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Phenological Characterization of *Physalis peruviana* L. Growth in a Greenhouse in the Northern Region of Espírito Santo State

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Authors' contributions

This work was carried out in collaboration among all authors. Author HRP prepared the practical work, performed the statistical analysis, drafted the protocol and drafted the first version of the manuscript. Author JRO carried out the writing of the manuscript and the literature review, in addition to the submission and review required by the editor and had the collaboration of authors MNS and JAA for writing the manuscript and reviewing literature. The authors MAAA, VSO and BAS collaborated in the statistical analysis. All the authors read and approved the final manuscript.

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ABSTRACT

Plant phenology is determined by phases that mark the appearance or disappearance of vegetative and reproductive organs, such as the appearance of plants, the appearance of buds, flowers and fruits. Thus, the present study aimed to evaluate the phenological behavior of *Physalis peruviana* L. grown in a greenhouse in the city of São Mateus - ES, verifying whether its production is feasible under the conditions presented. The experimental design used was completely randomized, totaling 34 plants, with treatments consisting of days after transplanting. The plant's conduction system was single-stemmed. The spacing used between the plants was triangular (0.55m x 0.55m

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x 1m). For the observation of phenophases, it was considered when 30% of the plants were in the following stages: Stage 1 - True Leaves; Phase 2 - Flower buds; Step 3 - Open flowers; Step 4 - Immature fruits; and Step 5 - Ripe fruits. At the end of the experiment, the following evaluations were performed: number of leaves, plant height, stem diameter, number of flower buds, number of flowers and number of fruits per plant. The averages were compared using the Scott-Knott test at 5% probability. The results showed that it is possible to produce Physalis peruviana L. under the conditions defined in a greenhouse in the region of São Mateus-ES, the crop showed good development in the vegetative, flowering and fruiting phases, starting the harvest 60 days after transplant.

Keywords: Golden berry; phenophases; solanaceae.

1. INTRODUCTION

Currently, one of the genera that has been most studied in *Physalis*, stands out in the species *Physalis peruviana* L., popularly known as fisalis or golden berry. One of the reasons, it is presented as a great source of food, either in the natural form or in the middle of the processing of sweets, juices, geographies. It is an important source of vitamins A and C, iron, phosphorus and also has several medicinal properties for the body [1].

Most of the species of *Physalis peruviana* L. have herbaceous characters and are distributed over several continents in the world, mainly in climatic and subtropical regions, with some species occurring natively in Brazil [2]. Colombia is the world's largest producer of this fruit, producing around 11,500 t year^{-1}, however, only 50% of this total is registered, the rest being used for other fins, as dehydrated, when this is not the standard export size [3].

In Brazil, a *Physalis peruviana* L. is incorporated into small fruit plants and consumed as exotic fruits at a high price [4]. Its cultivation is considered an excellent alternative for the national market, mainly for production in family properties [5]. However, in order to have a good chance of learning, the behavior of the plant species is necessary, which can vary in the functions of its local cultivation. Given the importance of this culture, work is being carried out across the country [6], studied the sowing time, phenology and plant growth of *Physalis peruviana* L. in Pelotas - RS, noting that the best time for sowing Physalis is in early September, in order to generate plants with productive characteristics similar to the main growing regions of this species. Tana [7] evaluated a phenology and characterization of fruits of Physalis species grown in the semiarid region of Bahia, found that high temperature and water scarcity compromised the development of the crop and defined that April would be the best time for sowing species of Physalis studied.

The phenology of a plant is determined by phases that mark the appearance or disappearance of vegetative and reproductive organs, such as the emergence of plants, the appearance of buds, flowers and fruits [4]. Their knowledge is important, as it allows to determine the period of development of the species and, above all, to plan the opportune times for the realization of cultural practices, such as application of fertilizers, pest control, diseases and invasive plants as well as in research of crop estimates, maturation season forecast and breeding programs [8], thus helping in the production of quality fruits, both for the fresh market and for industrialized products, such as preserves, juices, jellies and sweets [9].

According to Pinto [10] as physical-chemical characteristics related to the flavor, odor, texture and nutritional value used, quality characteristics to the commercialization and use of the pulp in the production of industrialized products. And these characteristics are related to the time of cultivation and management of a crop, fruits and fruits according to market standards.

In view of the above, phenology becomes of great relevance for the good development of the plant and, in the absence of such a study of the culture for the State of Espírito Santo, the present work aimed to evaluate the phenological behavior of *Physalis peruviana* L. grown in greenhouse in the municipality of São Mateus - ES.

2. MATERIALS AND METHODS

The experiment was conducted in a greenhouse , located at the Experimental Farm of the Federal University of Espírito Santo, Campus of the North University Center of Espírito Santo (CEUNES), in the city of São Mateus-ES, with

latitude of 18º40'19.6 ”South and longitude 39º51'23.7 ”West. The climate of the region, according to the classification of Koppen, Aw (humid tropical), with rains in summer and dry winter [11].

The experimental design used was completely randomized, with a total of 34 plants, with the treatments constituted in days after the transplant (DAT), the experiment was carried out between March and August 2016. To obtain the seedlings of *Physalis peruviana* L., seeds obtained from fruits acquired in a commercial establishment were used. These were sown in polyethylene trays containing 128 cells filled with Provaso® commercial substrate.

Two seeds per cell were placed, kept in a greenhouse, with controlled irrigation (performed 3 times a day, lasting 2 minutes each irrigation). When the seedlings had approximately 15 cm of thinning occurred, leaving only the most vigorous seedling in each cell.

The transplant of the seedlings occurred 36 days after germination, when they were approximately 20 cm high, being transferred to pots containing 4 L of soil characteristic of the region (sandy soil), where the necessary corrections were made, following Prezotti's recommendation [12] for the cultivation of cherry tomatoes, since the species belong to the same family**.**The plant's conduction system was single-stemmed, using bamboo for staking. The spacing used between the plants was 0.55 m x 0.55 m x 1 m, of the triangular type. The lateral shoots that emerged during the development of the plants were removed, leaving only the main branch. The harvest started to be carried out 95 days after the germination, when the fruits and the cup had a yellowish color, characteristic of the culture.

The evaluations of the phenological phases (vegetative phase, flowering and fruiting) were performed weekly from the seedling emergence. For the observation of phenophases, they were considered when 30% of the plants were in the following stages: Stage 1 - True Leaves: plants with a pair of true leaves fully expanded and approximately 20 cm in length, being able to transplant; Stage 2 - Flower buds: plants with prominent buds, the corolla protrudes from the cup, being identified as the beginning of flower buds; Stage 3 - Open Flowers: plants with flowers in two stages, with the corolla totally or partially open; Stage 4 - Immature Fruits: plants with fruit appearance, still in the stage of maturation; and Stage 5 - Mature Fruits: fruits with chalice coloration from greenish yellow.

The following evaluations were carried out: number of leaves; plant height, with millimeter rule, in cm; stem diameter, with the aid of a digital caliper, in mm; number of flower buds; number of flowers and number of fruits per plant. The averages were compared using the Scott-Knott test at the level of 5% probability using the statistical software Assistat [13].

3. RESULTS AND DISCUSSION

The duration of each stage of development of the plant of *Physalis peruviana* L. is observed, from germination to fruit maturation (Table 1).

The seeds germinated about 14 days after sowing. The transplant occurred when the seedlings reached the first stage of development (Stage 1), approximately 20 cm long, at 36 days after germination. [4] observed that their plants needed 20 to 30 days to germinate and another 30 days to be transplanted. [7], who worked with phenology of other species of Physalis (*P. angulata*, *P. ixocarpa* and *P. philadelphica*) in the Bahian semiarid region, took less than 15 days for their plants to germinate and, on average, 28 days for your plants to reach the stage of first pair of true leaves and be transplanted. In all experiments, sowing took place at an average temperature between 20 and 25 ºC. However, [6] needed, on average, 54 days for their plants to reach an ideal size to be transplanted, under conditions of temperature of 17.9ºC.

Table 1. Duration of the different developmental stages of *Physalis peruviana* grown in a greenhouse, Espírito Santo, 2016

Stage	Duration
Sowing to germination	10 – 20 days
Germination to transplantation	30 – 40 days
Transplantation to flowering	30 – 40 days
Flowering to fruiting	5 – 10 days
Fruiting to maturation	15 – 20 days

Fig. 1. characterizes stages 2, 3 and 4 of culture development. Fig. 1A shows the floral bud visible in the axilla of each node, developing two leaves, a vegetative bud and a floral bud at 27 days after transplanting. Soon after, the flower bud swelled (Figs. 1B and 1C), that is, the pre-anthesis. Subsequently, a small opening of the flowers

was seen (Fig. 1D), thus entering the anthesis phase. Flowering of Physalis occurred at 34 days after transplanting (Fig. 1E), being characterized by solitary, pedunculated and hermaphroditic flowers, derived from the axilla of the branches and consisting of a yellow corolla in a tubular shape with a purple spot at the base of the petals [14].

In the post-anthesis (Fig. 1F), the petals started to block and subsequently the fruit formed (Fig. 1G), which resulted in about 41 - 45 days after the transplant, or what was ripe (Fig.1H) at 50 - 60 days, and the maturation was characterized by the yellow color that the cup presented.

Table 2 shows the duration of each phenological phase registered for the culture and its respective duration as a result of the months after transplantation. It appears that the phase that has the longest duration is the vegetative phase, with four months. Mora-Aguilar, et al. [15] working with Phenology of *Physalis peruviana* L. in a greenhouse, observed that the longest phases were flowering and fruiting, and the shortest phase was vegetative. [4], working with Phenology of Physalis *peruviana* L., also recorded that the smallest phase was vegetative, however, evaluated their plants for nine months, where they also vegetated for four months. According to Mora-Aguilar, et al. [15], Physalis can behave as an annual or perennial plant, depending on the production environment, climate, soil and management.

Table 3 contains the growth and development data for *Physalis peruviana* L. plants. It can be seen that the height, as well as the stem diameter and the number of leaves of the plants, kept in full growth from the beginning to the end of the evaluations, thus showing that the plants adapted to the temperature variations of the region and that, even fruiting, it kept vegetating until 111 days after transplanting.

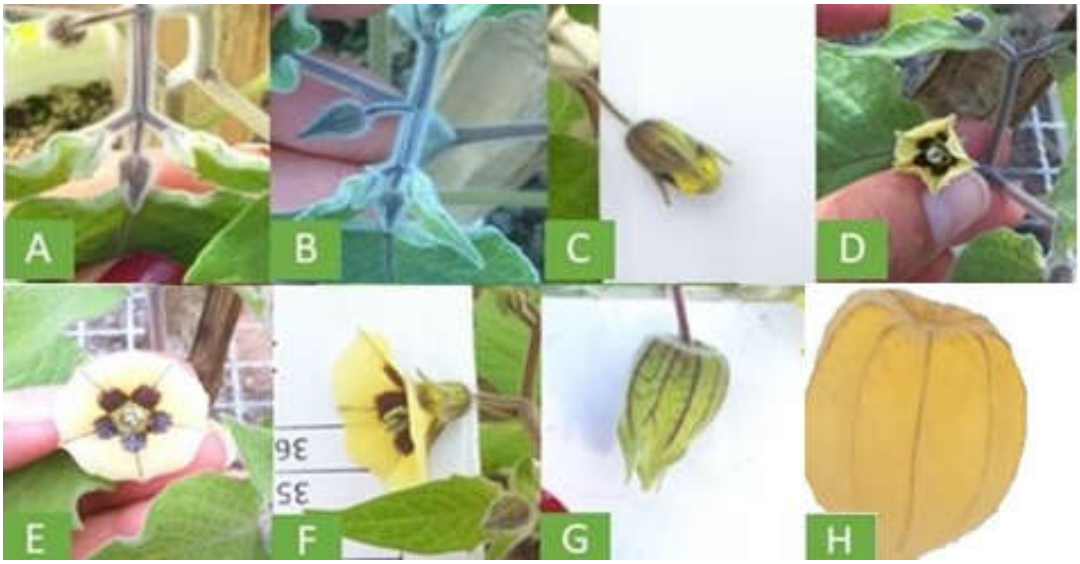

Fig. 1. Different stages of development of *Physalis peruviana* in a greenhouse, from the formation of the floral bud to fruiting, being: A - Visible floral bud; B - Swollen floral bud; C - Pre-anthesis floral bud; D - Anthesis; E– Flowering; F - post-anthesis; G - Fruit formation phase; H - Beginning of fruit ripening

Table 2. Phenological phases of *Physalis peruviana* L. grown in a greenhouse. Espírito Santo, 2016

Phenological phases	Months					
	March	April	May	June	July	August
Planting	X	X				
Vegetative			X	X	X	X
Flowering				X	X	X
Fruiting				X	X	X

According to [16], in *Physalis peruviana* L., vegetative growth is favored with the photoperiod and temperature. Tana [7] in turn, reported in her experiment, that there was a reduction in the aerial part from fruiting. Physalis plants when grown under favorable conditions of temperature and humidity (± 20 ºC and ± 70%, respectively) have the characteristic of rapid increase in height in the initial periods, followed by reduction due to the formation of flowers and fruits, which act as drain, thus requiring greater amounts of photosynthetic products for its growth, with a redirection of these, which were previously intended to increase in vegetative part [7].

Regarding the stem diameter, there was a significant difference in all evaluated dates (Table 3), remaining in full growth, with an increase of about 2 mm from 7 to 34 DAT, 3 mm from 34 to 62 DAT, 4 mm from 62 to 90 DAT and 3 mm from 90 to 111 DAT, obtaining a final diameter of 14.77 mm. Such an increase of 4 mm can be justified by a small drop in temperature, where the minimum reached 18ºC and the average at 22ºC.

And, as well as the height of the plant and the diameter of the stem, the number of leaves increased significantly according to the age of the plant, with a significant difference for all dates evaluated. Thus, the older the age, the greater the number of leaves. At the beginning of the evaluations, an average of approximately four leaves per plant was recorded and, from 90 to 111 DAT, the greatest increase in this parameter occurred, with an average increase of 33.22 leaves, reaching the end of the evaluations with around 89,82 sheets. [4], who also studied the phenology of Physalis peruviana, in the first month after transplanting, on average, four leaves per plant were recorded. However, the largest leaf emission occurred from 57 to 72 DAT, an average increase of 56 leaves. This, in only 102 days of evaluations after transplantation, had an average of approximately 79.72 leaves more than that recorded in the present study, that is, at 102 DAT, the plant had an average of 169.54 leaves per plant.

Flower buds emerged from 34 DAT, flowers started to appear about 14 days after the appearance of flower buds (48 DAT). Such results corroborate with [4], where their plants presented the first buds at 27 DAT and bloomed at 42 DAT, thus taking 15 days to open the flower buds. According to [4] Physalis presents better growth and development at temperatures of 8 to 20 ºC, however, excessive heat does not prevent fruit production, since, in Hawaii, for example, plants produce fruits under daytime temperatures around 27 to 30 ºC, which can also explain the continuous development of the plant, since, in Fig. 1, it can be noted that the lowest temperatures were 18 ºC and the highest, 27 ºC, taking into account average a temperature of 22.5 ºC in the flowering phase, thus staying in the ideal production temperature range. Thus, the plant emitted buds and flowered continuously and increasingly until the last evaluation (Table 3).

Regarding the number of flowers, it can be seen in Table 3 that they started to appear at 34 DAT. From 90 to 111 DAT, statistically, there was no significant difference, however they stand out when compared from 7 to 62 DAT. [4] obtained similar results in relation to the appearance of flowers. Its plants started to bloom 15 days after the appearance of flower buds, however, they showed an average of 9.62 flowers, a result superior to the present work. [6] obtained different results, in which their plants started to bloom around 45 DAT and 60 DAT, in two different plantations, however, these worked under lower temperatures, close to 18 ºC. According to Ângulo [17] high temperatures affect flowering and fruiting, promoting early senescence (temperatures above 30 ºC).

The number of fruits occurred after 62 DAT and continued to increase until the end of the evaluations, with significant differences on all dates evaluated. The greatest increase in the number of fruits was from 62 to 90 DAT, obtaining an increase six times greater than that recorded on the first date, and from 90 to 111 DAT, there was also a statistically significant increase, arriving with a total number of fruits per plant from 23.73 to 111 DAT. Rodrigues, et al. [4], in only 57 DAT, registered about 28.64 fruits per plant, higher than that obtained in the present work at 111 DAT. Rodrigues, et al. [4] at 102 DAT, obtained a total average of 122.69 fruits per plant, thus showing that their plants bear more fruit in less time of evaluation. Rufato, et al. [18] in turn, also did not obtain the same results, with the appearance of fruits on plants occurring, on average, about 100 DAT.

Table 3. Height of plants, stem diameter, number of leaves, number of flower buds, number of flowers and number of fruits per plant of *Physalis peruviana* L. as a function of the days after transplanting (DAT) Greehouse. Espírito Santo, 2016

DAT	Height of plants (cm)	Stem diameter (mm)	Number of sheets	Number of flower buds	Number of flowers	Number of fruits / plant
7	2,99 e	2,03 e	4,85 d	0,00 d	0,00 c	0,00 c
34	12,10 d	4,37 d	12,82 d	1,47 c	0,03 c	0,00 c
62	22,73 c	7,23 c	29,41 c	2,61 c	0,88 b	2,41 c
90	36,37 b	11,78 b	56,70 b	6,91 b	2,65 a	14,97 b
111	48,28 a	14,17 a	89,82 a	11,44 a	3,41 a	23,73 a
CV (%)	40,56	23,93	50,87	67,04	118	104,64

Averages followed by the same letter in the column do not differ by the Scott-Knott test at the 5% probability level

In other studies with solanaceae, it was observed that there is an acceleration of flowering in potatoes and tomatoes to an increase of 1 ºC in temperature [19], thus being able to justify the significant differences in the number of flower buds, number of flowers and number of fruits, as in Fig. 1. there is a clear increase of approximately 1ºC during the months of July and August. However, the average temperature has always remained close to 25ºC, which possibly impaired the setting of the flowers and also the better performance in fruiting. According to Lima, et al. [20] the cultivation of *Physalis peruviana* L. in places with high temperatures (approximately 30ºC) tends to favor vegetative growth, while in mild climate conditions (approximately 14ºC), there is stimulation to flowering, fruiting and sprouting. and the cycle tends to be shorter.

4. CONCLUSION

The results showed that it is possible to produce *Physalis peruviana* L. under the conditions defined in a greenhouse in the region of São Mateus-ES, the crop showed good development in the vegetative, flowering and fruiting phases, starting the harvest 60 days after transplant.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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