Comunicata Scientiae
Horticultural Journal

ORIGINAL ARTICLE
published: 24 May 2022
https://doi.org/10.14295/CS.v13.3332

Base temperature and plastochron of biquinho pepper are dependent on the plant development phase

Oscar Valeriano Sánchez Valera[1], Maria Inês Diel[2]*,
Marcos Vinícius Marques Pinheiro[4], Leonardo Antonio Thiesen[3], Braulio Otomar Caron[5],
Gizelli Moiano de Paula[5], Ezequiel Holz[5], Bruna Stringari Altissimo[5], Denise Schmidt[5]
[1]National Technological Institute of Mexico, Zongolica, Mexico
[2]Federal University of Pampa, Itaqui, Brazil
[3]Federal University of Santa Maria, Santa Maria, Brazil
[4]State University of Maranhão, São Luís, Brazil
[5]Federal University of Santa Maria, Frederico Westphalen, Brazil
*Corresponding author, e-mail: mariadiel@unipampa.edu.br

Abstract

The determination of the base temperature and the plastochron are important for the quantification of the growth and development of plants. The objective was to estimate the base temperature and determine the plastochron for *Capsicum chinense* cultivars during the vegetative and reproductive development phases at different planting times. The experiment was conducted in a randomized block design, 2x4 factorial scheme, cultivars of biquinho pepper (“BRS Moema”, “Airetama Biquinho ”) and growing seasons (S1-S2-S3-S4). The Air temperature was monitored during the vegetative and reproductive phases of the crop. Base temperature (Tb) was determined by the minimum mean square error method (MSE). For both phases of the crop development, plastochron was determined by linear regression between the number of nodes and the accumulated thermal sum (Sta). Tb and plastochron were not influenced by the cultivar. In the vegetative phase, Tb and plastochron were dependent on the sowing season, presenting on average Tb (16.8°C) and plastochron (43.6°C day^{-1}). In the reproductive phase both Tb and plastochron were similar at all sowing times, with averages of 16.7°C and 64.4°C day^{-1} plastochron, for base temperature and plastochron, respectively. Therefore, the emission of nodes is not influenced by the cultivar, but by growing season. With the plastochron values found it is concluded that the development of biquinho pepper is more accelerated during the vegetative phase than the reproductive one.

Keywords: *Capsicum chinense*; Degrees-day; Emission of nodes; Plant development stages; Temperatures

Introduction

Plants of the genus *Capsicum* are grown in various regions of the world. In the year 2014, around 482 hectares were cultivated worldwide and about 462 tons of the fruit were produced. Of these, approximately 19 thousand hectares were planted in Brazil, and the country was responsible for 4.39 tons of the produced fruit. Vietnam, Indonesia, India, Brazil and China stand out as the largest producers (FAO, 2017).

Among the species of this genus, it is worth mentioning the *Capsicum chinense*, popularly known as biquinho pepper, which can reach high commercial value, due to the marked flavor and aroma, being much appreciated both *in natura* and processed, since the fruits have absence or low pungency (Heinrich et al., 2015). The fruits of biquinho pepper have an average width between 12.1 and 16.6 mm; average length of fruit beak between 1.5 and 6.3 mm and average fruit length between 19.8 and 28.5 mm (Heinrich et al., 2015).

The temperature is an important factor that affects the growth of the plant (Guo et al., 2012) as it acts as regulator of the physiological processes of the plants, influencing their development. For most plants subjected to ideal air temperature conditions, developmental stages are not adversely affected, but under conditions of thermal stress, for example, plant survival may be negatively affected (Bahuguna & Jagadish, 2015). In addition, the air temperature acts directly in the phenological phases of the plants through the accumulated thermal sum and it is possible to describe the duration of a given cycle. An important development variable is the number of nodes emitted on the main stem, being estimated from the knowledge of the time necessary for the appearance of two successive nodes, defined as plastochron (Streck et al., 2005). Plant development, as well as the emission of nodes, occurs in a wide range of air temperature, and

Received: 26 March 2020
Accepted: 22 March 2021

within this is the minimum temperature, in which below it there is no development or, where it exists, occurs at slow rates that are almost negligible (Martins et al., 2011). The emergence of new structures in the plant and the accompaniment of these until senescence is important to help agronomic planning and cultural treatments, and thus, to increase productivity (Lucas et al., 2012), since the needs of each species are different during each stage or cycle phase. In addition, information related to the development of the plant can help in the elaboration of mathematical models that will allow to describe and to interpret the performance of the cultures (Charlo et al., 2011).

Thus, the objective of this work was to estimate the base temperature and plastochron of two cultivars of biquinho pepper during the vegetative and reproductive development phases, at different growing seasons.

Material and methods

Plant Material and culture conditions

The experiment was conducted in the experimental area of the Federal University of Santa Maria, *Campus* Frederico Westphalen, Rio Grande do Sul, Brazil, from August 2015 to May 2016 and located in the geographic coordinates 27° 23'40 "S and 53°25'45" W, with altitude of 490 m. According to the Köeppen classification, the climate of the region is *Cfa*, humid subtropical, presenting characteristics of rainy temperate, with average annual precipitation of 1800 mm well distributed throughout the year, and subtropical from the thermal point of view (Alvares et al., 2013).

Biquinho pepper (*Capsicum chinense*, L.) cvs. “BRS Moema” (red ripe fruits) and “Airetama Biquinho” (yellow ripe fruits) were used. The se cultivars have intermediate growth.

Stage of seedlings production in protected environment-Vegetative phase

For the vegetative phase the seedlings production stage was considered, being this one held in the galvanized steel greenhouse, with semicircular roof, measuring 20 m of length by 10 m of width and height of the right foot of 3.5 m, arranged in the north-south direction. The seeds of the two cultivars were sown in four seasons, in expanded polystyrene trays containing 128 cells, filled with commercial substrate and deposited two seeds per cell. After the first true leaves were emitted, the thinning of one of the germinated seedlings per cell was performed, remaining the most vigorous.

After 22 days of germination for S1 and S2 and 20 days for S3 and S4, the seedlings were transferred to a floating system, in benches at 1.5 m above ground, and were kept in a nutrient solution composed of Hidrogood®, Calcinit® and chelated iron at concentrations of 0.5, 0.4 and 0.06 g L^{-1}, respectively. Daily irrigation was carried out at 8 a.m., 10 a.m., 3 p.m. and 5 p.m. until the seedlings reached the transplant point.

Experimental design

In the vegetative phase the experiment was conducted in a randomized complete block design (DBC), in the 2x4 factorial scheme, two cultivars of biquinho pepper (BRS Moema and Airetama Biquinho) and four growing seasons, being August 24th, 2015 (S1), October 1st, 2015 (S2), November 13th, 2015 (S3) and March 15th, 2016 (S4).

Field cultivation stage - Reproductive phase

Area preparation and experimental conditions

The soil of the experimental area, in which the seedlings were transplanted, was plowed, meshed and entangled. Acidity correction and soil fertilization were carried out as recommended by the Commission of Chemistry and Soil Fertility (Comissão de química e fertilidade do solo - CQFSRS/SC, 2004). After correction and soil fertilization, the beds were covered with black color mulching, to maintain soil moisture and avoid competition with weeds. When the seedlings reached the transplant point, at 60 days for S1 and S2 and 40 days for S3 and S4, they were transplanted directly into the soil. For BRS Moema, 0.80 m spacing was used between rows and 0.50 m and for Airetama Biquinho of 1.20 m between rows and 0.80 m between plants as indicated by the company producing the seed. Irrigation was done via drip irrigation according to crop needs and meteorological conditions and, when necessary, phytosanitary control was performed.

Experimental design

For the reproductive phase, the experiment was conducted in DBC, in a 2x4 factorial scheme, two cultivars of biquinho pepper (*Capsicum chinense*), BRS Moema and Airetama Biquinho, and four transplant seasons, on October 21st, 2015 (S1) November 20th, 2015 (S2), January 9th, 2016 (S3) and April 19th, 2016 (S4), consisting of six replicates, and each replicate consisted of four plants.

Data collection

During the seedling stage production in protected environment, the air temperature was recorded using a digital thermometer located inside a meteorological shelter at 3.0 m distance from the seedlings bench and 1.5 m above ground. Daily, maximum and minimum temperatures were recorded at 9 am, with the maximum of the previous day and the minimum of the day of reading. The air temperature (maximum and minimum) in the field was recorded from the data collected from the automatic meteorological station of the National Meteorological Institute (INMET), located, approximately, 50 m away from the experiment place. Thus, using the minimum and maximum values, in which the daily average value of the air temperature occurred during the study period was calculated, with the following equation:

$$Tave=(Tmax+Tmin)/2$$

where Tave - average air temperature; Tmax - maximum temperature; Tmin - minimum temperature.

Experiment evaluations

In the vegetative and reproductive development phases counted the emission of nodes was counted three times a week. In the vegetative development, that is, during the moult stage, the nodal emission was evaluated in the main stem after emergence, considering a new node when the leaf petiole, located in the apical meristem, was visibly separated from the petiole of the opposite leaf. In the reproductive phase the node emission count was performed in one of the four stems of the third order, following the same pattern during the vegetative phase to consider the emission of a new node. Due to the frost damage that occurred during S4 (April 19th, 2016), the plants did not reach reproductive development, so we counted only for the vegetative phase at this time.

The accumulated thermal sum (STa) for the vegetative phase was calculated from the emergence of the plant and, for the reproductive phase, from the transplant, using the following equation (Arnold, 1960):

$$STa=\sum Std \quad °C\ day$$

$$STd=(Tave-Tb)°C\ day$$

$$STd=0, \text{ when } Tb>Tave$$

Where STa - cumulative thermal sum, STd - daily thermal sum, Tave - average air temperature; Tb - Base temperature.

Base temperature (Tb) for the emission of nodes was calculated by the methodology using the minimum mean square error method (MSE) obtained from the simple linear regression between the number of nodes (Nn) and the accumulated thermal sum (STa, °C day). That is, for each plant of each growing season, a simple linear regression was estimated, using a series of Tb with values from 0 to 25 °C, with increments of 0.5 °C. Therefore, Tb was the one that presented the lowest MSE in simple linear regressions. With the value of Tb estimated for the emission of nodes, we also estimated the plastochron (°C day node^{-1}), using the simple regression between the number of nodes (Nn) and the accumulated thermal sum (STa). Thus, the value of plastochron was considered as the inverse of the coefficient of the simple linear regression equation between Nn and Sta.

For both phases of development (Vegetative or Reproductive), base temperature (Tb) and plastochron were evaluated, and these were submitted to analysis of variance to verify the effect of the cultivars and the different cultivation times. ANOVA's assumptions were met, and when significant, the averages of the variables were compared by the Tukey test, at 5% of significance, using the statistical program Genes (Cruz, 2013).

Results

Trends air temperatures

For the seedling stage production in protected environment, during the evaluation of the experiment at S1, the lowest temperatures were recorded, with several periods below the Tb for the emergency-transplant phase (Figure 1A). For this period, the average temperature observed was 24.2 °C, registering absolute maximums and minimums with values of 45.4 °C on September 16th, 2016 and 1.8 °C on September 12th, 2016, respectively. At S2 and S3 average temperatures remained around 25.6 and 27.1 °C, with maximums of 42.1 and 42.7 °C on October 4th and December 20th, 2016, respectively, and minimums of 10.4 °C on October 18th, 2016 and 17.0 °C on November 14th, 2016 (Figure 1B, 1C). At S4, the highest temperatures (Figure 3D) were observed, with an average of 29.5 °C, with absolute values of 45.5 °C on April 16th, 2016 and 14.9 °C on March 25th, 2016. For the reproductive phase, after the transplanting of the seedlings in the field (Figure 1E), the average temperature of the seasons S1, S2, S3 and S4 were 23.3; 24.2; 25.3 and 19.8 °C, respectively. During these periods absolute air temperatures were recorded with values of 35.2 °C maximum on January 28th, 2016 and 2.0 °C minimum on April 28th, 2016.

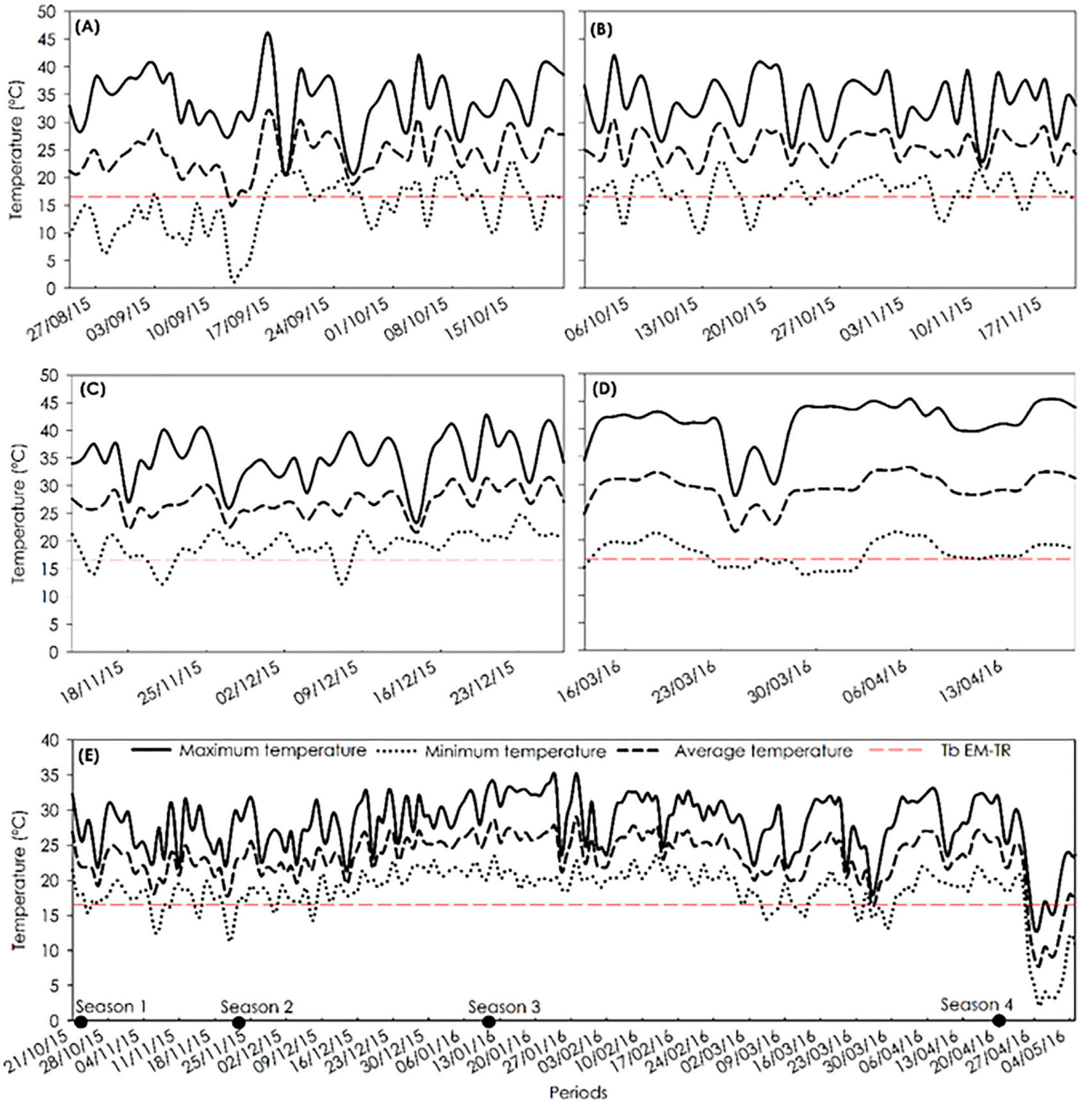

Figure 1. Air temperature recorded in the protected environment at S1 (A), S2 (B), S3 (C) and S4 (D) and in field (E) between August 2015 and April 2016 Tb: base temperature of biquinho pepper (*Capsicum chinense*) Black colored dots indicate the date of transplant emergence (EM), transplant (TR).

Estimation of the base temperature in cultivars of biquinho pepper in different planting seasons

According to the analysis of variance, for both evaluation phases (Vegetative and Reproductive) there was no significant interaction between growing seasons x cultivar for the variable base temperature (Tb). Separately, there were significant differences for growing seasons only for the vegetative phase (Table 1). For the factor cultivar there was no difference, by the F test at 5% of probability.

Table 1. Base temperature (Tb) for nods emission and plastochron of biquinho pepper (*Capsicum chinense*) cultivar BRS Moema and Airetama Biquinho.

Seasons	Tb (°C)		Plastochron (°C day node^{-1})	
	Vegetative phase	Reproductive phase	Vegetative phase	Reproductive phase
S1	13.4± 0.48 c	15.6± 1.84 a	55.7± 0.72 a	70.4± 0.66 a
S2	17.9± 0.44 ab	17.6± 1.17 a	40.8± 0.51 b	64.3± 0.31 a
S3	15.7± 1.63 bc	16.8± 1.17 a	35.2± 0.72 c	58.4± 0.29 a
S4	20.4± 0.67 a	-	42.2± 0.50 b	-
Means	16.8	16.7	43.6	64.4
CV(%)	17.5	8.81	9.77	9.87

Values are means ± standard error. Means followed by different letters in the column, comparing seasons, differ from each other according to the Tukey test at 5% probability error. Growing seasons: vegetative phase S1 = August 24th, 2015; S2 = October 1st, 2015; S3 = November 13th, 2015; S4 = March 15th, 2016; reproductive phase S1 = October 21st, 2015; S2 = November 20th, 2015; S3 = January 9th, 2016; S4 = April 19th, 2016. (-) Data not recorded by frost influence.

In the vegetative phase, for S1, a lower Tb with a value of 13.4 °C was observed, differing significantly from S2 and S4, which showed superiority in Tb, with values of 17.9 and 20.4 °C, respectively (Table 1). In the reproductive phase, although there was no significant difference ($p>0.05$), the calculated base temperature varied between the different transplant seasons of the seedlings, with values between 15.6 and 17.7 °C.

It was possible to observe lower temperatures in S1 of the vegetative phase and the lowest value of Tb, with 13.4 °C (Figure 1A), was estimated. However, at the seasons when the temperature was higher, Tb reached higher values, as observed in S4 at 20.4 °C (Figure 1D). For the reproductive phase, this tendency was not observed, because there were no temperatures that allowed to determine the minimum temperature supported by biquinho pepper.

It was observed a maximum variation of MSE in the estimation of Tb, with maximum variation between seasons of 7.0 and 2.2 °C for vegetative and reproductive phases, respectively, and it was possible to observe that the Tb values calculated in each plant were from 4.5 to 24.0 °C and 8.0 °C to 19.5 °C, for the vegetative and reproductive phases, respectively (Figure 2).

Plastochron estimation in cultivars of biquinho pepper in different planting seasons

According to the analysis of variance, for both evaluation phases (vegetative and reproductive) there was no significant interaction between the factors of planting seasons x cultivar for the variable plastochron. Separately, there were significant differences between growing seasons for the vegetative phase (Table 1). For the factor cultivar there was no difference, by the F test at 5% of probability.

In the vegetative phase, for the variable plastochron it was possible to observe a lower value in S3, being necessary 35.2 °C day node^{-1} for emission of a node, differing significantly from the other growing seasons. The highest plastochron was observed at S1 with a value of 55.7 °C day^{-1}, with variations of up to 20.2 ° C day^{-1} between sowing times, demonstrating that the plant needs a greater amount of heat for the emission of nodes (55.7 °C day^{-1}) (Table 1).

At S3, where the lowest value of plastochron was estimated, they occurred at higher temperatures, in the two development phases. For the reproductive phase, there was no difference between the growing seasons ($p<0.05$), however there was variation of 70.4 in S1, 64.3 in S2 and 58.4 in S3. In the S4 of the reproductive phase, it was not possible to estimate the plastochron, since at this season there were injuries in the plants provoked by the frost.

The results of the present work confirmed the higher thermal need of the cultivars in the reproductive phase, since a larger plastochron was observed, requiring a higher thermal sum for this phase of the production cycle (Figure 3).

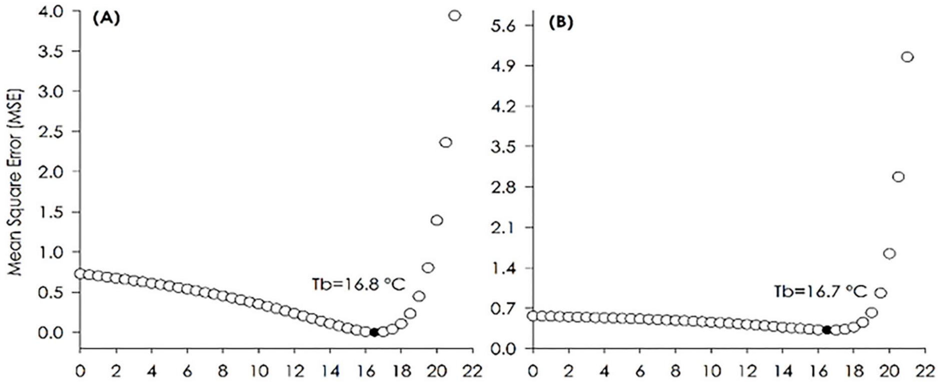

Figure 2. Mean Square Error (MSE) of the linear regression between the number of nodes in a stem and the accumulated thermal sum, using a series of base temperatures, during the vegetative (A) and reproductive (B) phases of *C. chinense* cvs. "BRS Moema" and "Airetama Biquinho" at the sowing date of November 13th, 2015 (S3) Black circle indicates the lowest MSE, representing the base temperature (Tb) for node emission.

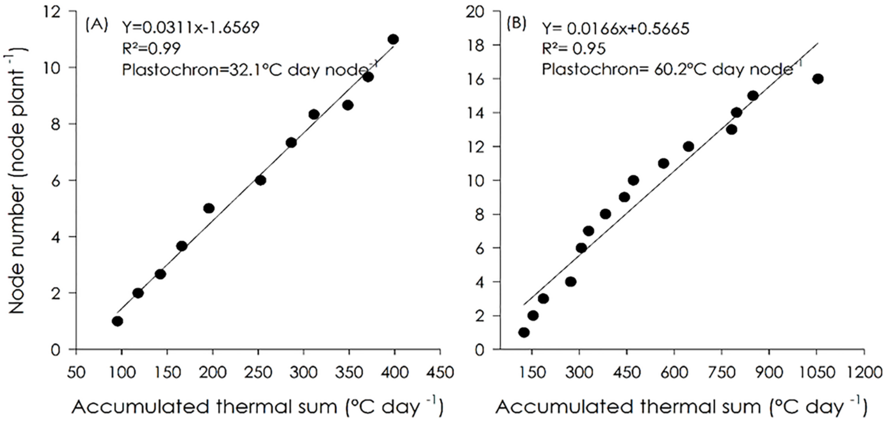

Figure 3. Linear regression between the number of nodes in a stem and the accumulated thermal sum, in the estimation of plastochron during the vegetative (A) and reproductive (B) phases of biquinho pepper (*Capsicum chinense*) cultivar BRS Moema and Airetama Biquinho at season of S2 (November 20th, 2015).

Discussion

Plant growth and its response to environmental changes are mediated by air temperature through changes in plant photosynthesis and respiration, in addition, extreme temperatures cause physiological effects with impacts on productivity and production quality (Sage & Kubien, 2007). The base temperature is of great importance, and therefore, its determination must be performed throughout the cycle, as it is dependent on the genotype and the analyzed development subperiod Streck et al. (2005b), that is, the plants detect the change of temperature and alter their responses (Bahuguna & Jagadish, 2015). The development of new structures is a phenological process dependent on temperature, and is often critical for the development of plants (Johnson & Thornley, 1985). In the present study there was no difference in base temperature between the evaluated genotypes, however, there were differences between the growing seasons, demonstrating the influence of temperature on the evaluated cultivars.

When the Tb is estimated by the method of the smaller MSE, it is necessary that the plant be submitted to low temperatures (Martins et al., 2007), since when subjected to high temperatures the method may not be viable, proving that, for the calculation of Tb, it is necessary a wide variation of temperatures between the different seasons, otherwise the estimate of the calculated Tb will not be close to the real one (Martins et al., 2012). In a study by Paula & Streck (2008), using the same method as the smaller MSE, they observed variation from 0 to 17.5 °C for *Brachiaria plantaginea* and 0 to 16.5°C for *Ipomoea triloba*. In *Zea mays*, a wide variation in MSE was also observed, pointing to the influence of high air temperatures as the main cause of this high difference (Streck et al., 2009). According to the results obtained, it was verified that there was a greater influence of the environment than of the genotype in the conditions in which the present study was carried out, that is, the node emission does not differ between cultivars in biquinho pepper, depending, in this case, on the influence of the air temperature. Many studies, in addition to finding differences in development related to the cultivation environment, also observed differences related to genotypes or cultivars. For example, Diel et al. (2017) evaluated the development of two strawberry cultivars and verified differences between cultivars in the leaf emission rate. Other works also report differences between cultivars in development between the cultivated seasons analyzed (Cocco et al., 2016; Mendonça et al., 2012), which is mainly due to the difference in temperature and the accumulated thermal sum between the seasons.

The estimation of plastochron was different in relation to the growing season, and the same was observed in several scientific studies that also emphasized the influence of the environment, since the greatest differences are found for sowing season, indicating that plastochron is more affected by the environment than by genotype (Martins et al., 2011), depending on the species being evaluated, as did not find significant differences for the plastochron in *Citrullus lanatus* between the growing seasons in three agricultural years.

Larger plastochron shows that the plant needs a greater amount of heat for the emission of nodes (55.7 °C day^{-1}), as happened in S1, when temperatures were lower (Figure 1A), and in many cases, the average temperature is below the base temperature; in this case, higher plastochron values indicate slow development, so lower values indicate fast development (Heldwein et al., 2010). For the species *Aspilia montevidensis*, the authors determined the plastochron at different growing seasons and observed that the highest values of plastochron had occurred at times with lower temperatures (Fagundes et al., 2008). Variables that indicate the development of plants can be easily correlated with air temperature, since this meteorological variable is directly linked to the physiology of development (Bahuguna & Jagadish, 2015), as observed in the present study for plastochron in biquinho pepper.

The value of plastochron often varies depending on the species being studied; Paula & Streck (2008) observed that in *Ipomoea triloba* the plastochron did not differ between the different growing seasons. For *Dianthus chinensis*, plastochron varied when submitted to different substrates, being attributed to nutrient differences in each substrate (Milani et al., 2017). On the other hand, for *Vitis vinifera*, 40.4 and 49.7 °C day per node were found for the "Cabernet Sauvignon" and "Chardonnay" varieties (Zeist et al., 2016). For *Crambe abyssinica*, under climatic conditions of Capitão Poço, in the state of Pará (North of Brazil), the estimation of plastochron was different for the periods from emergence to flowering, fruiting and senescence, respectively (Oliveira et al., 2015), in this case, differences were observed during the cycle, confirming the results found in the present study. Normally, the values of plastochron are expected to reduce the rate of increase in air temperature during growing seasons, since the thermal sum used in the plastochron calculation can be altered under high temperature conditions when considered only lower base temperature and the upper basal temperature supported by the culture is not used Renato et al. (2013) and this relationship was verified in the present work.

For both evaluation phases (vegetative and reproductive) it was possible to observe a reduction in the value of plastochron, when there was an increase in air temperature; this is due to the increase in the plant's metabolic activities (Bahuguna & Jagadish, 2015), accelerating its development. Under higher temperature conditions, along with higher radiation, more photosynthetic activity occurs when plant water requirements are met (Sage & Kubien, 2007); In this work the highest plastochron was observed during S1, that is, in this period the development of the culture was slower, because it was necessary to accumulate a higher thermal sum for the emission of nodes, due to the lower temperatures observed during this time. The results observed at this stage are important for establishing the crop (Silva et al., 2010), so the lower the plastochron, the faster the development of the crop.

Plastochron is important to define the best time for the production of seedlings and establishment of the crop in the field, in this case the seedlings of the seasons S1 and S2 reached transplant point at 60 days after sowing, while for the seedlings of S3 and S4 could be transplanted 40 days after sowing, about 20 days before the first seasons; in contrast, even S4 producing earlier seedlings, after being taken to the field, the reproductive phase coincided with a period of very low temperatures, which caused serious losses in fruit production, even being lethal to the plants. This factor can be taken into account by the producer in planning the establishment of field planting.

Conclusions

The results found in the present study indicate that the estimated base temperature for the emission of nodes in biquinho pepper cultivars BRS Moema and Airetama Biquinho is 16.8 and 16.7 °C for the vegetative and reproductive phases, respectively. The emission of nodes is not influenced by the cultivar, but by the growing season due to differences in air temperature. The values of plastochron found allow us to conclude that the development of the biquinho pepper culture is more accelerated during the vegetative than the reproductive phase. These results are essential for the production system of biquinho pepper, considering that the crop is still incipient and does not have as much information related to the species, besides being an important alternative in the diversification of activities in family farms.

Acknowledgement

The first author thanks CONACYT and the ‘Tecnológico Nacional de México’ for the scholarship granted. The other authors thank the Coordination for the Improvement of Higher Education Personnel (CAPES).

Disclosure statement

No potential conflict of interest was reported by the authors

References

Alvares, C.A., Stape, J.L., Sentelhas, P.C., Moraes Gonçalves, J.L., Sparovek, G. 2013. Koppen's climate classification map for Brazil. *Meteorologische Zeitschrift* 22: 711–728

Arnold, C.Y.1960. Maximum-minimum temperatures as a basis for computing heat units. *American Society for Horticultural Science* 76: 682–692.

Bahuguna, R.N., Jagadish, K.S.V. 2015. Temperature regulation of plant phenological development. *Environmental and Experimental Botany* 111: 83–90.

Bosland, P. 1993. Breeding for quality in Capsicum. Capsicum and Egplant. *Newsletter* 25–31.

Charlo, H.C.O., Oliveira, S.F., Castoldi, R., Vargas, P.F., Braz, L.T., Barbosa, J.C. 2011. Growth analysis of sweet pepper cultivated in coconut fiber in a greenhouse. *Horticultura Brasileira* 29: 316–323.

Cocco, C., Gonçalves, M.A., Junior, C.R., Marafon, A.C., Antunes, L.E.C. 2016. Carbohydrate content and development of strawberry transplants from Rio Grande Do Sul and imported. *Revista Brasileira de Fruticultura*, 38: 1–8.

Cruz, C.D. 2013. GENES - a software package for analysis in experimental statistics and quantitative genetics. *Acta Scientiarum. Agronomy* 35: 271–276.

Diel, M.I., Pinheiro, M.V.M., Cocco, C., Fontana, D.C., Caron, B.O., Paula, G.M., Pretto, M.M., Thiesen, L.A., Schmidt, D. 2017. Phyllochron and phenology of strawberry cultivars from different origins cultivated in organic substracts. *Scientia Horticulturae* 220: 226–232.

Fagundes J.D., Streck N.A., Storck L., Reiniger L.R.S., Kruse, N.D. 2008. Temperatura base, plastocrono e número final de nós no malmequer do campo. *Ciência Rural* 38(9):2471–2477.

FAO. 2017 FAO: Food and Agriculture Organization of the United Nations Statistics Division [WWW Document] URL http://wwwfaoorg/faostat/en/#data/QC

Guo H., Hu Q., Zhang Q., Feng S. 2012. Effects of the Three Gorges Dam on Yangtze River flow and river interaction with Poyang Lake, China: 2003–2008. *Journal of Hydrology* 416–417: 9–27.

Heinrich, A.G., Ferraz, R.M., Ragassi, C.F., Reifschneider, F.J. 2015. Caracterização e avaliação de progênies autofecundadas de pimenta biquinho salmão. *Horticultura Brasileira* 33: 465–470.

Heldwein, A.B., Streck, N.A., Sturza, V.S., Loose, L.H., Zanon, A.J., Toebe, M., Souza, A.T., Peters, M.B., Karlec, F. 2010. Plastocrono e rendimento de feijão-de-vagem cultivado sob ambiente protegido e no ambiente externo em semeadura tardia no outono *Ciência Rural* 40: 768–773.

Johnson, I.R., Thornley, J.H.M. 1985. Temperature dependence of plant and crop processes. *Annals of Botany*, 55: 1–24.

Kim, S., Park, M., Yeom, S.I., Kim, Y.M., Lee, J.M. 2014. Genome sequence of the hot pepper provides insights into the evolution of pungency in Capsicum species *Nature Genetics* 46: 270–278.

Lucas, D.D.P., Streck, N.A., Bortoluzzi, M.P., Trentin, R., Maldaner, I.C. 2012. Temperatura base para emissão de nós e plastocrono de plantas de melancia. *Revista Ciência Agronômica* 43: 288–292.

Martins, F.B., Reis, D.F., Pinheiro, M.V.M. 2012. Temperatura base e filocrono em duas cultivares de oliveira. *Ciência Rural* 42: 1975–1981.

Martins, F.B., Silva, J.C., Streck, N.A. 2007. Estimativa da temperatura-base para emissão de folhas e do filocrono em duas espécies de eucalipto na fase de muda. *Revista Árvore* 31: 373–381.

Martins, J.D., Radons, S.Z., Streck, N.A., Knies, A.E., Carlesso, R. 2011. Plastocrono e número final de nós de cultivares de soja em função da época de semeadura. *Ciência Rural* 4: 954–959.

Mendonça, H.F.C., Calvete, E.O., Nienow, A.A., Costa, R.C., Zerbielli, L., Bonafé M. 2012. Phyllochron estimation in intercropped strawberry and monocrop systems in a protected environment. *Revista Brasileira de Fruticultura* 34: 15–23

Milani, M., Martins, J.D., Lopes, S.J., Streck, N.A. 2017. Growth, plastochron, and the final number of nodes of china pink seedlings grown on different substrates. *Revista Ceres* 64: 413–418.

Oliveira, R.L.L., Lima, L.G.S., Souza, L.C., Moreira, A.R., Silva, R.T.L., Costa, A.V.A. 2015. Estimativa do plastocrono em crambe nas condições edafoclimáticas de Capitão Poço no Pará. *Nucleus* 12: 27–34.

Paula, G.M., Streck., N.A. 2008. Temperatura base para emissão de folhas e nós, filocrono e plastocrono das plantas daninhas papuã e corriola. *Ciência Rural* 38: 2457–2463.

Paulus, D., Valmorbida, R., Santin, A., Toffoli, E., Paulus, E. 2015. Crescimento, produção e qualidade de frutos de pimenta (*Capsicum annuum*) em diferentes espaçamentos. *Horticultura Brasileira* 33: 91–100.

Renato, N.S., Silva, J.B.L., Sediyama, G., Cand, P.E.G. 2013. Influência dos métodos para cálculo de graus-dia em condições de aumento de temperetura para as culturas de milho e feijão. *Revista Brasileira de Meteorologia* 12: 382–388.

Rosa, H.T., Walter, L.C., Streck. N.A., Andriolo, J.L., Silva, M.R., Angner., J.A. 2011. Base temperature for leaf appearance and phyllochron of selected strawberry cultivars in a subtropical environment. *Bragantia* 70: 939–945.

Sage, R.F., Kubien, D.S. 2007. The temperature response of C3 and C4 photosynthesis. *Plant, Cell and Environment* 30: 1086–1106.

Silva, P.I.B., Negreiros, M.Z., Moura, K.K.C., Freitas, F.C.L., Nunes, G.H., Silva, P.S.L., Grangeiro, L.C. 2010. Crescimento de pimentão em diferentes arranjos espaciais. *Pesquisa Agropecuária Brasileira*, 45: 132–139.

Sokona, D., Niamoye, Y.D., Paul, N.S., Olagorite, A., Aminata, D.N., Kadidiatou, G.T., Aissata, T.T., Seacute, K., Daouleacute, D.B. 2013. Overview of pepper Capsicum spp breeding in West Africa. *African Journal of Agricultural Research* 8: 1108–1114.

Streck, N.A., Lago, I., Samboranha, F.K., Gabriel, L.F., Schwantes, A.P., Schons, A. 2009. Temperatura base para aparecimento de folhas e filocrono da variedade de milho BRS Missões. *Ciência Rural* 39: 224–227.

Streck, N.A., Tibola, T., Lago, I., Buriol, G.A., Heldwein, A.B., Schneider, F.M., Zago, V. 2005. Estimativa do plastocrono em meloeiro (*Cucumis melo* L.) cultivado em estufa plástica em diferentes épocas do ano. *Ciência Rural* 35: 1275–1280.

Tolesa, G.N., Workneh, T.S., Melesse, S.F. 2017. Logistic regression analysis of marketability of tomato fruit harvested at different maturity stages and subjected to disinfection , storage condition and storage period treatments. *Biological Agriculture and Horticulture* 4: 40-52.

Zeist, A.R., Alberto, C.M., Camponogara, D.T., Rosarolla, M., Giacobbo, C.L., Welter, L.J. 2016. Plastochron estimate in grapevine Marselan and Tannat cultivars. *Científica*, 44: 471–476.

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.