# Temperature-base and soma thermal for *Zinnia* 'Profusion Cherry' potted grown in protected environment[1]

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**ABSTRACT**

The growing of consumer market demands introduction of new species of flowers and cultivars primarily for production under protected cultivation. The zinnia by the quickness of production can be regarded as an alternative, however demand studies by the lack of information in the literature. We evaluated the duration of different periods, the base temperature and thermal accumulation, expressed as degree-days for the potted zinnia 'Profusion Cherry', conducted under protected cultivation for different phenological subperiods. The test was conducted in a greenhouse covered with plastic and closed laterally with shading-net and the duration of subperiods were made to twenty times after sowing. The base temperature was determined by relative development and values-based temperature and thermal time in degree-days (DD). The results for the different phases were, respectively: first open flower-planting: 4.1 °C and GD 838, first open flower - 50% of flowers open: 3.0 °C and 184 GD and 50% of flowers open - senescence: 6.9 °C and 238 GD.
**Keywords**: phenology, growing degree days, relative development.

**RESUMO**

**Temperatura-base e soma térmica para a *Zínia* 'Profusion Cherry' envasada cultivada em ambiente protegido**

O crescente mercado consumidor de flores demanda introdução de novas espécies e cultivares principalmente para produção em ambiente protegido. A zínia, pela rapidez, qualidade e demanda de produção pode ser considerada como uma alternativa, porém demanda estudos devido à carência de informações na literatura. Portanto, foram feitas avaliações de duração em dias dos diferentes subperíodos, temperaturas-base e acúmulo térmico, expresso em graus-dia, para a *Zinnia* 'Profusion Cherry' envasada e conduzida em ambiente para diferentes subperíodos fenológicos. O ensaio foi realizado em estufa tipo túnel alto, coberta com plástico e fechada lateralmente com tela de sombreamento e as avaliações da duração dos subperíodos foram feitas para vinte épocas de semeadura. A temperatura-base foi determinada pelo método do desenvolvimento relativo e os valores de temperatura-base e soma térmica, em graus-dia (GD). Para os diferentes subperíodos, os resultados encontrados foram: semeadura - primeira flor aberta: 4,1 °C e 838 GD; primeira flor aberta - 50% das flores abertas: 3,0 °C e 184 GD e 50% das flores abertas - senescência: 6,9 °C e 238 GD.
**Palavras-chave**: fenologia, graus-dia, desenvolvimento relativo.

## 1. INTRODUCTION

Currently, floriculture is highly professional and competitive activity and the producer must be able to meet the consumer market and achieve high levels of productivity, standardization, good presentation and a high quality final product.

*Zinnia* is a plant that presents an infinity of shapes, sizes and flowers of many different bright colors. The hybrid, 'Profusion Cherry', interspecific between *Zinnia elegans* and *Zinnia angustifolia* HBK, shows interesting characteristics for cultivation in pots due to the fact of being short and compact, presenting usually 30 cm high and 38 cm wide. Zinnia presents capitulum-type inflorescences 5 cm diameter on average, with ligules color cherry red and lance-shaped leaves. It can be planted in pots, containers or gardens, forming massive sets of flowers. Besides that, the plant shows appropriate architecture to be planted in pots, and is easy to grow, presenting resistance to powdery mildew and bacterial spot (SAKATA, 2001).

Like other plant species, the development of *Zinnia* is influenced by meteorological elements such as solar radiation and air temperature. Reaumur started studies of the climate-plant interactions in 1735, who related the duration of plant development period with a sum of a constant temperature and after that pioneering study; others followed developing the system of thermal units or degrees-day.

The concept of degrees-days presupposes the existence of a base-temperature below which the plant does not grow, and if it does, it will be at much reduced rates. Each plant species or cultivar has a temperature-base feature, which can vary depending on the phenological stage of the plant, being common, however, the adoption of a single average value for the entire crop cycle, once its application is easier (CAMARGO et al., 1987; PEREIRA et al., 2002).

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Knowledge of climate requirements, from emergence to physiological maturation, is fundamental to predict the duration of the crop cycle as a function of the environment. This information, coupled with the knowledge of the phenology of the species can be used in planning the sowing time, the use of inputs and the time for harvesting (GADIOLI et al., 2000).

Different authors in Brazil determined the base-temperature (Tb) and the thermal requirements as a sum of the degree-day (DD) for many crops. As for annual crops the base-temperature vary between 4 and 14º C (ALVES et al., 2000; CAMARGO et al., 1987; BARBANO et al., 2001; GADIOLI et al., 2000; PEDRO JÚNIOR et al., 2004). Considering some perennial crops, it was concluded they present base-temperature of 10º C (SENTELHAS et al., 1995; PEDRO JÚNIOR et al., 1994). Regarding vegetables, the values varied from 5 to 9º C (MOTA, 1981; BARBANO et al., 2002). For ornamentals the variation of the temperature-base is higher (between 1.5 and 14° C), depending on the species (FISHER and LIETH, 2000; PASIAN and LIETH, 1994; DUFOUR and GUÉRIN, 2003; WURR et al., 2002; BOSCHI et al., 2004). The literature on the subject mentions that the base-temperature values are highly variable depending on the species, and consequently the thermal requirements vary according to the crop.

Knowledge of both the lower temperature limits for plants development, and their thermal requirements constitutes a tool to assist producers in planning the sowing and harvesting seasons (PASCALE and DAMARIO, 2004). However for *Zinnia* there is a lack of literature indicating the base-temperature and the thermal requirements for its development, and so this study was carried out with *Zinnia* 'Profusion Cherry', grown in pots under greenhouse conditions in order to determine the temperature-base as well as the thermal requirements expressed in degree-days, giving the producers a better knowledge of the species cycle and helping them to choose the better time of planting and harvesting.

## 2. MATERIAL AND METHODS

The experiment was carried out in an experimental area of Polo Regional de Desenvolvimento Tecnológico dos Agronegócios do Leste Paulista, in Monte Alegre do Sul (SP), at 22°43' S and 46°37' W, 777 m altitude, with *Zinnia* 'Profusion Cherry' grown in pots under greenhouse type high tunnel with the following dimensions: 30 m long, 8 m wide and 5 m high. Covered with low-density polyethylene plastic with a thickness of 100 µ, the greenhouse was closed laterally with 70% shade cloth, east west oriented. The experimental parcel consisted of 36 pots in a 6 x 6 scheme for each parcel. Phenological observations were performed in the 16 central pots, which were arranged on a bench 1 m above the ground with length and width of 8 and 1.5 m, respectively. Two seeds per pot have been sown to ensure the stand of a plant per pot of 0.6 L, commercially known as pot 13 (PINTO et al., 2005). Sowing was carried out every week interval during the period from February to June, totaling 20 sowing dates. The substrate used was the Multplant TDP 3010 at pH of 6.1. The fertilization, as suggested by Pinto et al. (2005) was done with Osmocote Sierra+micronutrients of slow release. Plants were irrigated daily keeping the substrate always moist for the proper development of the plants.

Measurement of maximum and minimum daily air temperatures was done by an automatic meteorological station of DAVIS INSTRUMENTS CORP, and software Groweatherlink version 1.0, installed inside the greenhouse at the level of the pots.

Phenological assessments were done twice a week, by using a grading scale to identify the different phenological stage of plants (GONÇALVES et al., 2008). The beginning and the end of the assessments for each treatment (sowing time) were determined by the date of sowing and by the senescence state of plants, respectively.

The phenological stages of development of *Zinnia* 'Profusion Cherry' were considered: 0: sowing of seeds not yet germinated; 1: sprouted seeds (seedling emergence); 2: seedlings with the first pair of true leaves; 3: seedlings of the second pair of true leaves; 4: seedlings with the apical buds visible, measuring 2 mm approximately; 5: plants with the first flower opened; 6: plants with 50% of the flowers opened; 7: plants with 90% of the flowers opened, and 8: plants with senescent flowers.

The base-temperature of the different phenological subperiods was determined by the method of the relative development (RD), according to Brunini et al. (1976) and Gbur et al. (1979), as follows:

$$\mathbf{RD = a + b.Tmed}$$

where, Tmed is the average temperature of the subperiod (°C); a and b are constants and RD was calculated by:

$$\mathbf{RD = 100/n}$$

where, n is the number of days of the subperiod considered.

When RD is zero, Tmed will be equal to the base-temperature, obtained by:

$$\mathbf{Tb = (-a/b)}$$

where, a and b are, the linear and the angular coefficients of the linear regression, respectively.

The calculation of the degree-day required to complete the different phenological phases, was performed according to the expression:

$$\mathbf{DD = \sum_{i=1}^{n} (Ti - Tb)}$$

where, DD are the degree-day accumulated during the period considerate; Ti is the average daily temperature (C); Tb is the base-temperature (C); n is the number of days of the period considered.

The degree-day accumulated and the base-temperatures were determined for the phenological subperiods of *Zinnia* 'Profusion Cherry' considered of higher importance to the producers, as follows: sowing – first flower opened (0 - 5), considered the phase of production; first flower opened – 50% of flowers opened (5 - 6), phase of commercialization and 50% of the flowers opened – senescence (6 - 8), phase relative to the consumer.

## 3. RESULTS AND DISCUSSION

**Duration of the phenological subperiods:** the duration of the phenological subperiods: (0 - 5); (5 - 6) and (6 - 8) and their relationship with the air temperature, as a function of the sowing date are presented in Figure 1. It shows that the subperiod (0 - 5) was shorter, lasting about 40 days, for sowings made within 40 to 80 days (Julian days), showing a tendency to increase to about 63 days for later sowings made until the 160th day (Julian Day). The duration of the subperiods indicates how long the *Zinnia* would stay in the greenhouse under the producer care, before it could be made available to the consumer market. It is worth mention that the *Zinnia* produced in open conditions should present different durations of subperiods of those observed for *Zinnia* grown under greenhouse conditions.

The duration of the subperiod (5 - 6) varied from 7 to 16 days whereas that of the subperiod (6 - 8) varied from 11 to 25 days for the different sowing dates. As far as is greatest subperiod (5 - 6), considered commercialization phase, greater shelf life. The influence of the temperature on the duration of the subperiods (Figure 1) allows to verify that for the subperiod (0 - 5) the correlation between the duration and the air temperature was high (r = 0.96). It was observed that for average temperatures of 17 ºC the duration was about 65 days, whereas for temperatures of 25 ºC the duration was about 40 days.

For the subperiods: (5 - 6) and (6 - 8) the relationship between the duration and the air temperature was lower, with correlation coefficients of 0.54 and 0.26, respectively, significant at 5%. Probably because they are shorter subperiods, they can be more subject to sampling errors. Yet, for the subperiod (5 - 6) it was observed that when temperature was 17 ºC the duration of the subperiod was 15 days, whereas for 25 ºC it was from 5 to 7 days. This indicates a lower durability of the flowers to the consumer, in the event of an exposure to elevated temperatures.

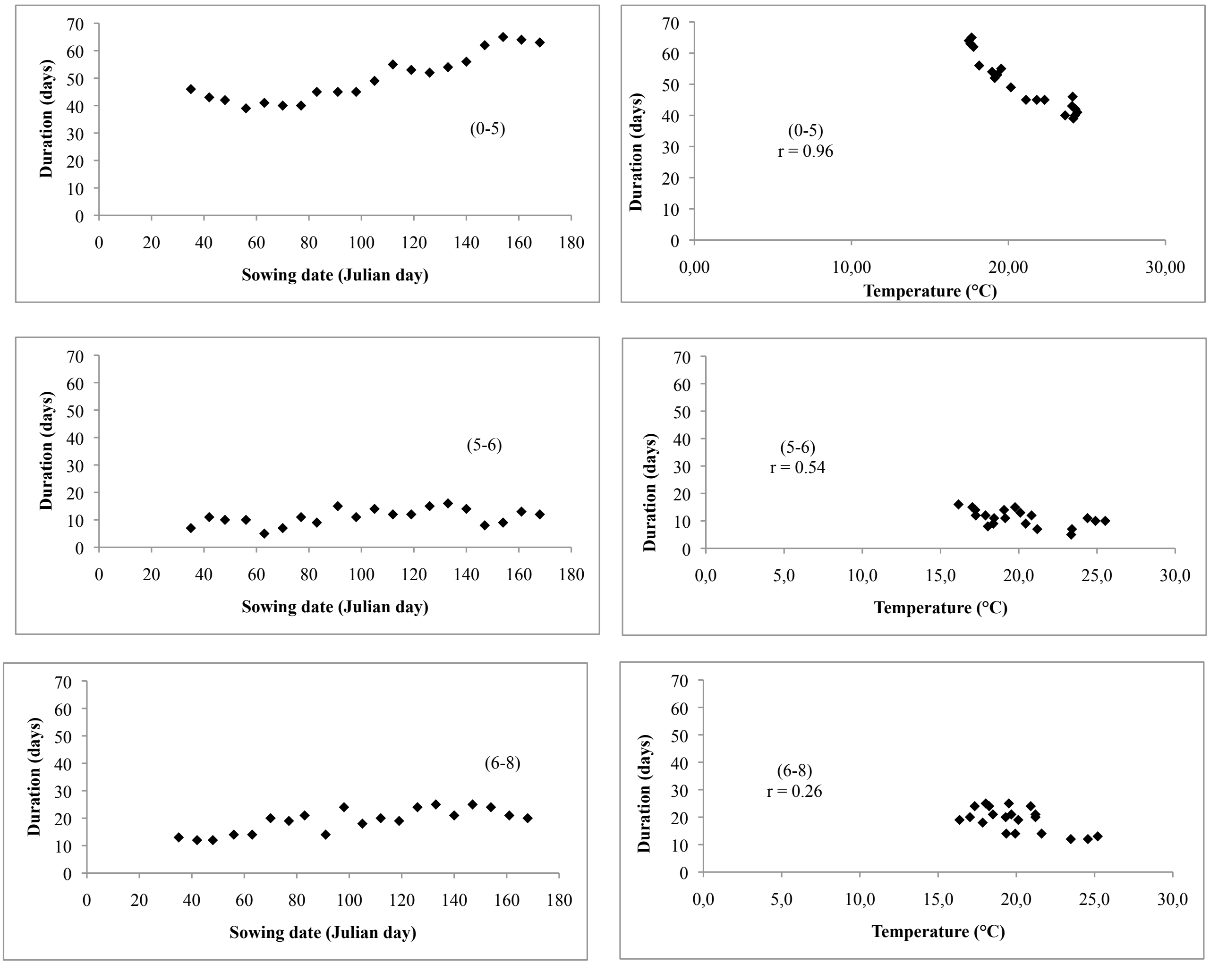


**Figure 1.** Duration of subperiods phenological zinnia 'Profusion Cherry' potted grown in protected cultivation: first open flower-planting (0 – 5); first open flower – 50% of flowers open (5 – 6); 50% of flowers open – senescence (6 – 8) for different sowing dates and relationship with the air temperature.

**Base-temperature:** the values of the base-temperature determined by the method of the relative development for potted *Zinnia* at the different subperiods are presented at Figure 2, corresponding to: 4.1, 3.0, and 6.9 °C, for the subperiods (0 - 5); (5 - 6) e (6 - 8), respectively.

It was observed that the determination coefficients ($R^2$) of the linear regression equations between the relative development and the average air temperature were higher for the longer subperiods. For subperiod (0 - 5) $R^2$ was 0.87, whereas for subperiods (5 - 6) and (6 - 8), they were 0.24 and 0.49, respectively.

Those differences in the value of $R^2$ occurred probably due to the short duration of the subperiods (5 - 6) and (6 - 8) which averaged from 10 to 20 days, allowing the occurrence of some sampling errors of phenological phase whose frequency from 3 to 4 days, could have influenced the values of $R^2$.

The values of base-temperature for *Zinnia* varied as a function of the subperiod, from 3 and 7 °C. These values were lower than the 10 °C generally used for most crops, but on the other hand they were very close to the 4.4 °C mentioned by Nuttonson (1957) for wheat. They are also close to the values of base-temperature related by Pasian and Lieth (1994) for roses that showed value of 5.2 ºC for the cultivars 'Cara Mia', 'Royalty' and 'Sonia'.

The lower values of base-temperature (3.0 ºC) were determined for the subperiod: first flower opened – 50% flowers opened. The determination coefficient ($R^2$ = 0.23) was too low and could have led to some error in estimating the duration of the subperiod. However, the length of this subperiod ranged from 7 and 15 days, and even if an error occurs this would be small from a practical point of view, having no influence on the production process.

On the other hand, for the subperiod: sowing – first flower opened, the most important period for the producer, the $R^2$ = 0.87 from the determination of base-temperature was more precise.

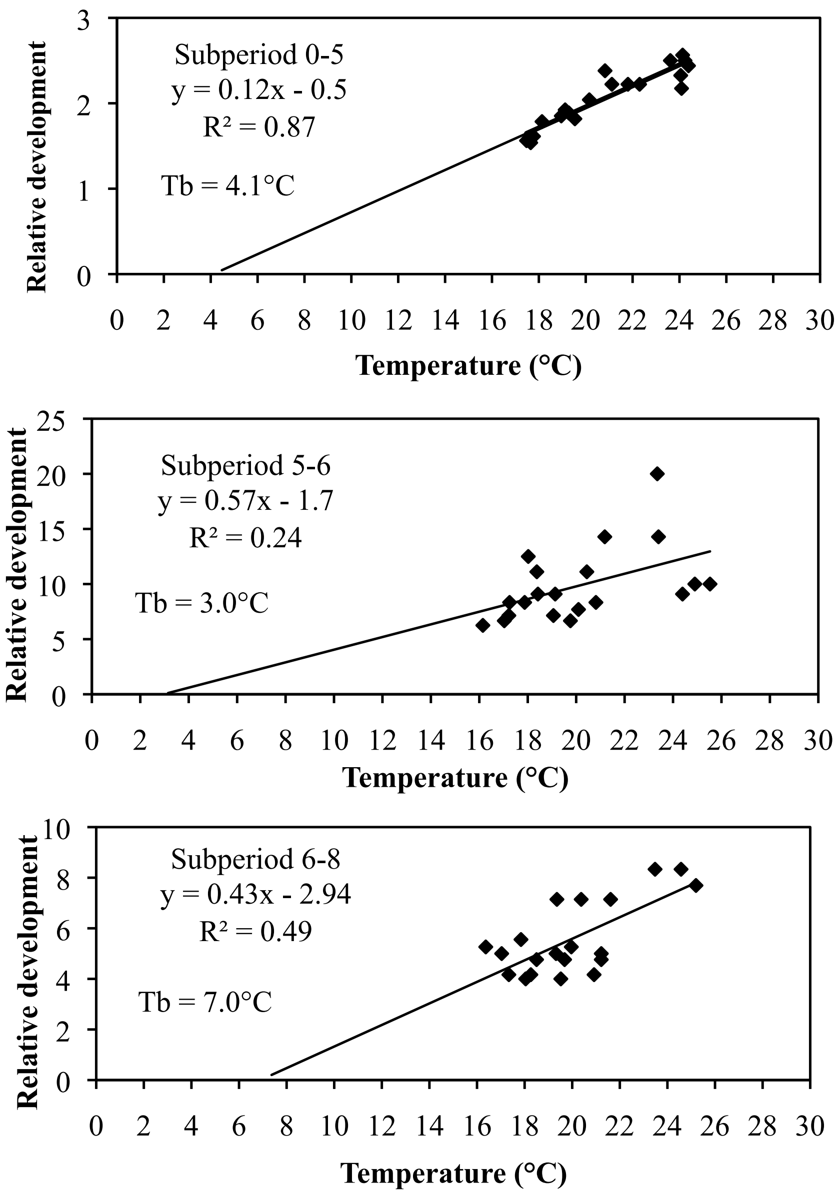


**Figure 2.** Determination of the base temperature for different subperiods phenological zinnia 'Profusion Cherry' bottled by the method of relative development (RD).

**Thermal requirements:** in Table 1 the values of the thermal requirements expressed in degrees-day, are presented for *Zinnia* 'Profusion Cherry' for the subperiods considerate more important in the production system, for the different sowing dates.

The degrees-day (DD) accumulated for the subperiod (0 - 5), as considering the Tb = 4.1 °C, for the different sowing dates averaged 838.1 DD, showing a standard deviation of 37.5 DD. During the experimental period, as a function of the differences observed in the duration of subperiod (0 - 5), the higher DD value observed was 939.5 DD, for the sowing date of 04/02, and the lower was 782.8 DD, for the sowing of 08/04.

For the subperiods (5 - 6) and (6 - 8), the degree-days accumulated were 184.5 and 238.0 DD. The standard deviation for the subperiods (5 - 6) e (6 - 8), were about 20% of the total degree-days required to complete each subperiod, and this could have induced an error of about 3 to 4 days, since in the warmer months there was an accumulation of 20 thermal units per day and in the cooler, around 15 units.

However, the subperiod (0 - 5), that is, from sowing to the first flower opened, when the plant would be under the care of the producers, the errors of the estimate of the duration of the subperiod by the accumulation of degree-days would be lower, as a function of the standard deviation (37.5 DD) and of the highest total degree-days needed to reach the stage of first flower.

**Table 1.** Thermal needs (degree-days) for different subperiods of Zinnia 'Profusion Cherry' grown under protected in Monte Alegre do Sul

| Sowing dates | Julian day | Thermal Requirement (DD) | | |
|---|---|---|---|---|
| | | Subperiod (0-5) | Subperiod (5-6) | Subperiod(6-8) |
| 04/02 | 35 | 939.5 | 142.2 | 238.2 |
| 11/02 | 42 | 878.0 | 237.7 | 209.7 |
| 17/02 | 48 | 860.8 | 225.6 | 195.4 |
| 25/02 | 56 | 801.4 | 218.7 | 202.7 |
| 04/03 | 63 | 852.0 | 101.2 | 179.1 |
| 11/03 | 70 | 825.6 | 126.5 | 247.3 |
| 18/03 | 77 | 800.0 | 169.7 | 249.7 |
| 24/03 | 83 | 837.2 | 157.7 | 264.9 |
| 01/04 | 91 | 814.3 | 250.8 | 172.0 |
| 08/04 | 98 | 782.8 | 177.1 | 268.8 |
| 15/04 | 105 | 802.7 | 224.2 | 194.2 |
| 22/04 | 112 | 864.5 | 170.1 | 201.3 |
| 29/04 | 119 | 819.8 | 179.6 | 175.7 |
| 06/05 | 126 | 796.2 | 211.7 | 247.8 |
| 13/05 | 133 | 817.2 | 209.3 | 275.0 |
| 20/05 | 140 | 800.0 | 200.0 | 240.9 |
| 27/05 | 147 | 861.4 | 120.1 | 314.7 |
| 03/06 | 154 | 894.5 | 138.5 | 334.4 |
| 10/06 | 161 | 869.4 | 224.0 | 299.5 |
| 17/06 | 168 | 862.7 | 214.1 | 282.4 |
| Mean | | 838.1 | 184.5 | 238.0 |
| Standard deviation | | 37.5 | 40.7 | 44.8 |

Subperiod (0 - 5): sowing the opening of the first flower; (5 - 6): opening of the first flower of 50% open flowers; (6 - 8): 50% open flowers senescence.

## 4. CONCLUSIONS

The observations made during the cycle of *Zinnia* 'Profusion Cherry' growing in pots under greenhouse conditions allowed to conclude that plants present cycles from 40 to 70 days, as a function of the air temperature and also that the base-temperature and the thermal requirements in degree-days for the different subperiods were (0 - 5): 4.1°C and 838 DD; (5 - 6): 3.0°C and 184 DD; (6 - 8): 6.9°C and 238 DD, respectively.

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