REVISTA FLORESTA Engenharia Florestal
ISSN 1982-4688
Edição 54
Universidade Federal do Paraná
Setor de Ciências Agrárias

PHENOLOGY OF *Trichocline catharinensis* Cabrera IN AN AREA OF ALTITUDE FIELDS, URUPEMA, SANTA CATARINA, BRAZIL

Angela Camila Lemos[1], Juliano Pereira Gomes[2], Jaçanan Eloisa de Freitas Milani[3], Gabriel Bazanela de Agostini[4*], Adelar Mantovani[5], Roseli Lopes da Costa Bortoluzzi[6]

[1]Secretaria de Educação do Estado de Santa Catarina, Lages, Santa Catarina, Brasil - angelacl@ymail.com
[2]Universidade do Estado de Santa Catarina, Departamento de Engenharia de Pesca e Ciências Biológicas, Laguna, Santa Catariana, Brasil - juliano.gomes@udesc.br
[3]Universidade Federal de Mato Grosso, Departamento de Engenharia Florestal, Cuiabá, Mato Grosso, Brasil - jacanan.milani@gmail.com
[4*]Universidade Federal de Mato Grosso, Programa de Pós-Graduação em Ciências Florestais e Ambientais, Cuiabá, Mato Grosso, Brasil – agostinigb@gmail.com
[5]Universidade do Estado de Santa Catarina, Centro de Ciências Agroveterinárias, Lages, Santa Catariana, Brasil - adelar.mantovani@udesc.br
[6]Universidade do Estado de Santa Catarina, Centro de Ciências Agroveterinárias, Lages, Santa Catariana, Brasil - roseli.bortoluzzi@udesc.br

Received for publication: 08/11/2023 – Accepted for publication: 08/04/2024

Resumo

Fenologia de Trichocline Catharinensis Cabrera em área de campos de altitude, Urupema, Santa Catarina, Brasil. Os campos de altitude catarinenses são dotados de grande riqueza de espécies com potencial econômico, como a *Trichocline catharinensis* Cabrera (Asteraceae), popularmente conhecida como cravo-do-campo, espécie herbácea que ocorre naturalmente no Sul do Brasil. A fim de indicar seu potencial ornamental, o estudo objetivou acompanhar a fenologia da espécie em uma área de campo nativo, na Floresta Ombrófila Mista Alto-Montana, com altitude variando entre 1450 e 1750 metros, inserida na Reserva Particular do Patrimônio Natural Estadual (RPPNE) Complexo Serra da Farofa, na Fazenda das Nascentes, Urupema, SC. Durante 13 meses (abril de 2015 a abril de 2016), em campanhas quinzenais foram monitorados 15 exemplares de *T. catharinensis*. As fenofases vegetativas e reprodutivas foram registradas quanto ao índice de atividade, presença (1) e ausência (0) da fenofases e posteriormente estimada sua sincronia. A espécie é perenifólia com renovação anual das folhas, uma vez em todos os meses avaliados a espécie apresentou brotação e senescência foliar. Todos os exemplares tiveram o registro de floração e frutificação, sendo que a floração teve início no mês de janeiro, com maior pico de botões florais e antese em fevereiro e março respectivamente, e frutificação de março até julho, sua floração é sincrônica. Correlações foram registradas apenas para as fenofases de brotação e botões florais com as temperaturas máxima e mínima. O amplo período de floração pode ser um fator positivo para o potencial ornamental, por apresentar folhagem verde-escura e capítulos amarelos, vistosos.
Palavras-chave: Mata Atlântica; Endêmica; Vulnerável; Ornamental.

Abstract

The high-altitude fields in Santa Catarina are endowed with a great richness of species with economic potential, such as *Trichocline catharinensis* Cabrera (Asteraceae), popularly known as "cravo-do-campo" (field carnation), a herbaceous species that occurs naturally in southern Brazil. In order to indicate its ornamental potential, the study aimed to monitor the phenology of the species in a native field area, in the Alto-Montane Mixed Ombrophilous Forest, with altitudes ranging from 1450 to 1750 meters, located within the Private Natural Heritage Reserve (RPPNE) Complexo Serra da Farofa, at Fazenda das Nascentes, Urupema, SC. For 13 months (from April 2015 to April 2016), 15 specimens of *T. catharinensis* were monitored biweekly. Vegetative and reproductive phenophases were recorded regarding activity index, presence (1) and absence (0) of phenophases, and their synchrony was subsequently estimated. The species is evergreen with annual leaf renewal; once in every month evaluated, the species showed budding and leaf senescence. All specimens had flowering and fruiting records, with flowering starting in January, with a peak of floral buds and anthesis in February and March, respectively, and fruiting from March to July, with synchronous flowering. Correlations were recorded only for the phenophases of budding and floral buds with maximum and minimum temperatures. The wide flowering period may be a positive factor for its ornamental potential, as it presents dark green foliage and showy yellow capitula.
Keywords: Atlantic Forest; Endemic; Vulnerable; Ornamental.

INTRODUCTION

The altitude fields, located in the Atlantic Forest Biome in southern Brazil, make up a phytophysiognomy represented by herbaceous vegetation, interspersed by small shrubs and sub-shrubs, distributed in mosaics of micro habitats with substrates that can vary in fertility, water retention capacity, and soil depth (BELO *et al.*, 2013). Although the altitude fields stand out worldwide for their enormous richness and high rate of endemism, they can still be considered an ecosystem threatened by the intense deterioration they have been suffering from anthropic action (MENEZES; GIULIETTI, 2000). Nevertheless, there is a lack of

studies that can address important aspects for the understanding of this richness, especially about species with commercial interest, highlighting phenological studies, which can fill gaps in the knowledge and conservation of this ecosystem. In this bias, phenology is the science that relates the climate with the periodic events of the species, in order to identify the phenomena of flowering, fruiting, budding, senescence and leaf fall. From these observations the knowledge of the life cycle is learnt, which is directly related to the environment of occurrence of each species (INOUYE, 2022).

Among the different factors that condition the phenological patterns of plant species, climatic seasonality is probably the most important, because in temperate regions, it is linked to abiotic factors such as temperature and photoperiod, these elements can directly control biological events or act on the sensory system of plants (SAKAI; KITAJIMA, 2019; ZELLWEGER *et al.*, 2020). In addition to the regional climate, plants are subject to other local environmental variations, such as altitude differences or nutrient availability, which may have an influence on the phenological behavior (BELO *et al.*, 2013).

When it comes to native plants, with ornamental potential that are barely studied, the phenology becomes even more important, because it helps to understand the vegetative and reproductive phases, such as flowering, fruiting, vegetative development periods and senescence of plants to have better care in the cultivation. The flowering seasons of the plants embellish the landscape and serve as attractions which can increase tourist activities. The species *Trichocline catharinensis* Cabrera, Asteraceae, commonly known as 'Field Carnation', of herbaceous life form, is an indicator of the altitude fields in the middle stage of regeneration in the Mixed Ombrophilous Forest and it is currently considered an endemic and vulnerable species (MONGE; SEMIR, 2020).

Given the above explanation, the aim was to describe the vegetative and reproductive phenology of *Trichocline catharinensis* Cabrera, Asteraceae, which is native in the altitude fields in the Southern Catarinense Plateau and correlate its phenophases with environmental data, indicating its possible ornamental use.

MATERIAL AND METHODS

Study Area

The study was conducted within a Conservation Unit, in the category of Private Reserve of State Natural Heritage (RPPNE), called Complexo Serra da Farofa, located between the coordinates 27º 52'37.33" (latitude) south and 49º 55' 14.39" (longitude) in the municipality of Urupema, Santa Catarina, Brazil, with 4,965.86 hectares, and altitude ranging from 1450 to 1750 meters.

The climate of the region is Cfb (subtropical climate with mild summers), humid, with rainfall well distributed throughout the year and average annual precipitation of 1800 mm. The average annual temperature is 13°C, being common the occurrence of snow, frost and icicle in the colder months, in addition to the presence of fog and high cloudiness.

The soils, because it is an area of altitude (above 1300 meters), are generally shallow with prominent horizon A and humic, belonging to the orders of Neosols and Cambisols (EMBRAPA, 2013). The grassland vegetation is interspersed in the matrix of Alto-Montana Mixed Ombrophilous Forest (FOM-AM) above 1000 meters of altitude, also known as Cloud Forest.

Species Phenology

Over 13 months (April 2015 to April 2016), biweekly field campaigns were carried out for the phenological follow-up of 15 individuals of *T. catharinensis*, which were selected following the criterion of occurrence along the walk (FOURNIER; CHARPANTIER 1975). The observations followed the aspects of the vegetative phenophases: budding (marked by the appearance of small leaves with 1/3 the size of the adult leaf) and leaf senescence (end of photosynthetic activity in the leaf); and reproductive: floral bud (closed capitulum, characterized by the beginning of the formation of the floral structure until anthesis), anthesis (represented by the opening of floral buds until senescence and fall of the petals), immature fruits (phase from fruit formation to growth, evaluated by the presence of green colored fruits) and mature fruits (characterized by the change in color and morphology).

To describe the phenological behavior, the Activity Index was used, which considers the presence (1) or absence (0) of the phenophase in the individual. This assessment is qualitative at the individual level, but quantitative at the population level (BENCKE; MORELLATO, 2002).

The seasonality of the phenophases was verified by circular statistical analysis, in which the days of the year were converted into angles (days of the year divided by 360), being January 1 the zero angle. Thus, the occurrence date or average angle was calculated (μ) and Rayleigh test was done (Z) which determines μ significance level. The length of the vector (r) varies from 0 (the phenological activity is evenly distributed throughout the year) to 1 (the phenological activity is concentrated in a period of the year) (NOGUEIRA *et al.*, 2013). The circular analyses were performed by the software Oriana 4.0 (Kovach, 2011).

The frequency of a given phenophase is proportional to the climatic seasonality, to this end the degree of synchrony of the species was calculated in the dry and rainy seasons, being considered the asynchronous event when < 20% of the individuals manifested the phenophase, little synchronous/low synchronous (20-60%) or high synchronous (> 60%).

Weather variables x Phenology

Spearman correlation analysis (r_s) was used to measure the forces of association between the evaluated phenophases and the meteorological variables. The phenophases were correlated with: accumulated monthly precipitation (mm), average monthly minimum temperature (°C), average monthly maximum temperature (°C) and average monthly relative humidity (%). These analyses were developed using the statistical program R (version 2.2.1, R Development Core Team 2010), using the Vegan library (OKSANEN *et al.*, 2010).

The accumulated precipitation between April 2015 and April 2016 was 2711.6 mm, when the highest monthly precipitation volumes were recorded in the months of September and October (387 mm and 292 mm), respectively. The minimum monthly temperature ranged from 6°C (July) to 13.7°C (March), and the maximum monthly temperature ranged from 11.9°C (July) to 20.7°C (March) (Figure 1), and the relative humidity ranged from 82.54% to 97.01% during the study period.

Meteorological data were provided by EPAGRI/CIRAM (Centro de Informações de Recursos Ambientais e de Hidrometeorologia de Santa Catarina) at the Planalto Sul weather station – 1064, Morro das Antenas, Urupema, Santa Catarina, Brazil, 5km away from the area of study.

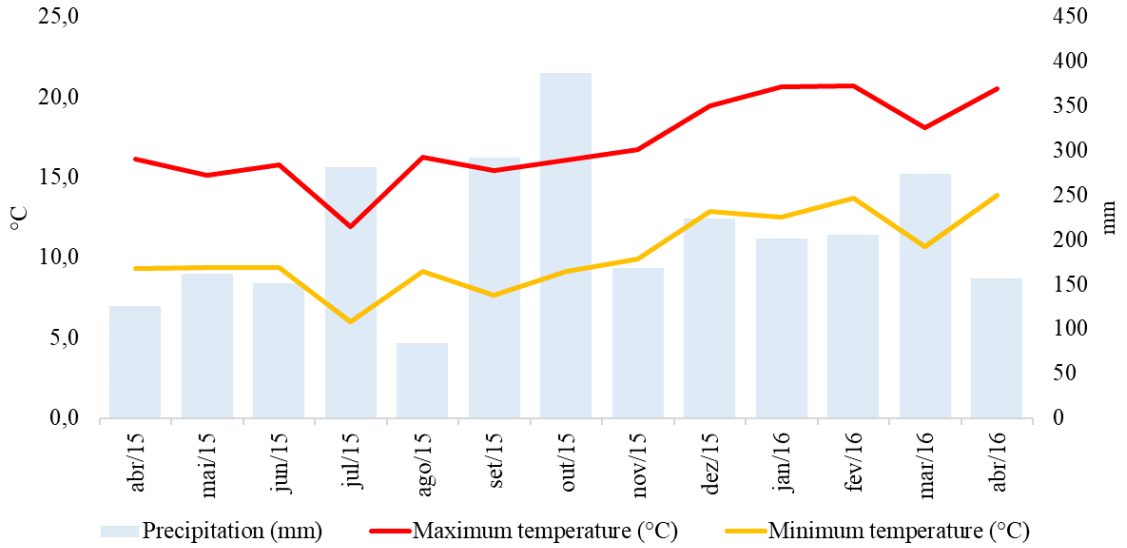

Figure 1. Cumulative monthly precipitation (mm), average monthly minimum temperature (°C), average monthly maximum temperature (°C), Morro das Antenas, Urupema, SC.

Figura 1. Acumulado mensal da precipitação (mm), média mensal da temperatura mínima (°C), média mensal da temperatura máxima (°C), Morro das Antenas, Urupema, SC.

RESULTS

Leaf senescence was observed in almost all months, and in July, August, September and November reached 100% of individuals with leaf fall. However, the species was not completely without leaves, but there was gradual replacement what characterizes the species as evergreen. Budding was observed during the entire monitoring period (Figure 2).

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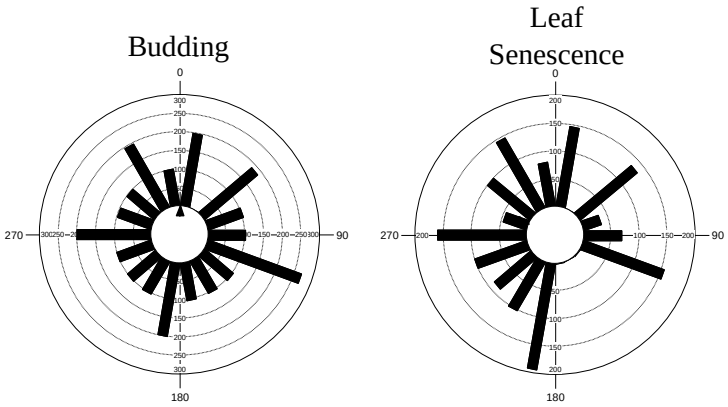

Figure 2. Vegetative phenology of *Trichocline catharinensis* in altitude field - Urupema SC- Brazil.
Figura 2. Fenologia vegetativa de *Trichocline catharinensis* em campo de altitude- Urupema SC- Brasil.

In all individuals evaluated, the flowering phenophase was verified, its reproductive period began in January extending until July. In the first fortnight of January, 2016, *T. catharinensis* started the emission of flower buds in two individuals (13.3%), in the second fortnight, five (33.3%) of the individuals presented flower buds. In February, thirteen (86%) of the individuals presented buds, four (26%) individuals in anthesis (first fortnight) and, in the last fortnight, eleven (73.3%) in anthesis and one (6.6%) with immature fruits. In March observed the presence of all reproductive phases, including mature fruits.

In April, all phenophases also occurred, but with a reduction in the number of buds, anthesis, immature fruits and more than 60% of mature fruits (Figure 3). The reproductive phase had a peak of flowering in February and March and a peak of fruiting in April and May, and in the months of June and July, its fruiting phase was ending. In the months of August to December there was no observation of reproductive structure, only vegetative.

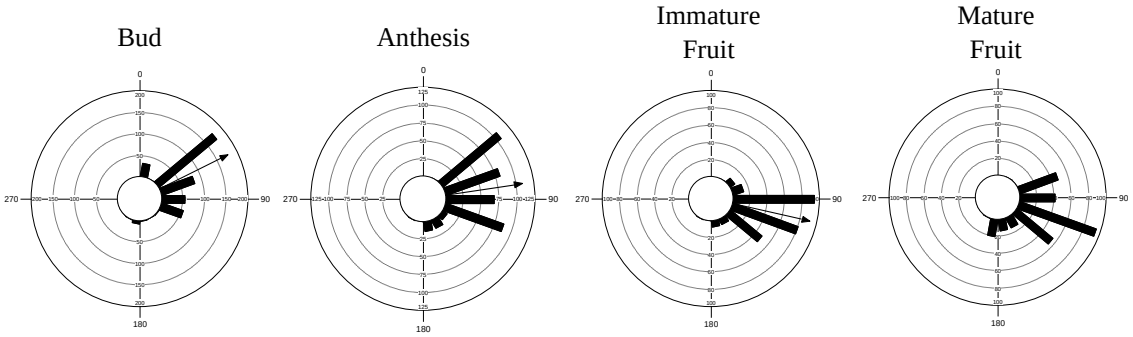

Figure 3. Reproductive phenology of *Trichocline catharinensis* in altitude field - Urupema SC- Brazil.
Figura 3. Fenologia reprodutiva de *Trichocline catharinensis* em campo de altitude- Urupema SC- Brasil.

Flowering began in January and extended until June, with predominance in February and March. The number of capitulum per individual varied from 1-5, and after fruit maturation, the emission of new inflorescences occurred. It is a species with a long reproductive period.

After the appearance of immature fruits, the appearance of pappus with its cypselas was observed (Figure 4). The cypselas detached from the floral receptacle and were dispersed by the wind. In this period, more than 90% of immature fruits were registered, whereas the mature fruits reached a little more than 60%, in the 15 individuals. This fact must be related to the time in which each observation was performed, because the mature fruits had already been dispersed.

For the 15 individuals of *T. catharinensis* that were followed in the study, the synchrony index for the population was high and more than 60% of the individuals presented phenophase in the same period.

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Figure 4. Reproductive and vegetative stages of *T. catharinensis* a - flower bud; b - anthesis; c - immature fruit; d - papus shaped mature fruit; e - leaf fall and sprouting; f - clump of T. catharinensis, at Fazenda das Nascentes, Urupema SC, Brazil. (Red arrow indicates the phenophase).

Figura 4. Fases reprodutivas e vegetativas de *T. catharinensis* a – botão floral; b - antese; c - fruto imaturo; d - fruto maduro em forma de pápus; e - queda e brotação foliar; f - touceira da T. catharinensis, na Fazenda das Nascentes, Urupema SC, Brasil. (Seta vermelha indica a fenofase).

Table 1. Circular statistics of the phenophases Reproductive and vegetative phases of *T. catharinensises.*
Tabela 1. Estatística circular das fenofases Fases reprodutivas e vegetativas de *T. catharinensises.*

Variable	Bud	Anthesis	Immature Fruit	Mature Fruit	Leaf Senescence	Budding
Number of observations	401	372	254	280	1548	2354
Average vector (μ)	63.17°	80.911°	102.659°	110.476°	292.336°	1.799°
Average vector length (r)	0.887	0.871	0.916	0.839	0.191	0.007
Circular standard deviation	28.016°	30.157°	24.023°	33.933°	104.185°	179.697°
Rayleigh test (Z)	315.724	281.987	213.052	197.164	56.726	0.126
Rayleigh test (p)	< 1E-12	< 1E-12	< 1E-12	< 1E-12	< 1E-12	8,82E-01

Negative and significant correlations were identified between budding phenophase with minimum temperature (-0.45) and maximum temperature (-0.46) and bud phenophase with minimum temperature (0.58) and maximum temperature (0.68). No correlations were detected with the variables precipitation and relative humidity as can be seen in Table 2.

Table 2. Spearman's correlation between environmental variables and phenophases of the monitored species *Trichocline catharinensis* between April 2015 to May 2016.

Tabela 2. Correlação de Spearman entre as variáveis ambientais e as fenofases da espécie monitoradas *Trichocline catharinensis* entre abril de 2015 a maio de 2016.

Phenophase/ Morphometry	Precipitation (mm)	Minimum temperature (ºC)	Maximum temperature (ºC)	Relative humidity (%)
Leaf Senescence	*ns*	*ns*	*ns*	*ns*
Budding	*ns*	-0.45	-0.46	*ns*
Bud	*ns*	0.58	0.68	*ns*
Anthesis	*ns*	*ns*	*ns*	*ns*
Immature fruit	*ns*	*ns*	*ns*	*ns*
Mature fruit	*ns*	*ns*	*ns*	*ns*

Note: Assuming significance probability of 95%. *ns* – non-significant.

DISCUSSION

In the study carried out in Serra do Oratório, Santa Catarina, Brazil, in the same morphoclimatic domain, the species expressed a similar phenological behavior, with the peaks of flowering and fruiting in the same months (BASTOS e GRIMALDI, 2020). The difference between the first and last observations of reproductive structures may be related to biotic factors, considering that it is necessary to consider the genetic and evolutionary factors of the species, because the patterns of nature are, mainly, results of the interaction between the environment and the genetic factors of the species (DAVIS *et al.*, 2022).

The flowering season differed from the description made by Cabrera and Klein (1973), stating that the flowering extends from September to April, with predominance in December. According to Inouye (2022), climate change has acted directly in the seasonal calendar of recurring events, especially in the flowering season of plants. It is noteworthy that as shown by the Intergovernmental Panel on Climate Change - IPCC (2021), after 1970, the global surface temperature increased at a faster pace than in any other 50-year period. Thus, it is assumed that temperature changes in recent decades are responsible for the temporal displacement of flowering in the species.

The vegetative phenological behavior of *Galianthe palustris* (Cham. & Schltdl.) Cabaña Fader & E. L. Cabral, other herbaceous species, when located in the same climatic conditions and altitude, has characteristics similar to *T. catharinensis*, since both recorded budding during the entire observation period, while leaf senescence in *G. palustris* recorded peak intensity in the months of July and August, according to *T. catharinensis* which were also observed higher intensities of this phenophase in the same months but also extending to September and November. The periods of anthesis, immature fruit and mature fruit are coincident, differences were observed during the phase of flower buds, in which for *G. palustres*, the occurrence of this phenophase is from January to April, and the peak from January to March, while for *T. catharinensis*, the record of the beforementioned phenophase occurred over ten months, with the peak in July, August, September and the first half of November (OLIVEIRA *et al.*, 2021). These phenological similarities, even among species without phylogenetic proximity but submitted to the same environmental conditions, may be indicative of the influence of environmental conditions in the analyzed phases.

The inversely proportional correlations between budding and maximum and minimum temperatures indicate that increasing temperature reduces the intensity of budding. Higher temperature is responsible for accelerating plant development metabolism (MARTINEZ *et al.*, 2015). However, for *T. catharinensis*, temperature increase acted in order to reduce budding, which may affect the photosynthetic rates of the plant. The absence of correlation of phenophases with precipitation and relative humidity may be related to the fact that, during the study period, the monitored individuals did not undergo water stress. In contrast, in the phenological study of Bastos and Grimaldi (2020), performed in Santa Catarina with *T. catharinensis*, a correlation was found between precipitation and anthesis, differing from the current study.

The characteristics observed in the phenological behavior of the species and its relations with meteorological variables favor the ornamental aspect, because the species presents startling capitula in yellow, giving the contrast with dark green leaves, having potential to be used in ornamentation by the population in mountainous region, and it can be grown in pots, gardens and well drained beds. Further studies about this species are recommended for more details.

CONCLUSIONS

- *Trichocline catharinensis* is a perenifolian species, producing foliage all year round. Reproductive phenophases are observed during a long period, reaching up to six months, then a favorable characteristic for the use in landscaping, and high synchrony in flowering contributes to its value and use as ornamental.
- The phenological behavior of the species is predominantly linked to climatic conditions, as there was a positive correlation between floral bud and minimum and maximum temperatures, and a negative correlation between budding and minimum and maximum temperatures

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