Ornamental Horticulture
ISSN 2447-536X | HTTPS://ORNAMENTALHORTICULTURE.EMNUVENS.COM.BR/RBHO
SBFPO Sociedade Brasileira de Floricultura e Plantas Ornamentais

SCIENTIFIC ARTICLE

Damage and lethal temperature due to heat stress in field grown dahlia

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Abstract

Dahlia is an ornamental plant well adapted to open field cultivation and is one of the crops in the "Flowers for All" Project, a nation-wide extension project. High temperatures and the duration of extreme heat waves are expected to be more frequent in the next decades. Therefore, understanding and determining the high temperature that causes irreversible damage in Dahlia flowers is of high interest for preparing farmers to mitigate and adapt their crop to climate change. The objective of this study was to determine the upper lethal temperature that causes irreversible damage on buds and flowers on open field grown dahlia. Commercial open field dahlia crops in five locations in Rio Grande do Sul (RS) State, Southern Brazil, during two growing seasons (2021/22 and 2022/23) were used in this study. During the period from 20 December 2021 to 30 January 2022 and from 14 January 2023 to 20 January 2023, daily observations were made in the dahlias in the five locations in order to identify symptoms of heat stress on leaves, buds and flowers such as leaf rolling, wilting, dry leaf edges, sunscald, burning and rotting. The appearance of those symptoms was correlated with maximum daily air temperature in order to estimate the lethal temperature. Irreversible heat injury in buds and flowers of open field grown dahlia start when air temperature reaches 35 ºC. Artificial shading, irrigation and planting date are management practices that can help farmers to protect dahlia flowers from heat stress.
Keywords: climate change, cut flowers, *Dahlia sp,* heat stress, heat injury, high temperatures.

Resumo

Dano e temperatura letal devido ao estresse por calor em dália cultivada a campo

A dália é uma planta ornamental bem adaptada ao cultivo a campo e é uma das culturas do Projeto "Flores para Todos", um projeto de extensão nacional. Estima-se que as altas temperaturas e a duração de ondas de calor extremo sejam mais frequentes nas próximas décadas. Portanto, entender e determinar a alta temperatura que causa danos irreversíveis nas flores da dália é de grande interesse para preparar os agricultores para mitigar e adaptar sua cultura às mudanças climáticas. O objetivo deste estudo foi determinar a temperatura letal superior que causa danos irreversíveis em botões e flores de dália cultivada a campo. Culturas comerciais de dálias cultivadas a campo em cinco locais no estado do Rio Grande do Sul (RS), sul do Brasil, durante duas temporadas de cultivo (2021/22 e 2022/23) foram utilizadas neste estudo. Durante o período de 20 de dezembro de 2021 a 30 de janeiro de 2022 e de 14 de janeiro de 2023 a 20 de janeiro de 2023, foram feitas observações diárias nas dálias nas cinco localidades, a fim de identificar sintomas de estresse térmico em folhas, brotos e flores, como enrolamento de folhas, murchamento, bordas secas das folhas, queimaduras solares, queimaduras e apodrecimento. O aparecimento desses sintomas foi correlacionado com a temperatura máxima diária do ar para estimar a temperatura letal. Lesões térmicas irreversíveis em botões e flores de dálias cultivadas a campo começam quando a temperatura do ar atinge 35 °C. Sombreamento artificial, irrigação e data de plantio são práticas de manejo que podem ajudar os agricultores a proteger as dálias do estresse térmico.
Palavras-Chave: estresse por calor, lesões por calor, altas temperaturas, mudanças climáticas, flores de corte.

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https://doi.org/10.1590/2447-536X.v29i2.2624
Received Feb 14, 2023 | Accepted May 16, 2023 | Available online Jun 7, 2023

Editor: José Carlos Sorgato

Introduction

In Brazil, the consumption of flowers and ornamental plants reproduces the scenario of developing countries and other countries in Latin America, Asia and Africa, that is, the demand concentrated on special dates and occasions of the calendar, such as International Women's Day, Mother's Day, Valentine's Day, The All Souls' Day, among others. The professional activity of production, commercialization and distribution of cut flowers and ornamental plants has been one of the most promising in Brazilian agribusiness (Menegaes et al., 2015; Junqueira and Peetz, 2017; Streck and Uhlmann, 2021).

Flower and ornamental crops is a promising sector for small landhoders, since it does not require an extensive area of land for cultivation and the production cycle of a large part of the species is short (Spier et al., 2020). However, to be successful with a flower crop, it is necessary to know the recommended planting time to have the flowers ready for commercialization at the recommended harvest time, mainly with open field crops (Uhlmann et al., 2017). Studies have been conducted on the cultivation of gladiolus in open field in Brazil, seeking to understand the influence of environmental factors, such as temperature, on the duration of the development cycle and on the quality of the selected cultivar (Schwab et al., 2018), but not for dahlias.

Dahlia sp is an ornamental plant well adapted to open field cultivation, with colorful flowers, and widely used as a garden plant and as a cut flower. Belonging to the Asteraceae family, Dahlia is native to the mountainous region of Mexico. It is an herbaceous, shrubby, perennial plant, with tuberous root system and upright growth. Its inflorescence is a capitulum of different types or shapes, such as orchid, anemone, pompom, waterlily, cactus and decorative, rounded in shape, with various colors of flowers and there are species of a flower of two colors. The propagation of this plant is by seeds, stem cuttings and tubers (Kashif et al., 2014). Because of these agronomic and ornamental traits, Dahlia is one of the crops of the "Flowers for All" Project, a nation-wide extension project that began in 2018 in order to promote the cultivation of flowers as a source of income and diversification for small landholders through species and genotypes of flowers that have rusticity, are ease of production and promote rapid financial return to farmers (Uhlmann et al., 2019; Streck and Uhlmann, 2021).

Air temperature has a direct influence on plant growth and development (Bergamaschi, 2007). The lowest/highest temperature below to/above which there is no plant development or development takes place at very low rates than can be negligible are called lower base temperature (Tb) and upper base temperature (TB) while the temperature at which plant development is at the maximum rate is called the optimal temperature (Topt) (Erpen et al., 2013). When temperature drops to below Tb freezing temperature or when temperature exceeds TB, then irreversible lethal temperatures (TLb and TLup, respectively) can be achieved and some organs of the plant or the whole plant die (Munns, 2018).

Cardinal temperatures for the development of dahlia are 5.5 ºC, 24.6 ºC and 34.9 ºC (minimum, optimal and maximum temperatures, respectively) during the vegetative phase, 2.4 ºC, 22.4 ºC and 31.3 ºC during the development phase of the floral bud and 5.2 ºC, 24.4 ºC and 33.1 ºC from the appearance of the bud to flowering phase (Brondum and Heins, 1993). Although there are cardinal temperatures in the literature for different developmental phases of dahlia, values of TLup for floral development that cause irreversible damage by heat stress in open field cultivation were not found. High temperatures are common during the summer months in the tropics and subtropics of Southern Brazil, such as the heat wave that occurred during the month of January 2022 in Rio Grande do Sul State. This heat wave was characterized by a record of several consecutive days with extremely high maximum air temperatures (exceeding 40 ºC). In some meteorological stations of the National Institute of Meteorology (INMET) and the Secretary of Agriculture, Livestock and Rural Development (SEAPDR), 15 consecutive days were recorded with maximum daily temperatures higher than 39 ºC (Cardoso et al., 2022). According to research carried out (Tazzo et al., 2022) The meteorological results corroborate the INMET bulletin, which indicated that the heat wave (12 to 23 January), covered all regions of the State (INMET, 2022). Such high temperatures and the duration of extreme heat waves are expected to be more frequent in the next decades (Intergovernmental Panel on Climate Change - IPCC, 2021). Therefore, understanding and determining the high temperature that causes irreversible damage in Dahlia flowers is of high interest for preparing farmers to mitigate and adapt their crop to climate change. The objective of this study was to determine the upper lethal temperature that causes irreversible damage on buds and flowers in open field grown dahlia.

Material and Methods

Commercial open field dahlia crops in Rio Grande do Sul (RS) State, Southern Brazil, during two growing seasons (2021/22 and 2022/23) were used in this study. During the 2021/22, the farms were located in Santa Maria/RS and Cachoeira do Sul/RS whereas during the 2022/23 the farms were located in Novo Cabrais/RS, Lajeado/RS and Júlio de Castilhos/RS. Details on the dahlia crops in each farm are in Table 1.

Table 1. Dahlia farms during two growing seasons (2021/22 and 2022/23) in Rio Grande do Sul State, Brazil, used in the study.

Location	*Cultivars*	*Planting Date (dd/mm/yyyy)*	*Date of first flowering (dd/mm/yyyy)*
Santa Maria	Rebecca´s World, Siberia, Promisse, Dark Spirit, Pompom	21/09/2021	01/12/2022
Cachoeira do Sul	Rebecca´s World, Siberia, Promisse, Dark Spirit, Pompom	14/10/2021	08/12/2022
Novo Cabrais	Rebecca´s World, Sibéria	18/11/2022	08/01/2023
Lajeado	Rebecca´s World, Sibéria	21/11/2022	15/01/2023
Júlio de Castilhos	Rebecca's World, Sibéria	18/11/2022	06/01/2023

Tubers from a private company were used by farmers. Tubers were planted in beds 1.0 m wide and 0.2 m height spaced 0.40 m x 0.40 m at 0.05 cm depth in all farms. All farmers used irrigation in their dahlia crops, except the crop in Santa Maria where no irrigation was used after 15 December 2021. In all farms, pre-planting fertilization was performed using 50g/m² of NPK, in formulation 5-20-20. When the first flower was harvest, a dressing fertilization was performed using 50g/m^2 of urea and 50g/m^2 of potassium chlorate.

Daily minimum and maximum air temperatures were collected from automatic meteorological stations of the INMET (2022), located in Santa Maria, Cruz Alta, Teutônia, and Rio Pardo. The weather station in Santa Maria represented the climate of the farm in Santa Maria and Novo Cabrais, the weather station in Cruz Alta represented the climate of the farm in Julio de Castilhos, the weather station in Teutônia represented the climate in Lajeado and the wather station in Rio Pardo represented the climate in Cachoeira do Sul.

Ten plants per cultivar were tagged in each farm at the time of the appearance of the floral bud, a moment that marks the beginning of the reproductive phase of the crop. During the period from 20 December 2021 to 30 January 2022, and from 14 January 2023 to 20 January 2023, daily observations were made in the dahlias in the five locations in order to identify symptoms of heat stress on leaves, buds, and flowers such as leaf rolling, wilting, dry leaf edges, sunscald, burning and rotting. The appearance of those symptoms were correlated with maximum daily air temperature measured at the meteorological stations in order to estimate the lethal temperature. The maximum temperature achieved the day before the symptom of heat stress was assumed to be the upper lethal temperature.

Results and discussion

Dahlia plants were exposed to a large variation in temperatures during the growing season in the two locations in 2021/22 growing season (Figure 1). During the period from 10 to 26 January 2022, an intense heat wave took place in the Rio Grande do Sul State as a result of an atmospheric blockage (SEAPDR, 2022) leading to an absolute maximum temperature of 39.6 °C and 40.8 °C in Santa Maria and in Cachoeira do Sul, respectively, and a16 days in a row of temperature above 33.1 ^{o}C, the upper base temperature (TB) for dahlia during the reproductive phase (Brondum and Heins, 1993), in both locations.

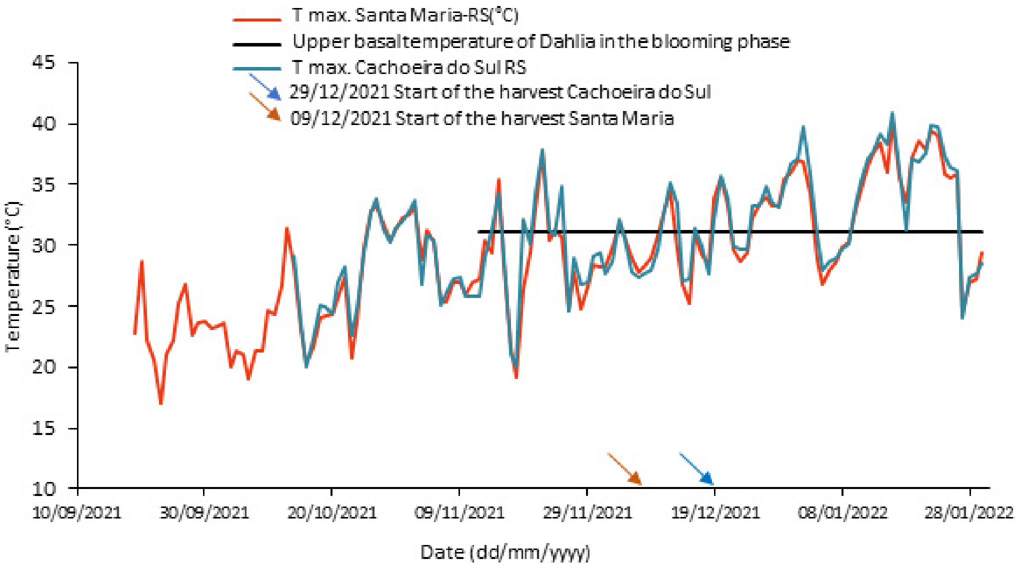

Figure 1. Maximum temperatures in Santa Maria and in Cachoeira do Sul-RS, Brazil, during the 2021/22 dahlia growing season.

During the 2021/2022 growing season, in Santa Maria the injury by heat stress (burning) on dahlia buds and flowers in all cultivars was first observed in Santa Maria on 12 January 2022 and the maximum temperature on the day before was 35.2 ºC (Figure 2). In Cachoeira do Sul, the burning of buds and flowers was first observed on 20 January 2022 and the maximum temperature on the day before was 37.2 ºC (Figure 2).

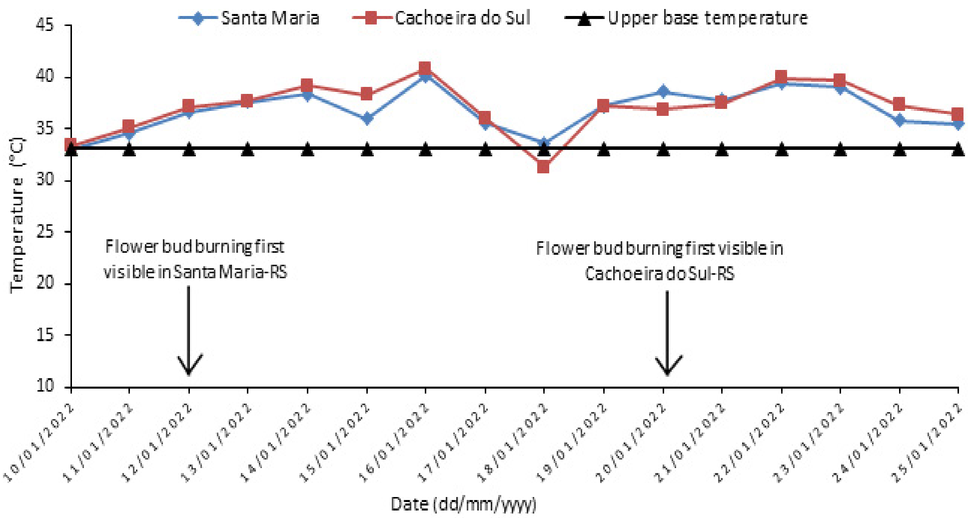

Figure 2. Maximum air temperature during the period that the first symptoms of heat damage (burning) on Dahlia buds and flowers occurred in Santa Maria and in Cachoeira do Sul, RS/Brazil. The dotted line corresponds to the upper base temperature (TB) for dahlia during the reproductive phase (Brondum and Heins, 1993).

Observations of heat stress symptoms during the 2022/2023 growing season were also well related with high temperatures in Novo Cabrais and Lajeado (Figure 3a), and in Júlio de Castilhos (Figure 3b). Until 16/01/2023, no symptoms were observed in the dahlia plants in Novo Cabrais and Lajeado. Then on 17/01/2023 the maximum temperature was 35.3 ºC in Novo Cabrais and 34.9 ºC in Lajeado and the first symptoms of burning on buds were observed on 18/01/2023 in both locations and cultivars, indicating that the lethal temperature was achieved on 17/01/2023. Similarly, but one week later, in Julio de Castilhos the first symptoms of burning on buds were observed on 24/01/2023 and the maximum temperature the day before was 34.8 ºC.

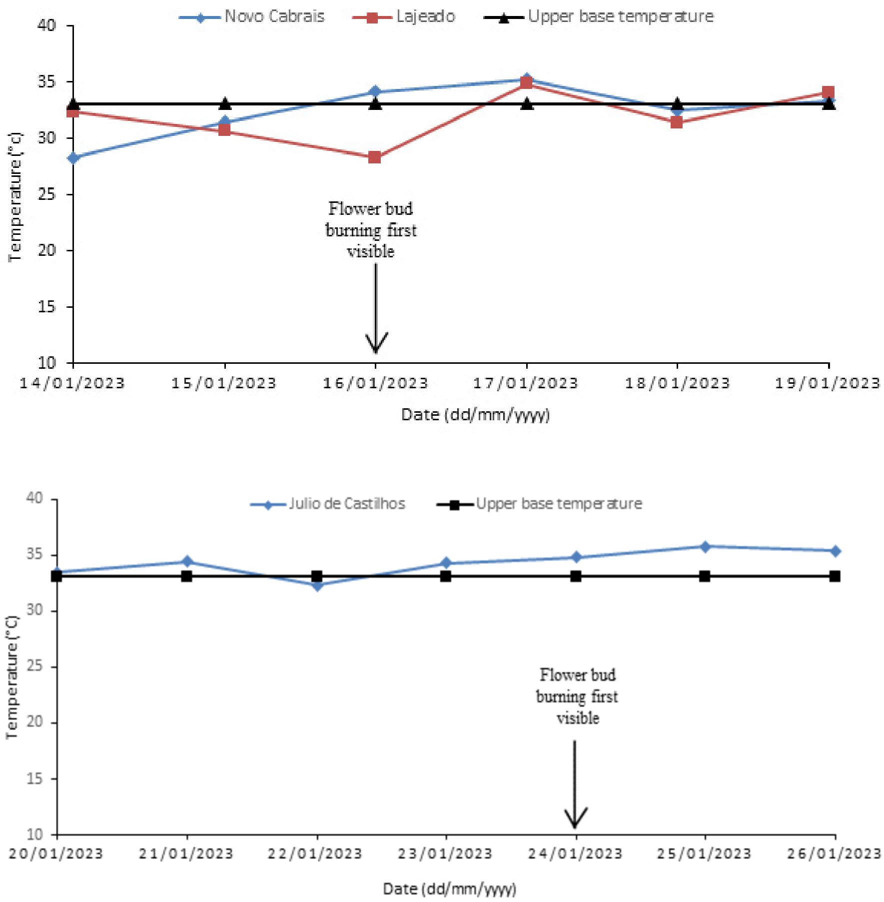

Figure 3. Maximum daily air temperature from 01/14/2023 to 01/19/2023 in Novo Cabrais/RS and Lajeado/RS (A) and Julio de Castilhos/RS from 01/20/2023 to 01/26/2023 (B). The dotted line corresponds to the upper basal temperature (TLup) of dahlia during the reproductive phase (Brondum and Heins, 1993).

From the results of the five locations, in four of them (Santa Maria, Novo Cabrais, Lajeado, and Julio de Castilhos) the temperature was close to 35oC the day before the symptom of burning on buds and flowers was observed. Only in Cachoeira do Sul the temperature that led to bud and flower burning was higher (37.2 ºC, Figure 2). Being conservative and for a safer recommendation for farmers, taking the average of the maximum temperature values the day before the first symptoms of burning at the four locations (Santa Maria, Novo Cabrais, Lajeado, and Julio de Castilhos), 35 °C (± 0.2 °C) is an indication of the lethal temperature that cause irreversible damage by heat stress in buds and petals of open field grown dahlias.

Symptoms of injury due to heat stress in the five locations during the two growing seasons were characterized as burning of sepals and petals (Figure 4) and were irreversible both on buds (Figures 4A, 4B, 4E, 4F, 4G, 4J) or on semi open and open flowers (Figures 4C, 4D, 4H, 4I, 4K, 4L). Flower development stopped in injured dahlia buds and flowers, with a typical "mummification" of the burned parts (Figures 4A to 4L).

Figure 4. Damage caused by high temperatures in dahlia bud and flowers cultivated in the field in Santa Maria (A, B, C and D), in Cachoeira do Sul (E, F, G and H), and in Julio de Castilhos (I, J, K and L), Rio Grande do Sul State, Brazil

A heat wave is a climatic phenomenon characterized by the rise of maximum or minimum air temperature above than expected for the same region and the same time of year for a period of at least three consecutive days, providing the formation of an uncomfortable environment and harmful to health and agriculture (Lopes and Fioravanti, 2017). According to the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC), evidence of observed changes in extremes in weather events such as heat waves and droughts increased since the previous AR5 and they are projected to increase in their frequency and intensity during the next decades (IPCC, 2021). The Summer 2021/2022 was remarkable hot and dry in Southern Brazil (Figure 2) (Cardoso et al., 2022), breaking records of high temperature in many locations across the Rio Grande do Sul State.

Cut flower crops are especially sensible to heat stress mainly because the marketable part of the plant (flower) is composed by petals and sepals whose tissue is very sensible to heat stress. In a recent study, Becker et al. (2021) demonstrated that temperatures above 34 ºC that cause burning of sepals and petals in gladiola flowers can be remarkable increased by climate change scenarios projected for the next decades in the state of Rio Grande do Sul State, Brazil. Results presented in this study show that heat waves with temperatures above 35 ºC cause irreversible injury to bud and flowers of cut dahlias.

In all locations, growing seasons and cultivars, injury due to heat was only observed in the reproductive parts (buds and flowers) of dahlia plants with no injury on leaves, stems and peduncles (Figure 4), i.e the vegetative parts of a dahlia plant are very resistant to heat stress (temperatures up to 40.8 ºC did not cause injury in leaves). Similar results were reported for gladiolus, were heat injury caused by temperatures above 34 ºC were not observed in vegetative parts (leaves), but were very remarkable on sepals and petals of the florets, and the last florets of the spike may not open if the crop is exposed to temperatures above 35 °C, even when under irrigation (Uhlmann et al., 2017; Schwab et al., 2018).

From the results of this study, a management practice that dahlia farmers can use to protect buds and flowers from heat injury is to use artificial shading with nets when dahlia are grown in regions that high temperature can achieve the threshold of 35 ºC. Another important management practice that farmers can take is to maintain dahlia plants well-watered. A water-stressed canopy can have up to 3 ºC greater temperature compared to a well-water canopy (Bockhold et al., 2011). Therefore, based on our results we hypothesize that in a dahlia crop that is under water stress, heat injury in buds and flowers can start when temperature reaches 32 ºC.

Another important management factor that can help dahlia farmers to minimize heat injury is planting date. In the Subtropics such as in Rio Grande do Sul State, planting dahlia early in Spring will provide harvesting stating when temperatures still are not very high, thus avoiding injury by heat. A second planting can be performed in late Summer, so that reproductive phase starts when temperatures are dropping in early Fall, thus also avoiding high temperatures.

Conclusions

Irreversible heat injury in buds and flowers of open field grown dahlia start when air temperature reaches 35 ºC. Artificial shading, irrigation, and planting date are management practices that can help farmers to protect dahlia flowers from heat stress.

Acknowledgments

To the farmers Milton Cauzzo, Maria Elza Silva de Carvalho and Diesser Artier Mota, Leonir Fátima de Oliveira de Freitas, Clóvis Fernando de Freitas, Mara Elaine Scortegagna Flores, Newton Flores e Sandra Puper for allowing measurements and observations on their dahlia crops. Authors thanks to The PhenoGlad Team for helping in collecting data.

Author contribution

MESF: conception of the work, collection, analysis and interpretation of the data, writing and critical review of the article. **RT**: conception of the work, collection, analysis and interpretation of the data, writing and critical review of the article. **CPOF**: conception of the work, collection, analysis and interpretation of the data, writing and critical review of the article. **TPR**: conception of the work, collection, analysis and interpretation of the data, writing and critical review of the article. **MHLS**: conception of the work, collection, analysis and interpretation of the data, writing and critical review of the article. **LOU**: work advisor, work conception, data collection, analysis and interpretation, writing and critical review of the article. **AZJ**: work advisor, work conception, data collection, analysis and interpretation, writing and critical review of the article. **NAS**: work advisor, work conception, data collection, analysis and interpretation, writing and critical review of the article.

References

BECKER, C.C.; STRECK, N.A.; UHLMANN, L.O; CERA, J.C.; FERRAZ, S.E.T.; SILVEIRA, W.B.; BALEST, D. S.; SILVA, L.F. Assessing climate change effects on gladiola in Southern Brazil. **Scientia Agricola**, v.78, n.1, e20180275, 2021. https://doi.org/10.1590/1678-992X-2018-0275

BERGAMASCHI, H. O clima como fator determinante da fenologia das plantas. In: REGO, C.M.; NEGRELLE, R.R.B.; MORELATTO, L.P.C. **Fenologia:** ferramenta para conservação, melhoramento e manejo de recursos vegetais arbóreos. Colombo: Embrapa Florestas, 2007. 291-310p.

BOCKHOLD, D.L.; THOMPSON, A.L.; SUDDUTH, K.A.; HENGGELER, J.C. Irrigation scheduling based on crop canopy temperature for humid environments. **Transactions of the ASABE**, v.54, n.6, p.2021-2028, 2011.

BRONDUM, J.J.; HEINS, R.D. Modeling temperature and photoperiod effects on growth and development of Dahlia. **Journal of the American Society Horticultural Science**, v.118, n.1, p.36-42, 1993. https://doi.org/10.21273/JASHS.118.1.36

CARDOSO, L.S.; VARONE, F.; JUNGES, A.H.; TAZZO, I.F. Condições meteorológicas ocorridas em janeiro de 2022 e situação das principais culturas agrícolas no estado do Rio Grande do Sul. **Comunicado Agrometeorológico**, n.34, p.6-29, 2022.

ERPEN, L.; STRECK, N.A.; UHLMANN, L.O.; LANGNER, J.A.; WINCK, J.E.M.; GABRIEL, L.F. Estimativa das temperaturas cardinais e modelagem do desenvolvimento vegetativo em batata-doce. **Revista Brasileira de Engenharia Agrícola e Ambiental,** v.17, n.11, p.1230-1238, 2013. https://doi.org/10.1590/S1415-43662013001100015

INMET. Instituto Nacional de Meteorologia**. Boletim Agrometeorológico Mensal.**, Porto Alegre, fevereiro de 2022. Available at: <https://portal.inmet.gov.br/uploads/boletinsAgroclimatologicos/BoletimAgro_2022-02-versaofinal.pdf>. Accessed on: Feb 23 2023.

INMET. Instituto Nacional de Meteorologia**.** Onda de calor persiste no Estado do Rio Grande do Sul. **INMET, Nota Meteorológica**, Porto Alegre, 20 janeiro de 2022.

IPCC (INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE). Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York: Cambridge University Press, 2021. 3-32p.

JUNQUEIRA, A.H.; PEETZ, M.S. Brazilian consumption of flowers and ornamental plants: habits, practices and trends. **Ornamental Horticulture**, v.23, n.2, p.178-184, 2017. http://dx.doi.org/10.14295/oh.v23i2.1070.

KASHIF, M.; RIZWAN, K.; KHAN, M.A.; YOUNIS, A. Efficacy of macro and micro-nutrients as foliar application on growth and yield of *Dahlia hybrida* L. (Fresco). **International Journal of Chemical and Biochemical Sciences**, v.5, p.6-10, 2014.

LOPES, R.J.; FIORAVANTI, C. Ondas de calor mais intensas, longas e frequentes. **Revista Pesquisa FAPESP**, v.262, p.25-29, 2017.

MENEGAES, J.F.; BACKES, F.A.A.L.; BELLÉ, R.A.; BACKES, R.L. Diagnóstico do mercado varejista de flores de Santa Maria, RS. **Ornamental Horticulture**, v.21, n.3, p.291-8, 2015. https://doi.org/10.14295/oh.v21i3.629

MUNNS, R. Temperature and acclimation. In: **Plant in action**. New Zealand: Australian Society of Plant Scientists, 2018. Avalilable at: https://rseco.org/content/chapter-14-temperature-and-acclimation.html. Accessed on: Jan 7, 2023.

SCHWAB, N.T.; STRECK, N.A.; UHLMANN, L.O.; BECKER, C.C.; RIBEIRO, B.S.M.R.; LANGNER, J.A.; TOMIOZZO, R. Duration of cycle and injuries due to heat and chilling in gladiolus as a function of planting dates. **Ornamental Horticulture**, v.24, n.2, p.163-73, 2018. http://dx.doi.org/10.14295/oh.v24i2.1174.

SEAPDR (SECRETARIA DA AGRICULTURA, PECUÁRIA E DESENVOLVIMENTO RURAL). **Prognóstico Climático Trimestral:** Março-abril-maio de 2022. Rio Grande do Sul: SEAPDR, 2022. Available at: https://www.agricultura.rs.gov.br/upload/arquivos/202203/03165918-boletimclimasimagro-2022-n06.pdf. Accessed on: Jan 29, 2022.

SPIER, J.; SILVA, V.N.; LEITE, J.G.D.B. Ornamental plants in Chapecó: Market characteristics and opportunities for Family farms. **Ornamental Horticulture**, v.26, n.3, p.346-55, 2020. https://doi.org/10.1590/2447-536X.v26i3.2152.

STRECK, N.A.; UHLMANN, L.O. Flowers for all; bridging the gap between science and society. **Chronica Horticulturae**, v.61, n.3, p.32-34, 2021.

TAZZO, I. F.; VARONE, F.; CARDOSO, L. S.; JUNGES, A. H. Condições meteorológicas ocorridas em fevereiro de 2022 e situação das principais culturas agrícolas no estado do Rio Grande do Sul. **Comunicado Agrometeorológico**, n.35, p.6-21, 2022.

UHLMANN, L.O.; BECKER, C.C.; TOMIOZZO, R.; STRECK, N.A.; SCHONS, A.; BALEST, D.C.; BRAGA, M.S.; SCHWAB, N.T.; LANGNER, J.A. Gladiolus as an alternative for diversification and profit in small rural property. **Ornamental Horticulture**, v.25, n.2, p.200-208, 2019. https://doi.org/10.14295/oh.v25i2.1541.

UHLMANN, L.O.; STRECK, N.A.; BECKER, C.C.; SCHWAB, N.T.; BENEDETTI, R.P.; CHARÃO, A.S.; RIBEIRO, B.S.M.; SILVEIRA, W.B.; BACKES, F.A.A.L.; ALBERTO, C.M.; MUTTONI, M.; PAULA, G.M.; TOMIOZZO, R.; BOSCO, L.C.; BECKER, D. PhenoGlad: A model for simulating development in Gladiolus. **European Journal of Agronomy**, v.82, p.33-49, 2017. https://doi.org/10.1016/j.eja.2016.10.001.