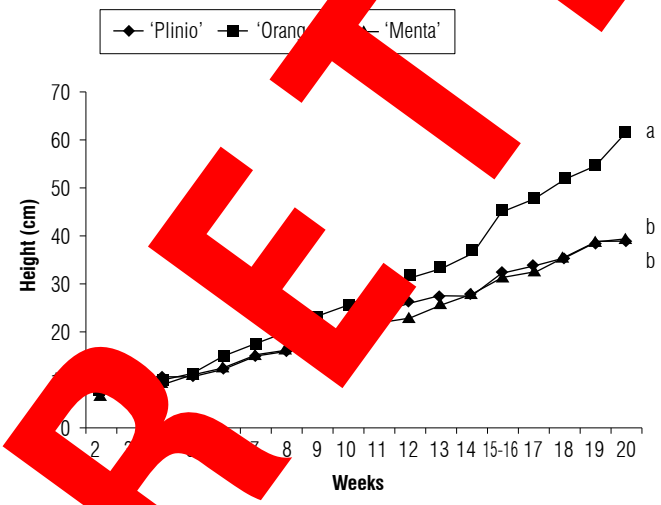

FIGURE 4. F... ight reached by the color paprika hybrids during the 20 weeks unde... nhouse conditions in the Bogota Plateau. Means with different letters indicate significant differences according to the Tukey test ($P \leq 0.05$).

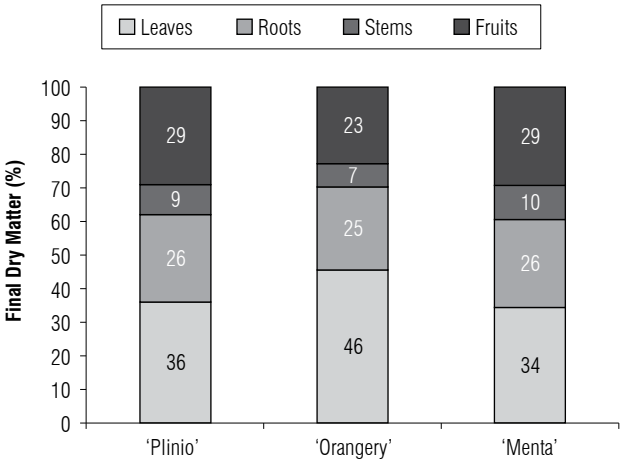

FIGURE 5. Final percentage of accumulated dry matter distribution in different organs: leaves, stems, roots and fruits, for each evaluated colored paprika hybrid under greenhouse conditions in the Bogota Plateau.

DM, registering the highest percentage of 29% in 'Plinio' and 'Menta RZ', while 'Orangery' presented 23%. The cumulative percentage of DM was higher in the 'Orangery' fruits, as compared to the other hybrids. Magán *et al.* (2007), in a study of paprika production in multi-tunnel cover in a greenhouse, found that the final dry matter in leaves, stems and fruits at 102 DAT was 29, 28 and 46%, respectively, similar results as those obtained in this research.

Allocation refers to the way the photosynthetic products are dedicated to meet the different metabolic processes and peculiar needs of the plant development. The distribution or redistribution concerns the mechanism for equitable and successful division ofthe earned resources for each demanding organ, whether they are tissues, cells, subcellular compartments or more complex organic systems (Komor, 2000).

Dry matter in the leaves, stems and roots: According to the ANOVA, no statistical differences were detected within these parameters between the three evaluated hybrids (P = 0.91; P = 0.4419; P = 0.0229 for Orangery, Plinio and Menta RZ, respectively). The content of DM in the leaves was similar in the hybrids up to sample number 5, which coincided with the flowering stage. 'Orangery' increased leaf DM, as compared to the other hybrids, and also presented the highest final value, followed by 'Plinio' and 'Menta RZ', registering 57.1, 51.8 and 44.5 g, respectively. Peil and Galvez (2005) stated that initially, a newly unfolded leaf behaves more like a demand organ, importing assimilates from other similar leaves, until it reaches 50% of its final size, gradually decreasing import and increasing carbon export. When a leaf has reached its full expansion and presents the maximum photosynthetic activity, it is basically a source organ or exports assimilates.

Assimilates produced by photosynthesis in the source organs, mainly leaves, are distributed via phloem between a plant's sink organs. In order to obtain an accelerated initial growth of young plants, a substantial increase in the leaf surface at this stage is essential because a large fraction of incident solar radiation is not intercepted by the leaves (Peil and Galvez, 2005). Photosynthetic and radiation use efficiency, expressed in the absorptivity of leaves, depend largely on the leaf-angle distribution, as mentioned by Vieira *et al.* (2009).

In respect to stem dry matter, 'Orangery' at 75 DAT, showed the highest accumulation, indicating the presence of greater carbohydrate demands. This hybrid revealed a higher number of branches, leaves, flowers and fruits, contrary to 'Plinio', which registered less dry matter due to the scares presence of branches and internodes and lower stem thickness. Dry matter production is the result of the efficiency of crop canopy interception and the use of radiation available during the growth cycle (Vieira *et al.*, 2009; Gardner *et al.*, 2010).

All three hybrids exhibited similar behavior for the root biomass accumulation, presenting approximately 9% of the dry matter. Somos (1984) stated that the weight of the root system corresponds only to 7-17% of the total plant weight, depending on the varietal type and culture conditions. Roots often make up only a small fraction of the total dry matter of crops grown under greenhouse conditions (Peil and Galvez, 2005); growth and root development is regulated by temperature, with roots and stems having different temperature thresholds and root growth occurring at temperatures above 7°C.

According to Tab. 1, there was a higher performance for hybrid Orangery, as compared to the other materials, presenting the highest number and weight of fruits per plant, reaching the highest yield per area 4.1 kg m^{-2}. Therefore, in this study, we can state that the hybrid Orangery increased photosynthetic capacity due to its greater leaf development; hence, it will be more productive, similar results were reported by Moreno-Pérez *et al.* (2011) for the hybrid Magno orange paprika epidermis, presenting a final yield of 5.7 kg m^{-2}. Casilimas *et al.* (2012) argued that the yield of a crop is determined by environmental factors, such as radiation, efficiency of biomass production and biomass fraction, which distributes the organs of interest.

Conclusions

Based on the results obtained under the greenhouse conditions of this research, it was concluded that the best option

Table 1. Performance components for hybrid colored peppers until the first harvest when 40% of the fruits showed the typical color of maturity.

Parameter	'Plinio'	'Orangery'	'Menta RZ'
Average fruit weight (g/fruit)	73	92	78
Average number of fruits/plant	6	12	5
kg/plant	0.438	1,104	0.390
kg m^{-2}	3.2	4.1	3.9

for commercial colored bell peppers is the hybrid Orangery, specifically taking into account the highest fruit dry matter, a total of 46%, as compared to the other varieties. However, before starting mass production of this colored bell pepper, its real productivity has to be established, as well as consumer preferences for any of the available fruit colors. Frank *et al.* (2001) conducted a conjoint analysis in the United States, which, besides other items, revealed a consumer preference for green fruits. A similar result could be obtained in Colombia.

Cited literature

Agarwal, A., S. Gupta, and Z. Ahmed. 2007. Influence of plant densities on productivity of bell pepper (*Capsicum annuum* L.) under greenhouse in high altitude cold desert of Ladakh. Acta Hortic. 756, 309-314.

Bowen, P. and B. Frey. 2002. Response of plasticultured bell pepper to staking, irrigation frequency, and fertigated nitrogen rate. HortScience 37, 95-100.

Bustan, A., E.E. Goldschmith, and Y. Erner. 1996. Carbohydrate supply and demand during fruit development in relation to productivity of grapefruit and 'Murcott' mandari... Hortic. 416, 81-88.

Cabezas, M. and G. Corchuelo. 2005. Estimación de la interc... tación de la radiación solar en papa criolla (*Solanum phureja*... Juz. et Buk.) en tres localidades colombianas. Agron. Colomb. 23, 62-73.

Cadahía L., C. 2005. Fertirrigación: cultivos ...ticos ...ornamentales. 3rd ed. Ediciones Mundi-Prens... Madrid.

Casilimas, H., O. Monsalve, C.R. Bojacá, R. ...agrán, ... Arias, and L.S. Fuentes. 2012. Manual de p...ción de pimentón bajo invernadero. F...dación Universi... Bogotá Jorge Tadeo Lozano, Bogo...

Cautín, R. and M. Agustí. 20... ological growth stages of the cherimoya tree (*Ann... che...* Mill.). Sci. Hortic. 105, 491-597. Doi: 10.1016/j.scienta.200...5

Cebula, S. 1995. Optimization of plant and sh... acing in greenhouse produ... of sweet pepper. Acta Hortic. 412, 321-329.

Cruz-Huerta, N... Ortiz-C...eceres, F. Sánchez del Castillo, and M.C. Me... Cas... 2005. Biomasa e índices fisiológicos en chile mor... vados en ...s densidades. Rev. Fitotec. Mex. 28, 287-293.

Daşga... H.Y. and K. Abak. 20... cts of plant density and number ...on yield and fruit characteristics of pepper grown in glassh... es. Turk. J. Agric. For. 27, 29-35.

... T... 199... lopmental and environmental control of ...tter partit...ing in peach. HortScience 34, 1037-1040.

De Swart, ... R. Groenwold, H.J. Kanne, P. Stam, L.F.M. Marcellis, an... Voorrips. 2004. Non-destructive estimation of leaf area for different plant ages and accessions of *Capsicum annum* L. J. Hortic. Sci. Biotech. 79, 764-770.

Frank, C.A., R.G. Nelson, E.H. Simonne, B.... he, and A.H. Simonne. 2001. Consumer preference... ice, and vitamin C content of bell peppers. H... cience 3... 800.

Gardner, F.P., R.B. Pearce, and R.L. Mit... 010. Physio... f crop plants. Scientific Publishers Journa... t., Londo...

Ghasemnezhad, M., M. Sherafati, and G.A. Payv... 11. V...a-tion in phenolic compoun... scorbic acid and ...ant activity of five coloured b... epper (*Capsicum annu...* fruits at two different harves... es. J. F... Foods 3, 44-49. Doi: 10.1016/j.jff.2011.02.00...

Hallmann, E. and E. Rembiałko... 012. Ch... terization of antioxidant com...pounds in swee... e... (*Capsicum annuum* L.) und... ganic and conven... owing systems. J. Sci. Food A... 92, 2409-2415. Doi: 10.1...02/jsfa.5624

Jovicich, E.J., ... fe, and J.J. VanSickle. 2004. U.S. imports of colore... bell pe... nd the opportunity for greenhouse production of pepper... rida. Acta Hortic. 659, 81-85.

Komor, E. 2000. Source physio... nd assimilate transport: the ...tion of sucrose metabolism, starch storage and phloem ...p... in source leaves and the effects on sugar status in phloem. Aust. J. Plant Physiol. 27, 497-505.

Le... V., S.F. Ob... r, P. Johnson, B. Krishnapilay, M. Mansor, ...hamad, a... S.K. Yap. 2000. Effects of irradiance and spe... ality ...leaf structure and function in seedlings of two Sou... an *Hopea* (Dipterocarpaceae) species. Amer. J. Bot. 87, 447-455. Doi: 10.2307/2656588

...án, J.J., J.C. López, A. López, and J. Pérez-Parra. 2007. Micro... y producción de materia seca de un cultivo de pimiento e... naderos con cubierta de plástico y cristal en el sureste español. Series Las Palmerillas. Publicaciones de Cajamar Caja Rural, Almeria, Spain.

M... rejo, L.M., F. Rodríguez, M. Giraldo, G. Cardona, M. Celis, J. Arias, M. García, L. Quintero, M. Cudris, S. Toquica, I. Monroy, M. Rodríguez, M. Duque, and J. Tohme. 2004. Caracterización de accesiones del banco de germoplasma de la región amazónica colombiana. pp. 13-27. In: Melgarejo, L.M., M.S. Hernández, J.A. Barrera, and X. Bardales (eds.). Caracterización y usos potenciales del banco de germoplasma de ají amazónico. Instituto Amazónico de Investigaciones Científicas-SINCHI, Bogota.

Montes-Hernández, S., E. Heredia G., J. Alfonso, and A. Gómez. 2004. Fenología del cultivo del chile (*Capsicum annuum* L.). pp. 43-47. In: Memorias de la Primera Convención Mundial del Chile 2004. Consejo Nacional de Productores de Chiles, Leon de los Aldama, Mexico.

Moreno-Pérez, E.C., R. Mora-Aguilar, F. Sánchez-Del Castillo, and V. García-Pérez. 2011. Fenología y rendimiento de híbridos de pimiento morrón (*Capsicum annuum* L.) cultivados en hidroponía. Rev. Chapingo Ser. Hortic. 17, 5-18. Doi: 10.5154/r.rchsh.2011.17.041

Mundarain, S., M. Coa, and A. Cañizares. 2005. Fenología del crecimiento y desarrollo de plántulas de ají dulce (*Capsicum frutescens* L.). Rev. Cient. UDO Agric. 5, 62-67.

Paschold, P.-J. and K.-H. Zengerle. 2000. Sweet pepper production in a closed system in mound culture with special consideration to irrigation scheduling. Acta Hortic. 458, 329-334.

Peil, R.M. and J.L. Galvez. 2005. Reparto de materia seca como factor determinante de la producción de las hortalizas de fruto cultivadas en invernadero. Curr. Agric. Sci. Technol. 11, 5-11.

Reséndiz-Melgar, R.C., E.C. Moreno-Pérez, F. Sánchez-Del Castillo, J.E. Rodríguez-Pérez, and A. Peña-Lomelí. 2010. Variedades de pimiento morrón manejadas con despunte temprano en dos densidades de población. Rev. Chapingo Ser. Hortic. 16, 223-229.

Sabater, F. 1977. La luz como factor ambiental para las plantas. An. Univ. Murcia 31, 1-24.

Silva Filho, D.F. da, M.C. Oliveira, L.H.P. Martins, H. Noda, and F.M. Machado. 2004. Diversidade fenotípica em pimenteiras cultivadas na Amazônia. Hortic. Bras. 22(suppl 2), 459-460.

Somos, A. 1984. The paprika. Akademiai Kiados, Budapest.

Soto-Ortiz, R. and J.C. Silvertooth. 2008. A crop phenology model for irrigated New Mexico chile (*Capsicum annuum* L.) type varieties. Vegetable Report P-152. College of Agriculture and Life Sciences, The University of Arizona, Tucson, AZ.

Soto-Ortiz, R., J.C. Silvertooth, and A. Galadima. 2006. Crop phenology for irrigated chiles (*Capsicum annuum* L.) in Arizona and New Mexico. Vegetable Report. College of Agriculture and Life Sciences, The University of Arizona, Tucson, AZ.

Sun, T., Z. Xu, C.-T. Wu, M. Janes, W. Prinyawiwatkul, and H.K. No. 2007. Antioxidant activities of different colored sweet bell peppers (*Capsicum annuum* L.). J. Food Sci. 72, 98-102. Doi: 10.1111/j.1750-3841.2006.00245.x

SOL, The International Solanaceae Genome P... 2004. SOL white paper. In: www.sgn.cornell.edu... roject/; consulted: May, 2015.

Thornley, J.H.M. and M.G.R. Cannell. 20... odelling the ... ponents of plant respiration: represen... and real... Ann. Bot. 85, 55-67. Doi: 10.1006/anbo.199... 10.1.../anbo.2000.1168

Torres R., E. 2009. Agromet... logía. 3th ed. Editorial ...rillas, Mexico DF.

USDA, United States Departm... ...ulture. 2010. Processing chile pepper pilot loss adjust... ...tandard... ...ndbook 2011 and succeeding ...rop years. FCIC... ...HILE PEPPER). Washington D...

Vieira, M.I., J.P. ...lo-Abreu, M.E. Ferreira, and A.A. Monteiro. 2009. Dr... ...d area partitioning, radiation interception and ...adiation... ...fficiency in open-field bell pepper. Sci. Hortic. 121, 404-4... 10.1016/j.scienta.2009.03.007

Vos, J. and P.E.L. Van der Putte... ...01. Effects of partial shading ...potato plant on photosynthesis of treaded leaves, leaf ...rea... ...xpansion and allocation of nitrogen and dry matter in ...components pl...nts parts. Eur. J. Agron. 14, 209-220.

Wu... ...C.E., J.R. F... ..., and K. Phelps. 2002. Crop scheduling and p... ...ion - prin... ...es and opportunities with field vegetables. Adv... ...76... ...-234. Doi: 10.1016/S0065-2113(02)76006-9

Notice of the article retraction

The present article, "Growth of three color hybrids of sweet paprika under greenhouse conditions - Crecimiento de tres híbridos de pimentón de colores en condiciones de invernadero" with Doi: https://doi.org/10.15446/agron.colomb.v33n2.49667 and authors appearing as Fernando Javier Peña Baracaldo and Ingeborg Zenner de Polanía, has been retracted by the Editor-in-Chief on August 16th 2021 as it was found to violate the author's rights and intellectual property rules.

The article´s retraction was implemented following the terms of the Fiscal 75 Delegado para el Circuito expressed in his communication dated August 12th, 2021. Consequently, Agronomia Colombiana informs all readers and users that the above-cited article has been retracted. Agronomía Colombiana strongly disapproves of any activity that leads to violation of the author's rights and always encourages its users to do the same.

Stanislav Magnitskiy, Editor-in-Chief