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Phenological Characterization and Productivity of the *Physalis peruviana* L., Cultivated in Greenhouse

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Abstract

The *Physalis peruviana* L. presents great nutritional value and economic viability, becoming an alternative for the small and medium producer and an innovation for the Brazilian horticulture. However, some information on cultivation, are still scarce. In this context, our objective is to characterizing the phenological phases and productivity of the *Physalis peruviana* cultivated in a greenhouse in the semiárido paraibano. This work was done in the experimental farm of the Federal University of Campina Grande, campus Pombal, Paraíba. The experiment was driven in a randomized blocks design, with five repetitions, each repetition constituted of five plants. The phenological phases were determined through the height, diameter of the stem, number of leaves, floral buttons, flowers and fruits per plant, production and productivity. The data were submitted to the variance analysis and polynomial regression. The vegetative phase of the *Physalis peruviana* L. is concluded in a period understood among 32 to 45 days after the transplant (DAT) and the reproductive phase extends until 161 DAT. In the conditions of the semiarid, the crop of the fruits of the *Physalis peruviana* L. begins to 71 DAT, with a dear productivity of approximately 2 340.95 kg ha^{-1}.

Keywords: phenophases, fisális, production, solanaceae

1. Introduction

The *Physalis peruviana* L. belongs to the family Solanaceae, known commonly as camapum, fisális or juá-de-capote It is being incorporate on the group of small fruits with high productive potential for tropical and subtropical areas, and gaining interest for the commercialization in natura and processing of fruits for presenting great nutritional value and economical attaché to all the parts of the plant (Novoa, Bojacá, Galvis, & Fischer, 2006; L. Rufato, A. Rufato, Schlemper, Lima, & Kretzschmara, 2008). The production cost is accessible to the small producers, due to its cultivation to occupy small areas and to possess an economical return considerably high (Lima, Gonçalves, Tomaz, Fachinello, & Rufato, 2010). For these reasons, this species is being seen as an excellent alternative to the small and medium rural producer (Rufato et al., 2008).

In Brazil, the *P. peruviana* is consumed as a fine fruit and produced on a small scale. However, it presents potentialities of nutritional and pharmacological interest for possessing natural bioactive substances, low acidity, a considerable tenor of ß-carotene, vitamin C and soluble solids, carotenoids, flavonoids, fisalinas, terpenes, besides it presents beneficial antibacterial activities to the man's health (Lopes, Freitas, Santos, & Tomassini, 2006; Licodiedoff, Koslowski, & Ribani, 2013).

The study of the phenological behavior determines, systematically, the repetitive biological events (phenophases) and relationship with the changes in a biotic way and abiotic. Therefore, the study measures the phases of the visible development of the vegetables, from the germination of the seeds, emission of leaves, flowers and fruits until the senescence of these organs (Calle et al., 2010). The phenological dynamics of the vegetable species is indispensable for the elaboration of conservation strategies and handling of these species (Falcão, Clemente, & Gomes, 2003).

The information on the phenology of a culture is so much important to recommend a new cultivation in a certain area, as well as to determine the climatic conditions in that the species grows better, reducing the failure risks significantly in the field (Antunes, Gonçalves, Ristow, Carpenedo, & Trevisan, 2008).

In Brazil, some studies were accomplished seeking the phenological characterization of the *Physalis peruviana*, however, these works have been accomplished mainly in the South area of the country (Rufato et al., 2008; Rodrigues, Penoni, Soares, Silva, & Pasqual, 2013; Betemps, Fachinello, Lima, Galarça, & Rufato, 2014). Studies on phenological aspects of this species, in the other areas of Brazil, are still incipient. In this context, it was our objetived to characterize the phenology and productivity of the *Physalis peruviana* L. cultivated in a greenhouse in the semi-arid region of Paraiba.

2. Material and Methods

2.1 Location and Experimental Conduction

The experiment was developed in a greenhouse, in the Experimental Farm of the Federal University of Campina Grande, campus Pombal, located in São Domingos' city, located to west of Paraíba (PB), with coordinates of 6°48′41.7″ S of latitude and 37°56′13.8″ W of longitude, to 190 m of altitude. According to the climatic classification of Köppen, adapted Brazil (Coelho & Soncin, 1982), the climate is of the type BSh, representing climate hot and dry semi-arid, with medium precipitation from 700 to 900 mm year^{-1}, annual medium temperature of 26.1 °C and annual medium evaporation from 1000 to 1100 mm (Francisco & Santos, 2017).

The extracted seeds of fruits were used on complete maturation and properly healthy, acquired commercially in João Pessoa-PB. The fruits were open with aid of a blade of bistoury no. 15 and the seeds were extracted manually, washed in running water under a sieve and disinfected with a solution to 2% of sodium hypochlorite solution for five minutes, for the elimination of pollutants and stayed for 30 minutes on a leaf of paper towel to eliminate the excess of water.

The sowing was done to 0.5 cm of depth, in polypropylene containers with capacity of 50 ml, properly perforated, filled out with commercial substratum Basaplant®, whose chemical characteristics are in Table 1. The seedlings were conditioned in a greenhouse, with dimensions of 24 × 10 × 3.5 × 4.5 m (length, width, right foot and central height, respectively) and covering in diffuser film of 120 micronsof thickness with anti-UV additives. They were irrigated three times a day, with aid of a watering can, being transplanted later for plastic vases, when they presented four definitive leaves, what happened to 30 days after the sowing.

Table 1. Chemical and physical composition of the substrate used in the production of seedlings (SPM) and in the cultivation (SCV) of the *Physalis peruviana* L., UFCG, Pombal, PB, 2017

	pH	P	$S\text{-}SO_4^{-2}$	K^+	Na^+	$H^+{+}Al^{+3}$	Al^{+3}	Ca^{+2}
	Water(1:2.5)	--------- mg dm^{-3} --------		---------------------------- cmol$_c$ dm^{-3} ----------------------------				
SPM	5.5	257.30	-	2.00	0.43	8.57	0.05	2.69
SCV	7.4	733.39	-	2.73	1.20	0.00	0.00	1.23
	Mg^{+2}	SB	CTC	M.O.	Sand	Silt	Clay	Class textural
	------------------ cmol$_c$ dm^{-3} ------------------			--------------------- g kg^{-1} ---------------------				
SPM	1.46	3.89	12.46	233.51	878	113	9	-
SCV	1.09	6.25	6.25	10.34	789	155	56	Frank sandy

Note. P, K, In the: Extractor Mehlich 1; SB: Sum of Exchangeable Bases; H + Al: Extractor Acetate of Calcium 0.5 M, pH 7.0; CTC: Capacity of Troca Cationic; Al, Ca, Mg: Extractor KCl 1 M; M.O. (Organic Matter): Walkley-Black.

25 vases were used, and a plant was added per vase. The same ones had capacity for 12 L, with a hole in the base and were filled out initially with 200 g of no. 1 and 10 substratum dm^3 composed of soil, polishes and manure, in the proportions 2:1:1, whose chemical characteristics and physics are presented in Table 1.

The irrigation was performed with the methodology of lizimetry drainage with aid of the following formulates: Vi = (Va – Vd)/(1 – FL), Where, Vi = Volume to be irrigated; Va = applied Volume; Vd = Volume drained after 24 hours of the application; FL = Leaching factor (10%).

The water volume was applied according to the capacity of the initial field, and based on the equation above, during the whole transport of the experiment, only the not drained volume was applied, keeping the soil close to the field capacity.

The chemical corrections of the substrate used in the vases were done after the transplant, being taken as a base the recommendations for the culture of the tomato (Filgueira, 2003; Thomé & Osaki, 2010) and the results of the chemical analysis of the substrate. Applications of $MgSO_4 \cdot 4H_2O$ and $CaSO_4$ were performed (1 Mol L^{-1}) to the 21 and 35 days after the transplant (DAT), using 1.5 ml soil dm^{-3}, and two applications of mixed fertilizer containing N, P, K, Ca and S (10, 10, 10, 4 and 11%, respectively) to the 28 and 42 DAT using 1.5 g soil dm^{-3}. As covering died, each vase received 100 g of the pulp of gram, dried and triturated, seeking to maintain the humidity and temperature of the soil.

The position of the cultivation line adopted in the experiment was East-west, with five rows, spaced 1,5m between lines and 1.0 m among plants. The system of transport of the plants was in espalier, with two main branches, being used three threads of galvanized wire, distanced 0.5 m of height, counting from the border of the vase, aligned longitudinally, for the correct tutoring of the branches (Muniz et al., 2011). For that, formation prunings were accomplished starting from 0.45 m of height and biweekly sprout thinning of the lateral branches.

The phytosanitary treatments happened through pulverizations with insecticides of the neonicotinoid (1 g L^{-1}) and avermectins (0.5 mL L^{-1}) chemical groups, through pulverizers manualy load, for the control of whitefly (*Bemisiaargentifolii*) and red acarid (*Tetranychusurticae*), respectively. Weedings manuals were accomplished in the vases to avoid the competition with the main culture. When observed the beginning of the anthesis, the plants were agitated manually to stimulate the self-pollination. The temperature and medium relative humidity registered during the transport of the experiment were of 30 °C and 58%, respectively.

2.2 Analyzed Variables

Height of the plant: measure between the lap of the plant and the located yolk in the extremity of the highest branch, through a graduate tape measure in centimeters and fastened in a pipe of rigid PVC. The results were expressed in centimeters;

Diameter of the stem: determined starting from the level of the soil, in the lap of the plant, with aid of digital pachymeter and the results expressed in millimeters;

Number of leaves: quantified starting from the first leaf of the inferior part, until the apical meristem of the last branch. It was considered just those that presented the limbo totally expanded;

Number of floral buttons, flowers and fruits: accomplished through countings of the total number of variables per plant;

Production and the productivity: they began starting from the 77 to 168 DAT, being considered with base in the number of fruits picked by each plant. For the production, the values were expressed in g.plant^{-1}. For productivity, was taken into account the spacing adopted in the experiment. The results were expressed in Kg ha^{-1} and regarded in agreement with the equation: Productivity = (production of plant (Kg) x 10.000 m^2)/(area occupied by plant).

2.3 Design Experimental and Analyze Statistics

The experiment was driven in a randomized blocks design, with five repetitions, constituted of five plants in each repetition. The data were submitted to the variance analysis and polynomial regression, making use of the statistical program SISVAR (Ferreira, 2014).

3. Results and Discussion

In Figure 1, the occurrence of the different phenological phases of the *Physalis peruviana* is observed cultivated in a greenhouse, in function of the evaluation periods after the transplant. It can be verified that the vegetative phase presented larger duration in relation to the other phases, being concluded among 10 to 143 days after the transplant (DAT). The reproductive phase, that involves the flowering stages and fructification, consisted of the period from 30 to 154 DAT, with the crop of the ripe fruits accomplished when the chalice and the fruit presented orange coloration, accomplished starting from 71 DAT, being prolonged until 161 DAT. Rodrigues et al. (2013) and Silva (2017), evaluating the phenology and the productivity of the *Physalis peruviana* cultivated in a greenhouse, also observed that the reproductive phase presented larger duration when compared with the vegetative phase.

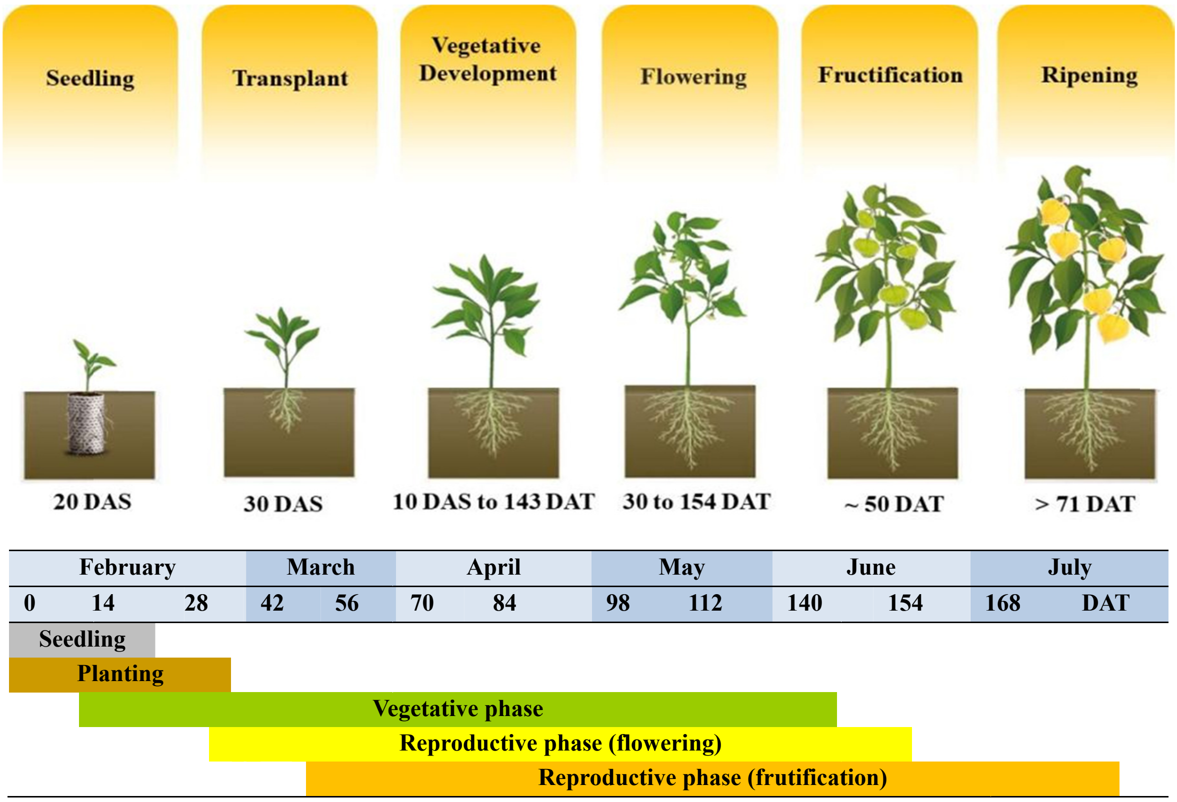

Figure 1. Phenological behavior of the *Physalis perunviana* L., cultivated in a greenhouse, in function of the evaluation periods after the transplant, UFCG, Pombal, PB, 2017

Note. DAS: days after the sowing; DAT: days after the transplant.

The height of the plant of *P. peruviana* increased gradually in function of the days after the transplant with quadratic tendency, reaching maximum values of 125 cm to 143 DAT (Figure 2A), presenting biomass accumulation during the normal growth which demonstrates that the species presents adaptability to the conditions in which the experiment was executed, where temperatures of 30 °C and humidity varying from 58 to 65% were registered.

In agreement with Lima (2009), the cultivation of the *Physalis peruviana* under high temperatures (approximately 30 °C) tends to favor its growth. According to Miranda (2005) in favorable conditions of temperature and humidity (±20 °C and ±70%), the *Physalis peruviana* presented fast increase in height for a period of 130 DAT, following by slow growth due to formation of flowers and fruits. Silva (2017), evaluating the phenology of the *Physalis peruviana* under different saline concentrations, cultivated in the climatic conditions of the semiarid of Paraíba in a greenhouse, verified maximum height of 120 cm to 120 DAT. N. Peixoto, C. Peixoto, Vaz, Neri, and Monteiro (2010), studying the growth and the production of the *Physalis pubescens* in response to the organic manuring, cultivated in a field in the State University of Goiás, verified that to 79 DAT the plants reached 120 cm of height, when fertilized with 30 t ha^{-1} of corral manure, which, associated with the climatic conditions of the area, might have favored the fast growth of the plants.

Analyzing the diameter of the stem, quadratic behavior was observed in function of the evaluation periods after the transplant, reaching maximum values of 15.24 mm to 135 DAT (Figure 2B). This increase is consequence of the modifications that happen in the stem in development, which changes from primary structure to secondary structure of development, in function of the appearance of secondary meristem that promotes the growth of the stem in thickness for the deposition of new woven and accumulations of reservations in the same ones. According to Muniz, Marchi, Coldella, Rufato, and Kretzschmar (2015) in the measure in that the plant grows and grows, the diameter of the stem tends to increase, however, this happens in a gradual way. These same authors, evaluating the vegetative growth and the productive potential of the *Physalis peruviana* in Lages, Santa Catarina, observed maximum value for the diameter of 13.92 mm to 210 DAT.

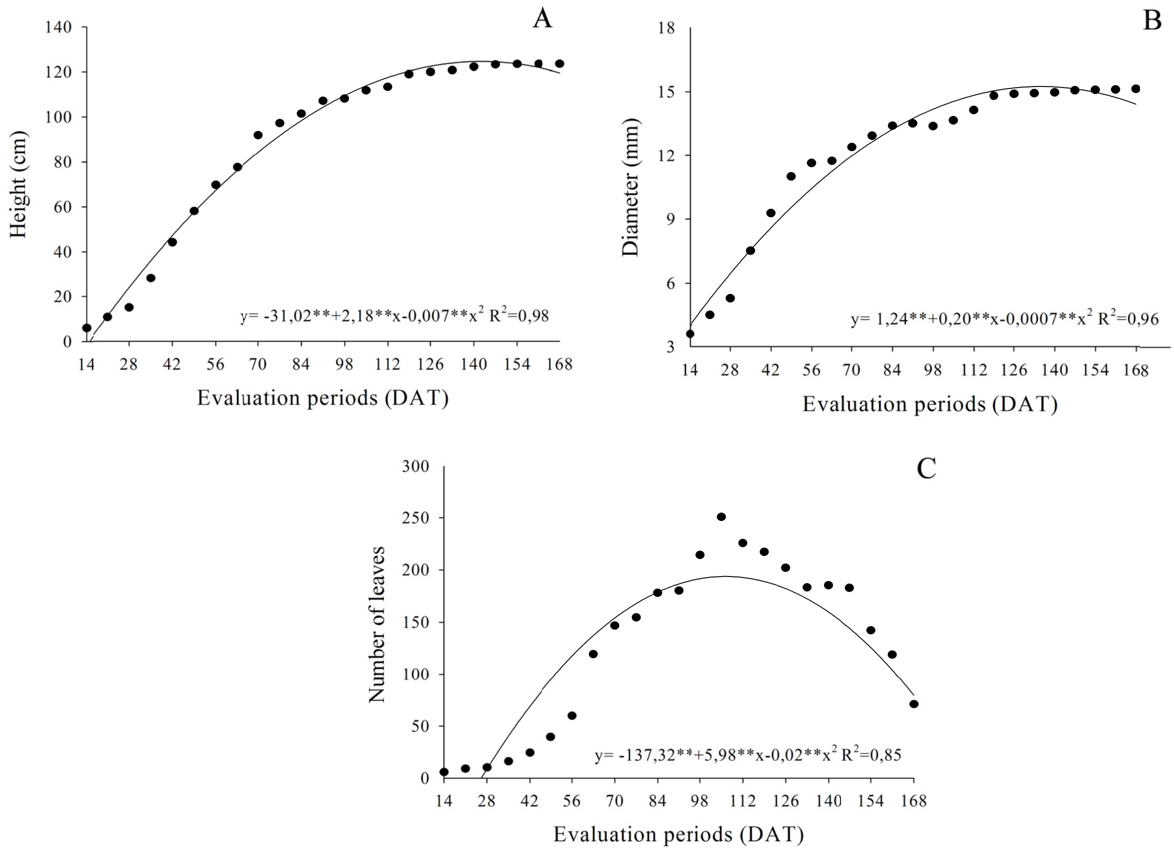

Figure 2. Height (A); diameter of the stem (B) and number of leaves (C) of the plants of the *Physalis peruviana* L., cultivated greenhouse, in function of the evaluation periods after the transplant, UFCG, Pombal, PB, 2017

In the number of leaves of *P. peruviana*, quadratic behavior was verified with maximum values of 197 leaves by plant to 112 DAT (Figure 2C). That result is superior to the observed by Silva (2017), that when studying the phenological behavior of the *Physalis peruviana* in the climatic conditions of the semi-arid of Paraíba, verified maximum value of 108 leaves for plant to 90 DAT. Rodrigues et al. (2013), verified that the increase in the number of leaves of the *Physalis peruviana* happened in a growing way in function of the days after the transplant, reaching observed maximum of 169.54 leaves for plant to 102 DAT, when cultivated under maximum temperature of 33.2 °C and low of 7.6 °C, in the South area of Minas Gerais.

Reduction to the number of leaves was observed after 112 DAT, being prolonged until the end of the appraised period (Figure 2C). That decrease happened due tosenescence of the leaves, due to the translocation of photoassimilates for the drains of the plant. According to Zapata, Saldarriaga, Londoño, and Diaz (2002) the species presents a natural tendency of senescence and fall of the leaves, when there is the process of maturation of fruits.

The behavior of the *P. peruviana* in the different stages of reproductive development, from the appearance of the floral button to the formation of the fruit is in the Figure 3.

The reproductive phase of the *P. peruviana* was characterized with the appearance of the floral buttons in the armpit of each knot (Figure 3A), starting from this moment it was observed the development of two leaves, a vegetative one and other floral one to 30 DAT. About the 31 to 32 DAT, the swell of the floral button was observed (Figure 3B), starting the pre-anthesis phase (Figure 3C) and anthesis (Figure 3D) of the 33 to the 35 DAT. In similar conditions, Silva (2017), analyzing the phenological behavior of the *Physalis peruviana*, in the climatic conditions of the semi-arid of Paraíba, verified that the first floral buttons appeared to 33 DAT. However, Rodrigues et al. (2013), studying the phenology and the productivity of the *Physalis peruviana* cultivated in a greenhouse in Lavras, Minas Gerais, they observed emission of floral buttons to 25 DAT.

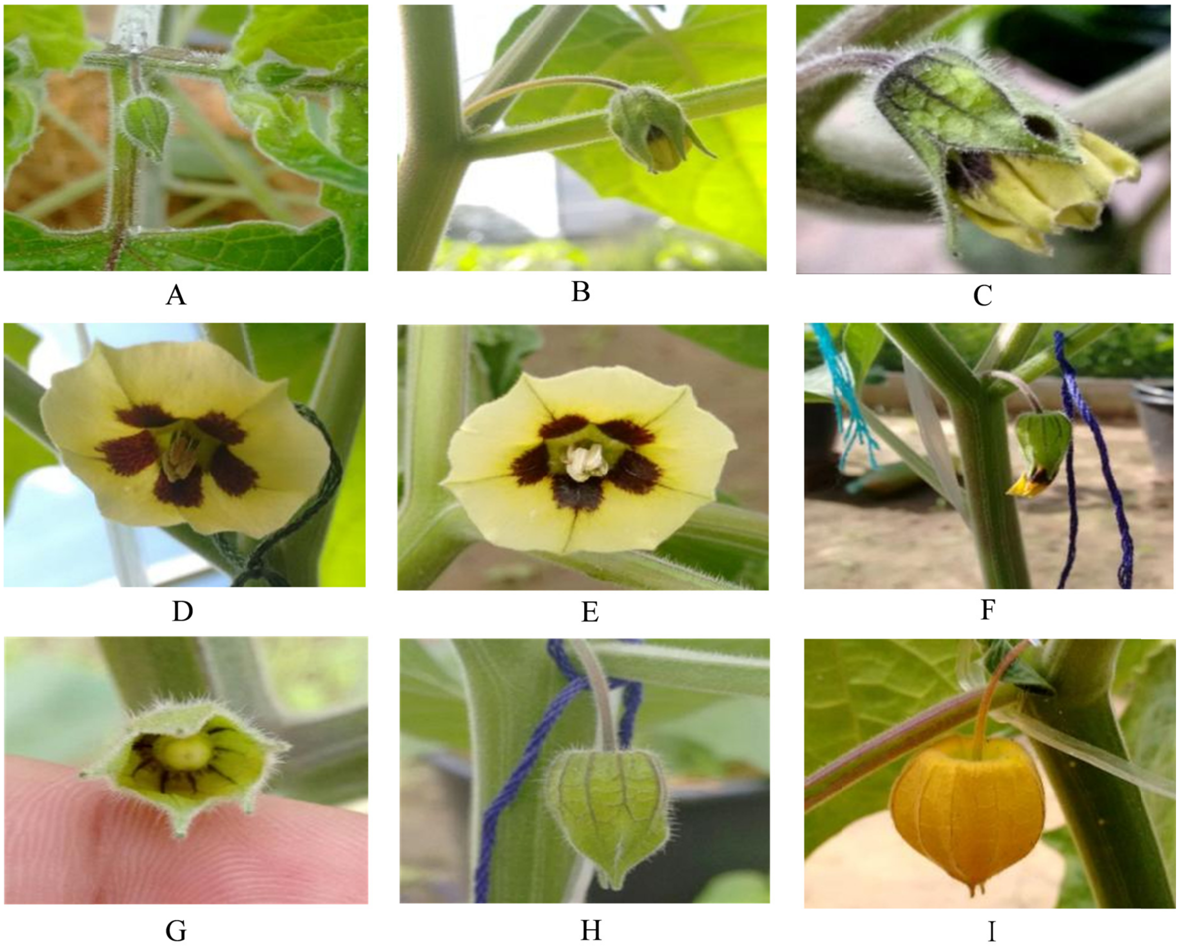

Figure 3. Different phases of the reproductive development of the *Physalis peruviana* L., cultivated greenhouse: floral button (A); button floral swollen (B); floral button in pre-anthesis (C); anthesis (D); flowering (E); formation of the fruit (F); after anthesis (G); green fruit (H) and ripe fruit (I), UFCG, Pombal, PB, 2017

The flower of the *Physalis peruviana* presents corollapentamas of yellow coloration with purple center (Figure 3E) which open completely to 35 DAT. However, Rodrigues et al. (2013), verified that the stigma of the flowers of *P. peruviana* is placed to the same height of the anthers, favoring the self-pollination in a greenhouse. The after anthesis stage was characterized by the closing and fall of the petals (Figure 3F) and subsequent beginning of the formation of the fruit (Figure 3G) among 36 and 37 DAT, developed protected by the chalice, increases the coloration green when immature (Figure 3H) and orange when they reach maturity (Figure 3I) starting from 71 DAT.

When evaluating the behavior of the *Physalis peruviana*, under different saline concentrations of the irrigation water, cultivated in a greenhouse in the semi-arid region of Paraíba, Silva (2017) verified that the first manifestations regarding reproductive phase started with the appearance of the floral buttons to 33 DAT with pre-anthesis and anthesis phases happening about 33 and 36 DAT, respectively.

The number of floral buttons in the plants of the *Physalis peruviana* counted along the evaluation periods is in the Figure 4A. It was observed that the data were adjusted to a quadratic equation, reaching maximum value of 20 floral buttons per plant to 83 DAT, starting from when happened gradual and continuous decline in the number of floral buttons along the other evaluation periods, getting to interrupt emission completely to 154 DAT, characterizing the execution of a productive cycle of the *Physalis peruviana*, in the conditions of the semi-arid region of Paraíba. Values inferior were observed for Rodrigues et al. (2013) that evaluate the phenology of the *Physalis peruviana*. Were observed maximum values of 15.86 floral buttons per plant to 57 DAT, reducing to 13.06 to 72 DAT, when cultivated in a greenhouse in the environmental conditions of the area of Lavras, MG.

For the variable number of flowers, quadratic behavior was observed, reaching maximum value of 17 flowers to 80.72 DAT. Later, drastic reduction was verified in these values along the appraised period, characterizing that in this period the *P. peruviana* had accomplished a cycle (Figure4B). That reduction was also observed for Rodrigues et al. (2013) evaluating the phenology and the productivity of the *Physalis peruviana*. Those same authors verified that the plants reached maximum values of 9 flowers per plant to 72 DAT.

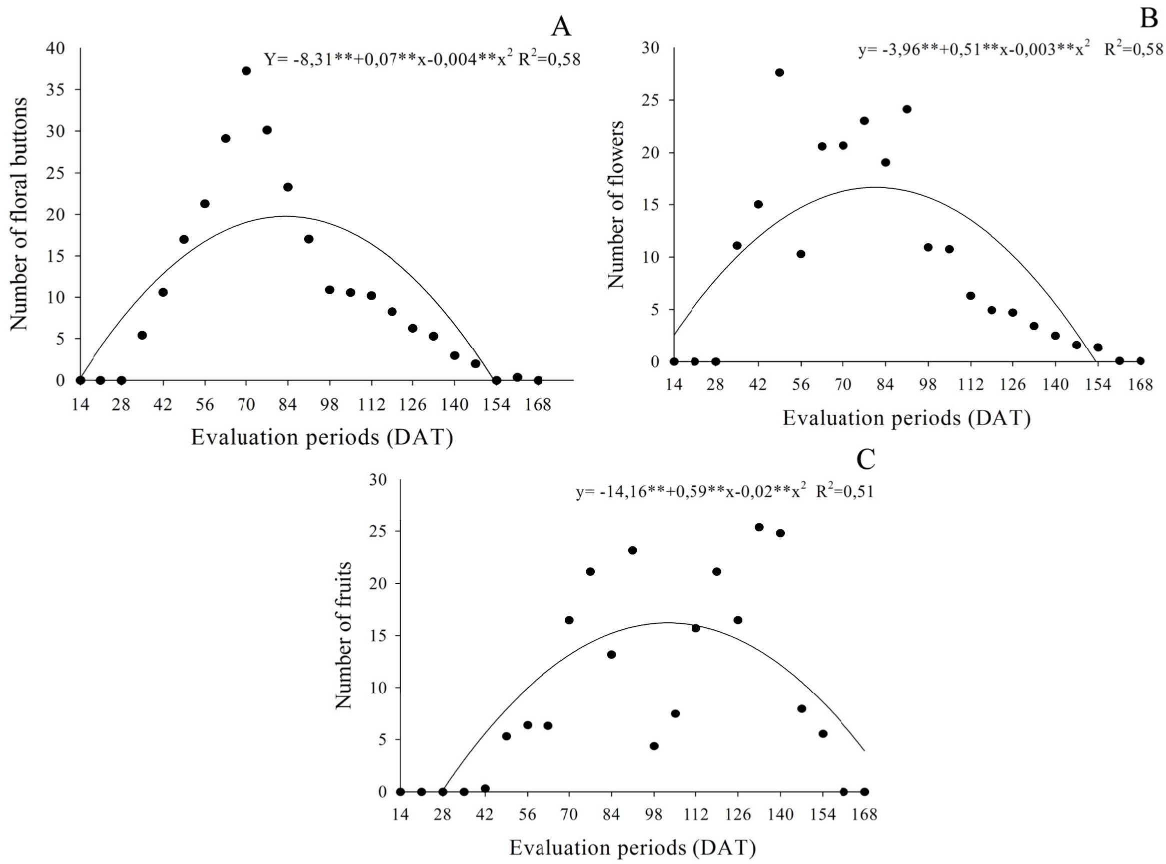

Figure 4. Number of floral buttons (A); number of flowers (B) and number of fruits (C) of the plants of the *Physalis peruviana* L., cultivated in a greenhouse, in function of the evaluation periods after the transplant, UFCG, Pombal, PB, 2017

The difference observed between the medium number of floral buttons and the one of flowers by the plants of the *Physalis peruviana* was consequence of the floral abortion, that can be related to factors of the atmosphere (temperature and relative humidity) or physiologic (related the photo-assimilates unavailability in the period of high competition between sources and drains or nutritional deficiency), as it highlights Silva (2017) when evaluating the phenology of *Physalis peruviana* cultivated in different saline levels in the semi-arid region of Paraíba. Silva et al. (2013) reinforce, although in the tomato cultivation in a greenhouse, superior temperatures to 32 °C can cause abscission floral, bad formation of the pollen tube and aging of the ovum.

As for the number of fruits per plant, it is observed that there was increase in due to the growth and development of the plant, reaching maximum of 16 fruits per plant to 103 DAT. It was still verified, that after this period there was reduction in the number of fruits to the end of a productive cycle of the culture (Figure 4C). That result differs from the one observed by Rodrigues et al. (2013), that studied the phenological development of the *Physalis peruviana*, in the climatic conditions of the South of Minas Gerais, cultivated in a greenhouse, and obtained maximum values of 122 fruits per plant to 102 DAT, this high number of fruits can be consequence of the influence of abiotic factors (temperature) and of the spacing of the culture (1.5 × 1.5 m) in which the experiment was performed.

The production and the productivity of the *P. peruviana* cultivated in a greenhouse reached observed maximum values of 351.06 g plant^{-1} and 2 340.95 Kg ha^{-1}, respectively, which presented expressive picks to 154 DAT

(Figures 5A and 5B). Rodrigues et al. (2013), evaluated the phenology and the productivity of the *Physalis peruviana* in the area of Lavras - MG, and observed production and productivity of 215 g $plant^{-1}$ and 955 Kg ha^{-1}. However, the experiment was driven in vases with capacity for 4 L, with maximum and minimum temperatures of 33.2 and 7.6 °C respectively, conditions different from the observed in this experiment. Therefore, the handling and the climatic factors possess direct influence on the production and the productivity.

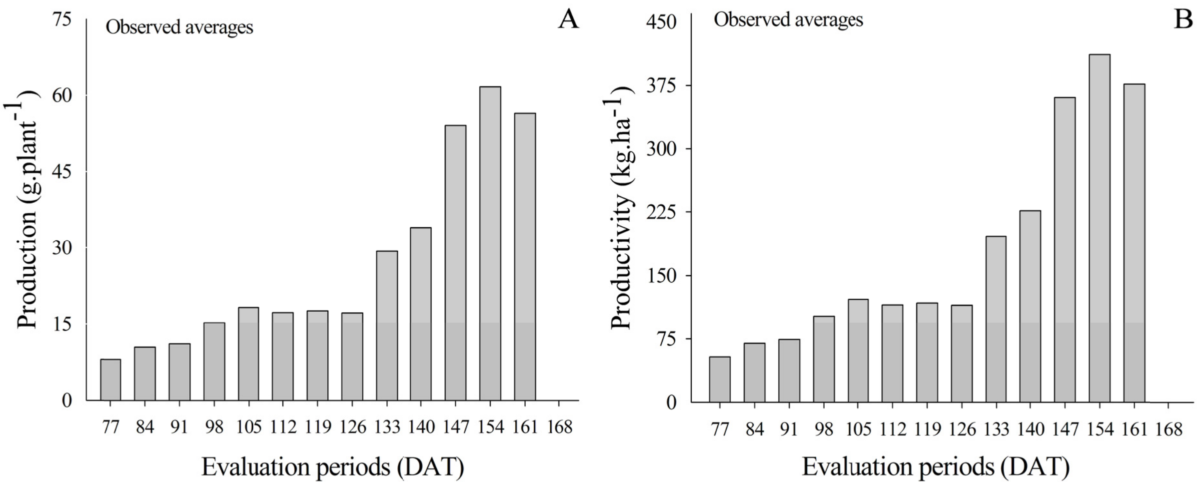

Figure 5. Production (A) and productivity (B) of plants of the *Physalis peruviana* L., cultivated in a greenhouse, in function of the evaluation periods after the transplant, UFCG, Pombal, PB, 2017

Lima (2009), studying the phenology of the *Physalis peruviana* in Pelotas-RS, verified maximum and minimum values of productivity of 14.360 kg ha^{-1} and 6.900 kg ha^{-1}, when cultivated with tutoring system in "V" inverted and vertical with narrow ribbon, respectively. The high productivity observed by this author happened due to the experiment to be performed in a field that, if compared to the cultivation in vase, doesn't possess limitations for the development of the root system, for being an atmosphere with larger soil volume.

Taking into account the appraised factors, is possible to affirm that the *Physalis peruviana* presented adaptability to the climatic conditions of the area of the semiarid of the Northeast, with high productivity and with possibility of a second productive cycle.

4. Conclusions

It is possible to produce the *Physalis peruviana* L. in the environmental conditions used greenhouse in the semiarid region of Paraíba.

The vegetative phase of the *Physalis peruviana* L. is concluded in a period understood among 32 to 45 DAT and the reproductive phase extends until 161 DAT.

In the conditions of the semiarid, the crop of the fruits of the *Physalis peruviana* L. begins to 71 DAT, with dear productivity of approximately 2 340.95 kg ha^{-1}.

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