

ISSN 1678-3921

Journal homepage: [www.embrapa.br/pab](http://www.embrapa.br/pab)

For manuscript submission and journal contents,  
access: [www.scielo.br/pab](http://www.scielo.br/pab)

## Bud-break promoters for the improvement of the budburst of pecan cultivars

**Abstract** – The objective of this work was to evaluate the effect of different bud-breaking substances on the budburst of the Barton, Desirable, and Jackson pecan (*Carya illinoensis*) cultivars. The experimental design was a randomized complete block with four replicates. The treatments consisted of spraying different rates of commercial bud-break promoters on the trees of these cultivars, in order to induce budburst. The budburst percentage of axillary buds and the budburst heterogeneity index (BHI) were evaluated. Regardless of the used rate, the application of the hydrogen cyanamide product improved the budburst of the tested cultivars and reduced the BHI. In addition, water soluble N + Ca at 6% and water soluble N + organic C soluble in water at 7% significantly improve the budburst and reduce the BHI of the evaluated cultivars, being, therefore, potential alternatives to replace hydrogen cyanamide.






**Index terms:** *Carya illinoensis*, bud break, budburst homogeneity, dormancy release.

### Promotores para a melhoria de brotação de cultivares de noqueira-pecã

**Resumo** – O objetivo deste trabalho foi avaliar o efeito de diferentes substâncias indutoras de brotação nas cultivares de noqueira-pecã (*Carya illinoensis*) Barton, Desirable e Jackson. O delineamento experimental foi em blocos ao acaso, com quatro repetições. Os tratamentos consistiram da aplicação de diferentes concentrações de produtos comerciais nas plantas dessas cultivares, para a indução de brotação. Foram avaliados a percentagem de brotação de gemas axilares e o índice de heterogeneidade de brotação (IHB). Independentemente da concentração utilizada, a aplicação do produto cianamida hidrogenada melhorou a brotação das cultivares testadas e reduziu o IHB. Além disso, N solúvel em água + Ca a 6% e N solúvel em água + C orgânico solúvel em água a 7% melhoram significativamente a brotação e reduzem o IHB das cultivares avaliadas e são, portanto, potenciais alternativas para substituir a cianamida hidrogenada.


**Termos para indexação:** *Carya illinoensis*, brotação, homogeneidade de brotação, superação de dormência.

Pecan is a temperate fruit species that requires the accumulation of low temperatures during the winter to overcome dormancy (Zheng et al., 2021). Chilling accumulation in Southern Brazil ranges from 200 to 1,000 chilling hours (<7.2°C, CH), depending on the cultivar (Crosa et al., 2021), which is usually sufficient to overcome the dormancy of pecan nuts. However, Southern Brazil is known as a typical warm-

Horacy Fagundes da Rosa Júnior<sup>(1)</sup> ,  
Mateus da Silveira Pasa<sup>(1)</sup> ,  
Marcelo Barbosa Malgarim<sup>(1)</sup> ,  
Ezequiel Helbig Pasa<sup>(1)</sup>  and  
Júlia Damé Fonseca Paschoal<sup>(2)</sup> 

<sup>(1)</sup> Universidade Federal de Pelotas, Faculdade de Agronomia Eliseu Maciel, Caixa Postal 354, CEP 96010-900 Pelotas, RS, Brazil.  
E-mail: [horacyf@gmail.com](mailto:horacyf@gmail.com),  
[mateus.pasa@gmail.com](mailto:mateus.pasa@gmail.com),  
[malgarim@ufpel.edu.br](mailto:malgarim@ufpel.edu.br),  
[ezequielpasa@gmail.com](mailto:ezequielpasa@gmail.com)

<sup>(2)</sup> Universidade Federal de Pelotas, Faculdade de Biotecnologia, Caixa Postal 354, CEP 96010-900 Pelotas, RS, Brazil.  
E-mail: [juliadfp@outlook.com](mailto:juliadfp@outlook.com)

 Corresponding author

Received  
April 18, 2022

Accepted  
July 19, 2022

#### How to cite

ROSA JÚNIOR, H.F. da; PASA, M. da S.;  
MALGARIM, M.B.; PASA, E.H.; PASCHOAL,  
J.D.F. Bud-break promoters for the improvement  
of the budburst of pecan cultivars. **Pesquisa  
Agropecuária Brasileira**, v.57, e02956, 2022.  
DOI: <https://doi.org/10.1590/S1678-3921.pab2022.v57.02956>.



winter climate region, which show a wide range of temperature fluctuation during the winter (Lamela et al., 2020), and great variations in CH accumulation throughout years. Budburst and flowering in such conditions are usually deficient, not uniform (Pasa et al., 2018a), and they frequently lead to reduced yields. An alternative to overcome these problems is the use of rest-breaking substances to partially compensate for the lack of CH, which is a common practice widely used in apple orchards to promote budburst (Pasa et al., 2018a; Marques et al., 2022).

The most widely used rest-breaking agent is hydrogen cyanamide (Dormex) showing high efficiency to overcome dormancy in several fruit species, such as apple (Pasa et al., 2018a; Marques et al., 2022), peach (Chen & Beckman, 2019), and grapevine (Sudawan et al., 2016). However, its high toxicity is a limiting factor (Petri et al., 2014), the reason why studies on rest-breaking substances of low toxicity and good efficiency are important (Pasa et al., 2018a). In pecan nuts, studies regarding rest-breaking agents are scarce worldwide and not yet known in Brazil. Recent studies have shown that more environment friendly, rest-breaking compounds (based on inorganic nitrogen, glutamic acid, and amino acids) – such as Erger (Petri et al., 2014; Pasa et al., 2018a), Sincron (Petri et al., 2014), Siberio and Bluprins (Petri et al., 2021) – have a similar efficiency in apples.

The objective of this work was to evaluate the effect of different bud-breaking substances on the budburst of the Barton, Desirable, and Jackson pecan nut cultivars.

The experiment was carried out in a commercial orchard of pecan nuts located in the municipality of Encruzilhada do Sul, in the state of Rio Grande do Sul, Brazil (30°37'21.2"S, 52°42'16.8"W, at 485 m altitude), in the 2019/2020 and 2020/2021 growing seasons. The climate of the region, according to Köppen-Geiger's classification is Cfa, that is, humid subtropical, oceanic climate, without a dry season and with a hot summer (Alvares et al., 2013). The accumulation of chilling hours (CH) below 7.2°C (45°F), from June 15 to September 15 was 475 hours in 2019, and 773 hours in 2020. Chilling units (CU) in the mentioned period were 1,047 and 1,239 in 2019 and 2020, respectively, in the conditions of the experimental site during the experiment (Figure 1) The soil of the experimental orchard is an Argissolo Vermelho-Amarelo distrófico

(Santos et al., 2018), i.e., an Ultisol (Soil Survey Staff, 2014).

Plant material consisted of pecan trees of the Barton, Desirable, and Jackson cultivars, which were planted in the winter of 2015 and trained to a central leader system. These cultivars complement each other regarding pollination. Trees were spaced 8.5 m between rows and 8.5 m between trees within the row, totaling 138 trees per hectare. The experiment was carried out in a randomized complete block design, with four replicates of three trees in each plot. Only the central tree was used for evaluation, leaving one at each end as border. Trees were chosen by uniformity of size, trunk diameter, and health. Treatments were sprayed to the same trees in both seasons. Orchard management was performed according to commercial growing standards and were similar for all treatments, that is, trees were fertilized according to soil analysis, at the beginning of the growing season, pruned during the winter, and sprayed with fungicides to avoid diseases – mainly pecan scab (*Venturia effusa*). The orchard was not irrigated.

The treatments consisted of different rates of the following commercial bud-break promoters: hydrogen cyanamide (HC, 52% a.i, w/v) at 1, 2, and 3% (Dormex, BASF S.A., São Paulo, SP, Brazil); water soluble nitrogen (18.7%, w/v) and calcium (4.2%, w/w) (WSN+Ca) at 2, 4, and 6% (Erger, Valagro do Brasil Ltda., São Paulo, SP, Brazil); organic matter (80%, w/w), free amino acids (2%, w/w), and organic nitrogen (0.3%, w/w) (OM+FAA+ON) at 2, 4, and 6% (Sincron, Daymsa do Brasil, Indaiatuba, SP, Brazil); water soluble nitrogen (15%, w/v) and calcium oxide (4.5%, w/v) (WSN+CaO) at 4, 6, and 8% (Siberio, Green Has, São Paulo, SP, Brazil); and water soluble nitrogen (8% w/w) and organic carbon soluble in water (5%, w/w) (WSN+OCS) at 3, 5, and 7% (Bluprins, Biolchim, São Paulo, SP, Brazil). Hydrogen cyanamide treatments were supplemented with 3% mineral oil (Iharol, at 76% a.i., w/v) (Iharabras, Sorocaba, SP, Brazil), while all other treatments were supplemented with 3% calcium nitrate (CaN) (YaraLiva Calcinit at 15.5% N and 19% Ca, w/w) (Yara Brasil Fertilizantes, Santo Antonio de Posse, SP, Brazil).

Treatments were applied to plants on 9/10/2019 and 9/18/2020, when buds were between the stages 001 (beginning of bud swelling) and 003 (end of bud swelling), according to BBCH scale (Lancashire et al.,

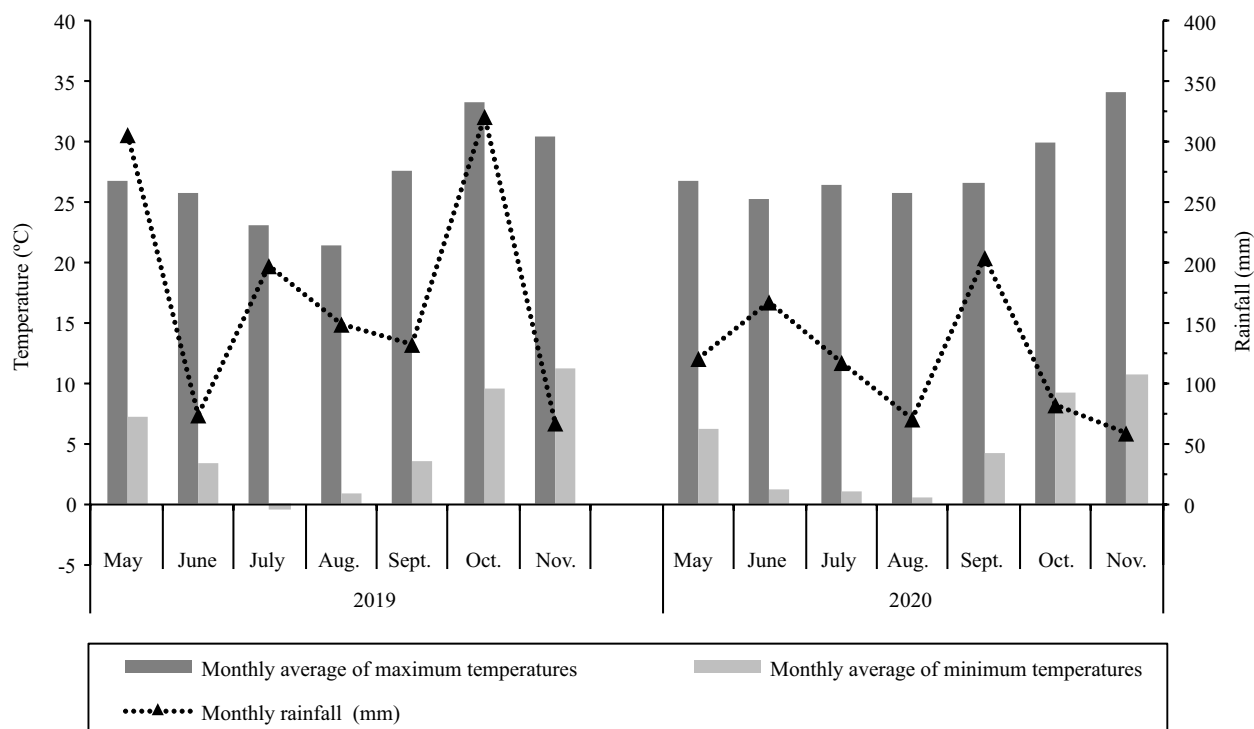
1991). Spraying was performed on trees to the point of runoff with a backpack sprayer, during the morning (9:00–11:00 h), when temperature ranged from 20 to 25°C, relative humidity was 70–75%, and wind speed was from 1.9 to 2.2 km h<sup>-1</sup>. Water pH was about 5.95. Each tree was subjected to spraying of approximately 1 L of solution.

In both seasons, the percentage of budburst of axillary buds and budburst heterogeneity index (BHI) were evaluated. Eight uniform one-year-old shoots were selected to perform the evaluations. These chosen shoots were 20–30 cm long and had between 15 and 25 axillary buds; water sprouts were avoided. Budburst was obtained by the ratio between buds breaking dormancy and the total number of buds of each shoot, expressed as percentage (%). Budburst was evaluated at 30 days after the application (DAA). Buds breaking dormancy were considered as those which were at least in the stage 009 (green tip clearly visible), according to the BBCH scale (Lancashire et al., 1991). The standard deviation (SD) within each treatment/replicate was determined from the eight one-year-old shoots selected, and then the coefficient of

variation was calculated as  $CV = [(SD/\text{average axillary bud break}) \times 100]$ , which was called the budburst heterogeneity index (BHI). The CV ranged from 0 to 100%, expressing the homogeneity of budburst among shoots within the treatment.

Statistical analyses were performed using the R software (R Core Team, 2014). Data of 'Desirable' pecan budburst in 2019/2020 and of BHI of 'Jackson' in 2020/2021 were transformed by arcsin [square root (n + 1)] to meet the assumptions of the analysis of variance. Data were analyzed for statistical significance by the F-test and, when means were significant, Scott-Knott's test was performed to group the treatment means.

In the 2019/2020 growing season, a significant effect of treatments was observed for all parameters evaluated and cultivars. The greater budburst was induced by HC at 1%, in 'Barton'; by HC (1, 2, and 3%), WSN+Ca (4 and 6%), and WSN+OCS (7%) in 'Desirable'; and by HC (1, 2, and 3%), in 'Jackson' (Table 1). Hydrogen cyanamide at all rates resulted in the lower BHI of all cultivars, but other treatments had similar effect, such as OM+FAA+ON (4%), WSN+CaO (8%), and



**Figure 1.** Monthly average of minimal and maximum temperatures, and monthly rainfall at the experimental site, in 2019 and 2020 growing seasons.

WSN+OCS (7%) in 'Barton'; WSN+Ca (4 and 6%) in 'Desirable'; and WSN+Ca (4 and 6%), WSN+CaO (6 and 8%) and WSN+OCS (7%) in 'Jackson' (Table 1).

Our results show that the budburst of all tested cultivars was improved by hydrogen cyanamide, and that BHI reduced, irrespectively of the rate applied. These results agree with those found for 'Maxi Gala' and 'Fuji Suprema' apples (Petri et al., 2014; Pasa et al., 2018a, 2018b), which showed consistent improvement of budburst with hydrogen cyanamide at 0.7%. Given the limited information on the subject, rates from 1 to 3% were evaluated, and the results show that in future studies lower rates could be tested to check this agent efficiency.

Considering the 2020/2021 growing season, budburst and BHI were significantly affected by treatments in all cultivars, except for BHI in Jackson (Table 2). Budburst and BHI were not improved by any treatment in 'Barton' in this growing season. Indeed, budburst was reduced for all rates of OM+FAA+ON and WSN+CaO, and WSN+OCS at 3%, while BHI

increased in all rates of OM+FAA+ON. However, budburst of 'Desirable' was improved by all treatment application, in comparison with the control, and the best results were observed in the application of HC (1, 2, and 3%), whereas BHI was not significantly reduced by any treatment, in comparison with the control. For 'Jackson', all treatments, except for OM+FAA+ON (all rates) improved budburst, in comparison with the control. The greatest budburst in this cultivar was observed with the application of HC (at all rates) and WSN+OCS (7%), followed by WSN+Ca (2, 4, and 6%).

It is possible to observe that, in the second season, the effect of bud-break promoters was less evident, with budburst percentages of control trees greater than in the first season. Indeed, treatments did not improve budburst or reduced BHI of 'Barton', in comparison with the control. This effect may be explained by the greater chilling accumulation in the 2020/2021 season (773 CH; 1,239 chilling units), in comparison with that of the 2019/2020 growing season (475 CH, 1,047 chilling units). Even though pecan nuts may have a

**Table 1.** Budburst percentage and budburst heterogeneity index (BHI) of three pecan (*Carya illinoensis*) cultivars, as affected by different bud-break promoters, in the 2019/2020 growing season<sup>(1)</sup>.

Treatment	Barton		Desirable		Jackson	
	Budburst (%)	BHI (%)	Budburst (%)	BHI (%)	Budburst (%)	BHI (%)
Control	15.0c	45.7a	36.3b	52.6a	54.8b	33.7c
HC 1% + MO 3%	85.7a	19.6b	89.8a	10.1b	95.0a	5.9d
HC 2% + MO 3%	58.2b	29.4b	89.7a	10.5b	93.7a	5.5d
HC 3% + MO 3%	58.9b	37.1b	96.2a	7.0b	93.7a	8.4d
WSN+Ca 2% + CaN 3%	30.2c	67.9a	42.4b	56.4a	56.5c	38.2c
WSN+Ca 4% + CaN 3%	41.0c	64.4a	75.4a	20.0b	62.8b	15.7d
WSN+Ca 6% + CaN 3%	33.7c	58.7a	71.8a	32.8b	69.9b	9.8d
OM+FAA+ON 2% + CaN 3%	17.9c	59.6a	48.8b	56.3a	40.3c	42.4c
OM+FAA+ON 4% + CaN 3%	11.4c	22.2b	17.7b	62.6a	18.1d	62.6b
OM+FAA+ON 6% + CaN 3%	8.5c	68.2a	23.0b	53.4a	30.6d	34.8c
WSN+CaO 4% + CaN 3%	34.8c	55.3a	44.2b	48.9a	41.6b	85.6a
WSN+CaO 6% + CaN 3%	47.6b	52.3a	44.0b	39.5a	69.7b	22.8d
WSN+CaO 8% + CaN 3%	18.7d	27.0b	58.0b	52.5a	70.2b	17.5d
WSN+OCS 3% + CaN 3%	48.7b	66.1a	45.6b	56.3a	66.6b	37.7c
WSN+OCS 5% + CaN 3%	36.9c	64.2a	55.7b	49.7a	71.4b	43.0c
WSN+OCS 7% + CaN 3%	65.0b	31.2b	76.0a	54.0a	76.8b	13.6d
p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

<sup>(1)</sup>Different letters within columns indicate significant differences, by Scott-Knott's test, at 5% probability. The following promoters were applied to the cultivars on 9/10/2019: HC, hydrogen cyanamide (52% a.i, w/v) (Dormex); WSN+Ca, water soluble nitrogen (18.7%, w/v) and calcium (4.2%, w/w) (Erger); OM+FAA+ON, organic matter (80%, w/w), free amino acids (2%, w/w), and organic nitrogen (0.3%, w/w) (Synchron); WSN+CaO, water soluble nitrogen (15%, w/v) and calcium oxide (4.5%, w/v) (Siberio); and WSN+OCS, water soluble nitrogen (8% w/w) and organic carbon soluble in water (5%, w/w) (Bluprins); MO, mineral oil; CaN, calcium nitrate.

regular development in regions with low chilling accumulation (Fronza et al., 2018), Zheng et al. (2021), a great improvement of budburst of pecan nut was observed as exposure to chill increased, and the time required to reach maximum budburst was reduced. The effect of the greater chilling accumulation from the first to the second season on treatment effect can be observed by the fact that any treatment reduced BHI relative to control, i.e., chilling supplied was capable to fulfill even control trees requirement, regardless the cultivar. Similar results were observed in a three-year study of 'Fuji Suprema' apple trees, in which the authors observed differences only in the BHI induced by promoters in the year of lower chilling accumulation (Pasa et al., 2018b).

Cultivar responses to treatments were somehow similar, and hydrogen cyanamide induced greater budburst and lower BHI, but there were positive cultivar responses to WSN+Ca (6%) and WSN+OCS (7%). However, in the second growing season, there was no budburst improvement in 'Barton', even in response to hydrogen cyanamide.

Even though hydrogen cyanamide is still the most widely applied substance to induce bud break (Marques et al., 2022) in fruit trees with proved efficiency, other substances (mainly nitrogen-based compounds have shown to be approximately or equally efficient, such as WSN+Ca, which has been extensively studied in apples, with optimum rates varying from 2 to 4% combined with either CaN or mineral oil (Pasa et al., 2018a). A recent study showed that the bud release from dormancy of 'Anna' apple trees was correlated with increased levels of soluble nitrogen, total nitrogen, and polyamines (small aliphatic nitrogenous compounds) (El-Yazal & Rady, 2012), which partially explains the positive effect of nitrogenous substances, such as WSN+Ca on budburst, as observed in the present study, in which WSN+Ca 6% + CaN 3% had an efficiency like hydrogen cyanamide, irrespectively of the cultivar tested. However, rates greater than 7% in apples are not recommended, since negative impacts may occur on fruit set, resulting in higher operational issues and costs given the greater substance volume needed for application, according to Petri et al. (2021).

**Table 2.** Budburst percentage and budburst heterogeneity index (BHI) of three pecan (*Carya illinoensis*) cultivars, as affected by different bud-break promoters, in the 2020/2021 growing season<sup>(1)</sup>.

Treatment	Barton		Desirable		Jackson	
	Budburst (%)	BHI (%)	Budburst (%)	BHI (%)	Budburst (%)	BHI (%)
Control	64.9a	12.9b	59.4e	19.0b	71.0c	16.3
HC 1% + MO 3%	74.5a	13.3b	85.0a	9.8b	86.9a	8.1
HC 2% + MO 3%	73.2a	12.0b	84.7a	5.6b	88.4a	4.8
HC 3% + MO 3%	69.7a	13.2b	84.8a	9.7b	87.6a	7.9
WSN+Ca 2% + CaN 3%	66.4a	14.9b	70.7d	12.2b	83.3b	10.0
WSN+Ca 4% + CaN 3%	69.4a	15.6b	75.2c	11.0b	82.5b	10.7
WSN+Ca 6% + CaN 3%	69.0a	15.1b	73.3c	19.7b	82.1b	13.7
OM+FAA+ON 2% + CaN 3%	43.2c	33.8a	50.6f	29.7a	70.5c	10.9
OM+FAA+ON 4% + CaN 3%	38.6c	28.2a	50.3f	25.0a	70.0c	12.9
OM+FAA+ON 6% + CaN 3%	33.5c	33.7a	47.3f	31.9a	70.1c	12.8
WSN+CaO 4% + CaN 3%	53.4b	18.5b	66.7d	17.0b	79.9b	9.8
WSN+CaO 6% + CaN 3%	55.4b	21.5b	69.5d	11.0b	81.0b	11.0
WSN+CaO 8% + CaN 3%	58.7b	22.3b	70.5d	32.0a	83.3b	14.3
WSN+OCS 3% + CaN 3%	62.1b	21.2b	73.9c	12.7b	83.1b	9.6
WSN+OCS 5% + CaN 3%	68.0a	14.6b	75.2c	12.3b	83.5b	10.3
WSN+OCS 7% + CaN 3%	70.2a	19.8b	79.8b	13.0b	84.9a	7.7
p-value	< 0.001	0.0413	< 0.001	< 0.001	< 0.001	0.4219

<sup>(1)</sup>Different letters within columns indicate significant differences, by Scott-Knott's test, at 5% probability. The following promoters were applied to the cultivars on 9/18/2020: HC, hydrogen cyanamide (52% a.i, w/v) (Dormex); WSN+Ca, water soluble nitrogen (18.7%, w/v) and calcium (4.2%, w/w) (Erger); OM+FAA+ON, organic matter (80%, w/w), free amino acids (2%, w/w), and organic nitrogen (0.3%, w/w) (Syncron); WSN+CaO, water soluble nitrogen (15%, w/v) and calcium oxide (4.5%, w/v) (Siberio); and WSN+OCS, water soluble nitrogen (8% w/w) and organic carbon soluble in water (5%, w/w) (Bluprins); MO, mineral oil; CaN, calcium nitrate.

Budburst of the tested cultivars are improved by hydrogen cyanamide (HC), as well as BHI is reduced, regardless of the applied rate. Besides, WSN+Ca (6%) and WSN+OCS (7%), consistently improve budburst and reduce BHI in all cultivars and, therefore, are potential alternatives to replace hydrogen cyanamide.

### Acknowledgments

To Fundação de Amparo à Pesquisa do Estado do Rio Grande do Sul (Fapergs), for financial support (grant number 19/2551-0001899-1); and to Pecanera Brasil, for kindly providing plant material and supporting the research.

### References

- ALVARES, C.A.; STAPE, J.L.; SENTELHAS, P.C.; GONÇALVES, J.L. de M.; PAROVEK, G. Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, v.22, p.711-728, 2013. DOI: <https://doi.org/10.1127/0941-2948/2013/0507>.
- CHEN, C.; BECKMAN, T.G. Effect of a late spring application of hydrogen cyanamide on high-chill peaches. *Agronomy*, v.9, art.726, 2019. DOI: <https://doi.org/10.3390/agronomy9110726>.
- CROSA, C.F.R.; DE MARCO, R.; SOUZA, R.S. de; MARTINS, C.R. Dormência vegetativa da noqueira-pecã: uma revisão. *Agropecuária Catarinense*, v.34, p.78-82, 2021. DOI: <https://doi.org/10.52945/rac.v34i2.1139>.
- EL-YAZAL, M.A.S.; RADY, M. Changes in nitrogen and polyamines during breaking bud dormancy in 'Anna' apple trees with foliar application of some compounds. *Scientia Horticulturae*, v.136, p.75-80, 2012. DOI: <https://doi.org/10.1016/j.scienta.2012.01.001>.
- FRONZA, D.; HAMMANN, J.J.; BOTH, V.; ANESE, R. de O.; MEYER, E.A. Pecan cultivation: general aspects. *Ciência Rural*, v.48, e20170179, 2018. DOI: <https://doi.org/10.1590/0103-8478cr20170179>.
- LAMELA, C.S.P.; REZEMINI, F.; BACINO, M.F.; MALGARIM, M.B.; HERTER, F.G.; PASA, M. da S. Dormancy dynamics of 'Tannat' grapes in warm-winter climate conditions. *Agricultural and Forest Meteorology*, v.288, p.1-9, 2020. DOI: <https://doi.org/10.1016/j.agrformet.2020.108016>.
- LANCASHIRE, P.D.; BLEIHOLDER, H.; VAN DEN BOOM, T.; LANGELÜDDEKE, P.; STAUSS, R.; WEBER, E.; WITZENBERGER, A. A uniform decimal code for growth stages of crops and weeds. *Annals of Applied Biology*, v.119, p.561-601, 1991. DOI: <https://doi.org/10.1111/j.1744-7348.1991.tb04895.x>.
- MARQUES, L.O.D.; PASA, M. da S.; MELLO-FARIAS, P.C.; HERTER, F.G. Influence of budburst inducers replacing hydrogen cyanamide on phenological parameters of 'Castel Gala' apple trees. *Scientia Horticulturae*, v.295, e110867, 2022. DOI: <https://doi.org/10.1016/j.scienta.2021.110867>.
- PASA, M. da S.; FELIPPETO, J.; NAVA, G.; SOUZA, A.L.K. de; BRIGHENTI, A.F.; PETRI, J.L. Performance of 'Maxi Gala' apple trees as affected by budbreak promoters, in São Joaquim-SC. *Revista Brasileira de Fruticultura*, v.40, e-537, 2018a. DOI: <https://doi.org/10.1590/0100-29452018537>.
- PASA, M. da S.; FELIPPETO, J.; NAVA, G.; SILVA, C.P.; BRIGHENTI, A.F.; CIOTTA, M.N. Performance of 'Fuji Suprema' apple trees treated with budbreak promoters, in São Joaquim-SC. *Revista Brasileira de Fruticultura*, v.40, e-325, 2018b. DOI: <https://doi.org/10.1590/0100-29452018325>.
- PETRI, J.L.; LEITE, G.B.; COUTO, M.; GABARDO, G.C.; HAWERROTH, F.J. Chemical induction of budbreak: new generation products in replacement of hydrogen cyanamide. *Acta Horticulturae*, v.1042, p.159-166, 2014. DOI: <https://doi.org/10.17660/ActaHortic.2014.1042.19>.
- PETRI, J.L.; SEZERINO, A.A.; HAWERROTH, F.J.; PALLADINI, L.A.; LEITE, G.B.; MARTIN, M.S. de. **Dormência e indução à brotação de árvores frutíferas de clima temperado**. Florianópolis: Epagri, 2021. 153p. (Epagri. Boletim Técnico, 192).
- R CORE TEAM. **R: a language and environment for statistical computing**. Vienna: R Foundation for Statistical Computing, 2014.
- SANTOS, H.G. dos; JACOMINE, P.K.T.; ANJOS, L.H.C. dos; OLIVEIRA, V.Á. de; LUMBRERAS, J.F.; COELHO, M.R.; ALMEIDA, J.A. de; ARAÚJO FILHO, J.C. de; OLIVEIRA, J.B. de; CUNHA, T.J.F. **Sistema brasileiro de classificação de solos**. 5.ed. rev. e ampl. Brasília: Embrapa, 2018. 356p.
- SOIL SURVEY STAFF. **Keys to soil taxonomy**. 12<sup>th</sup> ed. Washington: USDA, 2014. 360p.
- SUDAWAN, B.; CHANG, C.-S.; CHAO, H.-F.; KU, M.S.B.; YEN, Y.-F. Hydrogen cyanamide breaks grapevine bud dormancy in the summer through transient activation of gene expression and accumulation of reactive oxygen and nitrogen species. *BMC Plant Biology*, v.16, art.202, 2016. DOI: <https://doi.org/10.1186/s12870-016-0889-y>.
- ZHENG, J.; HÄNNINEN, H.; LIN, J.; SHEN, S.; ZHANG, R. Extending the cultivation area of Pecan (*Carya illinoensis*) toward the south in southeastern subtropical China may cause increased cold damage. *Frontiers in Plant Science*, v.12, art.768963, 2021. DOI: <https://doi.org/10.3389/fpls.2021.768963>.