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Evaluating chemicals for inducing budburst in peach orchard grown in subtropical conditions

Avaliação de produtos químicos para indução de brotação em pomar de pessegueiro cultivado em condições subtropicais

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Highlights

Hydrogen cyanamide (HC) increased flowering, fruit set and yield.
Crop performance was increased by using HC or nitrogen fertilizer + calcium nitrate.
It is not possible to recommend just calcium nitrate for peach tree budburst.

Abstract

The availability of chill hours influences the break dormancy, sprouting and production of temperate fruit trees in different regions. During the winter, the chilling requirements for growing peaches in subtropical locations are restricted, and certain chemicals are required to overcome dormancy and induce budburst. As a result, further information concerning the use of these compounds on stimulating sprouting in peach trees is required. The purpose of this study was to evaluate the ability of hydrogen cyanamide, nitrogen fertilizer, and calcium nitrate to trigger budburst in the 'Douradão' peach orchard, which is in the subtropical area of São Paulo state, Brazil. The following tree chemicals were tested: 0.6 % hydrogen cyanamide, 2.5 % nitrogen fertilizer with 4 % calcium nitrate, 4 % calcium nitrate, and control. The hydrogen cyanamide accelerated, predicted, and focused blooming on plants, along with improving fruit set and output. Furthermore, combining nitrogen fertilizer with calcium nitrate accelerated budburst, which boosted flowering, output per tree, and yield. The spraying of the peach plants with just calcium nitrate produced results like those obtained in the control. The results allow for the use of hydrogen cyanamide or nitrogen fertilizer + calcium nitrate as an option for triggering budburst in Douradão cultivar peach trees under subtropical circumstances, depending on the orchards system management used.

Key words: *Prunus persica* (L.) Batsch. Hydrogen cyanamide. Nitrogen fertilizer. Calcium nitrate.

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Resumo

A disponibilidade de horas de frio influencia a quebra da dormência, brotação e produção de árvores frutíferas de clima temperado em diferentes regiões. Os requerimentos de frio para o cultivo de pessegueiros em regiões subtropicais são limitados durante o inverno e alguns produtos químicos são necessários para superar a dormência e induzir a brotação. Portanto, são necessárias mais informações sobre o uso desses compostos na promoção da brotação em pessegueiros. Este trabalho teve como objetivo avaliar a cianamida hidrogenada, o fertilizante nitrogenado e o nitrato de cálcio para brotação, num pomar de pessegueiro 'Douradão', localizado em região subtropical do estado de São Paulo, Brasil. Para isso, três produtos químicos foram avaliados: 0,6% de cianamida hidrogenada; 2,5% de fertilizante nitrogenado + 4% de nitrato de cálcio; 4% de nitrato de cálcio e o controle. A cianamida hidrogenada aumentou o florescimento das plantas, além de aumentar a frutificação e a produção. Além disso, fertilizante nitrogenado + nitrato de cálcio também proveram a brotação, potencializando o florescimento e a produção das plantas. A pulverização dos pessegueiros somente com nitrato de cálcio apresentou desempenho semelhante ao observado na testemunha. Os resultados permitiram indicar a utilização da cianamida hidrogenada ou fertilizante nitrogenado + nitrato de cálcio, como alternativa para indução de brotação em pessegueiros cultivar Douradão, em condições subtropicais, dependendo do sistema de cultivo adotado nos pomares.

Palavras-chave: *Prunus persica* (L.) Batsch. Cianamida hidrogenada. Fertilizante nitrogenado. Nitrato de cálcio.

Although the peach tree (*Prunus persica* L. Batsch) is a temperate plant species, peach crop production in tropical and subtropical locations has progressively grown over time (Hernandez et al., 2021). Crop genetic modification programs are led to the cultivation of peaches in subtropical and tropical climates all over the world (Pio, Souza, Kalcsits, Bisi, & Farias, 2019; Pantelidis, Mavromatis, & Drogoudi, 2021).

The climatic conditions in Southern Brazil's subtropical humid zones are highly variable, with inconsistent winter dormancy caused by conflicting air masses of tropical and subtropical origins, resulting in both insufficient chill accumulation in some years or places and a late frost risk during bloom. Furthermore, temperatures exceeding 18-20ºC are common and unfavourable during the endodormancy (Fadón, Herrera, Guerrero, Guerra, & Rodrigo, 2020).

The peach tree needs winter chill to break dormancy and develop. Inadequate circumstances will have a negative impact on budburst, flowering, and fruit output. The number of chilling hours ≤ 45°F or ≤ 7.2ºC required by peach plants to overcome dormancy is measured (Fadón et al., 2020). Other research has shown that higher temperatures are equally effective in encouraging bud emergence, particularly in cultivars with reduced chilling needs, i.e., up to 15 °C (Fadón et al., 2020).

Subtropical peach orchards should be planted with varieties that are less demanding in chilling hours. The cultivar Douradão was chosen since it is commonly produced in the state of São Paulo and has minimal chilling requirements (i.e., 200 hours). This cultivar's trees exhibit medium vigour and compact growth (Ferreira et al., 2019).

Chemical applications to budburst are critical for mitigating the consequences of inadequate cooling in temperate fruit plants, such as budburst uniformity (Pio et al., 2019; Ferreira et al., 2019).

Because it is particularly efficient for breaking dormancy and encouraging budburst, including being widely used to stimulate and standardize sprouting, hydrogen cyanamide (HC) is the most commercially utilized substance to induce budbreak in various fruit species. Although the mechanisms of action of HC are unclear, several studies have shown that it inhibits catalase function, resulting in elevated amounts of hydrogen peroxide (H_2O_2) in buds and therefore boosting oxidative stress that overcomes dormancy (Pinto, Lira, & Ugalde, 2021). Peach producers in the subtropical parts of São Paulo state, Brazil, typically utilize HC 0.6 % (Ferreira et al., 2019).

Despite these encouraging findings, HC has been demonstrated to be harmful to applicators after repeated exposure (İmrak, Küden, Küden, Sarier, & Çimen, 2016). The HC was classed as toxicity category I by the Environmental Protection Agency (EPA), which means it is very hazardous and highly irritating. Such constraints have limited the product's usage in some foreign markets, such as the European Union (Hernández & Craig, 2016), but have also fuelled the search for alternatives that pose fewer environmental risks, such as potassium nitrates, calcium nitrates (CN), mineral oils (Seif El-Yazal, Seif El-Yazal, & Rady, 2014), and nitrogen fertilizer (NF) (Erger®) (İmrak et al., 2016; J. M. A. Souza et al., 2021).

According to Petri, Leite, Couto, Gabardo and Hawerroth (2014), the major ideal qualities for an HC replacement are that it be low cost, efficiently stimulate sprouting, and have low toxicity for plants and the environment.

Nitrogen fertilizer (Erger®) is a mixed mineral fertilizer made up of inorganic nitrogen, carbohydrates (mono and polysaccharides), calcium, and diterpenes (VALAGRO, 2021), which stimulate cellular respiration, reactivate nitrogen metabolism, and promote cell division and elongation. During the restart of plant growth, these processes are intensive. NF can be used alone or in conjunction with calcium nitrate (CN). The latter is used to stimulate bud emergence in peach trees growing in moderate winter climates.

Preliminary studies with peach cultivars conducted by Ferreira et al. (2019) using concentrations of NF at 0, 1.25, 2.50, and 3.75 %; associated with 4 % calcium nitrate revealed that NF 2.50 % positively affected cultivars development, providing broader sprouting, flowering, and fruit set; thereby also, greater production.

Calcium nitrate (CN), which is constituted of 15.5 % nitrogen and 26.5 % calcium, has also been employed in isolation as a sprouting inducer in temperate fruit trees. The application of 6% of the product boosted the levels of amino acids like proline and arginine, as well as growth hormones like auxins and gibberellins, in 'Anna' apple buds. In connection to the administration of thiourea and the control, these biochemical alterations related to higher flowering and fruit production in plants (Seif El-Yazal et al., 2014)

Despite the compounds' ability to enhance budburst, additional research was needed to compare the efficiency of these agents in subtropical peach orchards. As a result, the purpose of this study was to find chemical possibilities for promoting budburst in 'Douradão' peach during two crop seasons in Botucatu, São Paulo state, Brazil.

The experiment was conducted out at the School of Agriculture (FCA/UNESP), which is located at 22º51'55"S, 48º27'22"W, and 810 m a.s.l. The area's climate is described as *Cfa*, which means hot temperate climate (mesothermic), with concentrated rains from November to April (summer) and an average annual rainfall of 1.374 mm; the mean temperature of the warmest month reaches 22°C (Cunha & Martins, 2009).

According to Citadin, Raseira, Herter and Silveira's (2002) methodology, the number of hours with temperatures below 7.2ºC or 15ºC was measured from January to December in 2017 and 2018. From 1 March to 31 July 2017, the region accumulated 4.2 chill hours (CH) ≤ 7.2ºC, while from 1 May to 31 August 2018, the area accumulated 1.8 CH ≤ 7.2ºC. During the same time frame, the accumulation of CH ≤ 15ºC was 278.7 and 312.6 ≤ 15ºC in the first (2017) and second crop seasons (2018), respectively. In 2017, the average rainfall was 1880.6 mm, while in 2018, it was 1310.89 mm.

The orchard was planted with 6-year-old 'Douradão' peach trees (*Prunus persica* L. Batsch) at 6 m between rows and 4 m between plants (i.e., 416 trees ha^{-1}) without irrigation. Peaches were analysed in two crop seasons, 2017, and 2018. The trees were grown in a cup system, grafted onto 'Okinawa' rootstock, and handled in accordance with peach orchard regulations.

All budburst promoters were sprayed immediately after fruiting pruning, with the following treatments: treatment 1: control (100 % water); treatment 2: 2.5 % NF (Erger®) + 4.0 % calcium nitrate ($Ca(NO_3)_2$); treatment 3: 4.0 % CN; and treatment 4: 0.6 % HC (520 g L^{-1} of hydrogen cyanamide). Each tree was received 2.5 L containing various chemicals and 2% surfactant (Agral®) (Figure 1).

The fruits were collected when they attained physiological maturity, as indicated by a shift in background color from green to light yellow and a minimum Brix value of 10º Brix (Figure 1).

Eight mixed branches (average length of 25 cm) were randomly picked for each plant and scattered in its median region along the whole circle of the canopy. The number of vegetative and flowering buds in each of the selected branches was counted prior to the start of the assessments.

The phenological stages listed below were examined:

The proportion of sprouted vegetative buds, as determined by equation 1 (F. M. B. Souza et al., 2017), is represented by the relative rate of budburst:

$$RRB = TNSVB \times 100 \div TNVB \quad (1)$$

Where:

RRB = relative rate of budburst; TNSVB = total number of sprouted vegetative buds; TNVB = total number of vegetative buds.

According to equation 2 (F. M. B. Souza et al., 2017), the relative rate of flowering shows the percentage of flower buds that produced fruits:

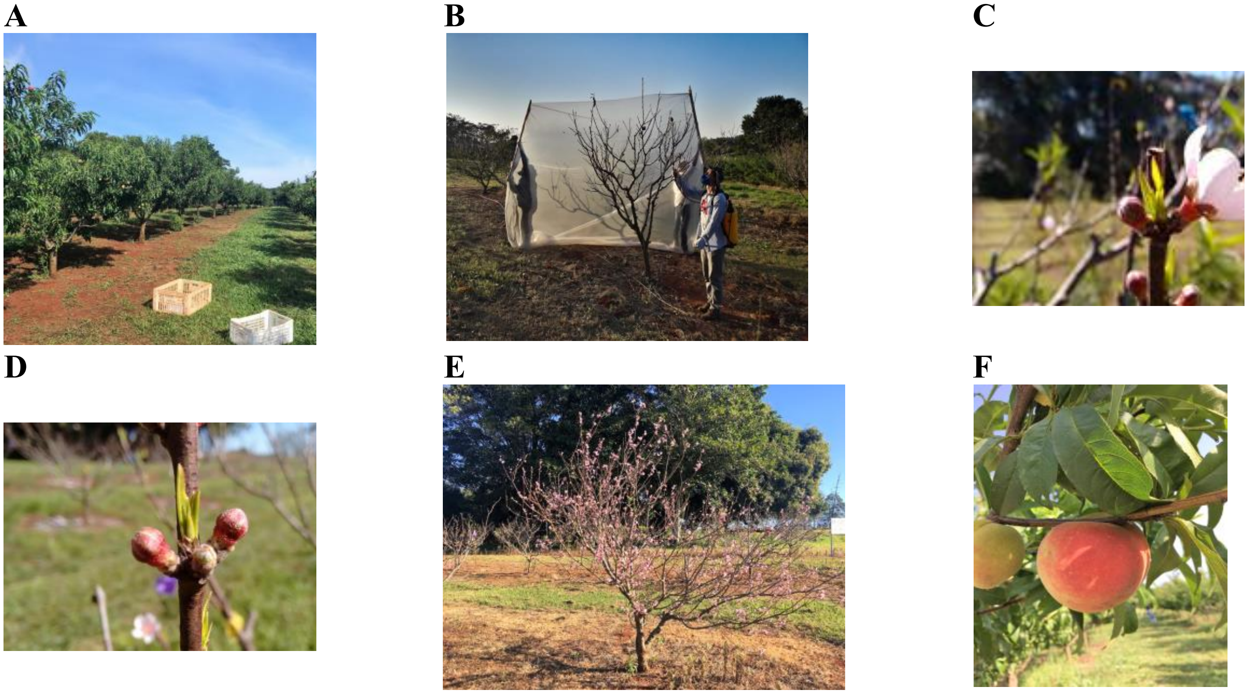

Figure 1. Images from the experimental site.
A) Panoramic view of the peach orchard. B) Spraying of chemicals. C) Opening flowers. D) Budburst. E) Full flowering. F) Fruits at harvest time.

$$RRF = TNFB \times 100 \div TNFB \quad (2)$$

Where:

RRF = relative rate of flowering; TNFB = total number of flowering budburst; TNFB = total number of flowering buds.

The relative rate of fruit set, which measures the proportion of fixed fruits, was calculated 20 days following full bloom at the time of hand thinning by the equation (3) (F. M. B. Souza et al., 2017):

$$RRFS = TNFF \times 100 \div TNFB \quad (3)$$

Where:

RRFS = relative rate of fruit set; TNFF = total number of fixed fruits; TNFB = total number of flowering budburst.

The total number of fruits harvested from each tree determined the number of fruits per tree; production per tree was calculated by multiplying the total number of fruits by the fresh weight of the fruits, expressed in kg plant^{-1}, and yield that considered the planting density of 416 trees ha^{-1}, expressed in t ha^{-1}.

The experimental design was a randomized block with five repetitions in a split-plot configuration (4x2). For two crop seasons, the plots were represented by chemicals and subplots. Trees were used as replicates in each experimental plot. The data was subjected to analysis of variance (ANOVA) at 1% and 5% probability levels, and means were compared using the Tukey test.

Results showed that there was no significant interaction between chemicals and crop seasons for any of the variables. However, crop season and chemicals had a considerable influence on the proportion of sprouting, flowering, and fruit set (Table 1).

Table 1
Budburst, flowering, fruit set percentage, number of fruits per tree, production and yield in peach trees cv. Douradão as a result of the crop season and chemicals sprayings. Botucatu, SP, Brazil, 2019

Crop season	Budburst (%)	Flowering (%)	Fruit set (%)
2017	36.20 a	31.40 a	26.61 a
2018	32.92 b	14.45 b	14.45 b
MSD	3.13	5.73	4.64
Chemicals	**Budburst (%)**	**Flowering (%)**	**Fruit set (%)**
Control	27.21 b	14.54 c	16.63 c
NF + CN	38.66 a	26.00 b	24.26 ab
CN	36.88 a	14.69 c	18.07 bc
HC	36.00 a	36.42 a	29.86 a
MSD	5.28	8.47	6.39
Crop season	**Number of fruits per tree**	**Production (kg per tree)**	**Yield (t ha^{-1})**
2017	100.58 a	10.36 a	4.32 a
2018	36.62 b	4.10 b	1.71 b
MSD	26.94	3.38	1.41
Chemicals	**Number of fruits per tree**	**Production (kg per tree)**	**Yield (t ha^{-1})**
Control	42.38 c	4.83 c	2.01 c
FNF + CN	75.15 ab	6.99 b	2.91 b
CN	61.83 bc	6.10 bc	2.54 bc
CH	95.05 a	10.37 a	4.32 a
DMS	24.95	2.10	0.60

The same letter in the column means that the Tukey's test findings do not differ significantly at 5% probability.

There were fewer chill hours bellow ≤ 15ºC during the 2017 crop season. In 2017, there were 4.2 CH below ≤ 7.2ºC and 278.7 ≤ 15ºC in 2017, whereas in 2018, there were 1.8 CH ≤ 7.2ºC and 312.6 ≤ 15ºC. The onset of budding and blooming in 2018 was influenced by the occurrence of low temperatures, which included more cold hours and higher daytime temperatures. Nonetheless, in August 2018, a period of high cumulative chilling hours (≤ 15 °C) (114.8 hours) was linked with heavy rainfall (113.1 mm) and strong winds. There was a rise of 61.5 chilling hours ≤ 15°C and 90.7 mm of precipitation compared to the previous crop season. These unfavourable conditions happened precisely at the period of plant resumption, when they were in the sprouting and blooming stages, and resulted in excessive flower fall, reducing fruit output.

Regardless of chemical treatments, the results for budburst, flowering, and fruit set percentage in 2017 were greater than those in 2018. As a outcome, these variations resulted in a 3.28 % decrease in budburst, a 16.95 % decrease in flowering, and an 8.82 % decrease in fruit set. Climate changes that occurred during the second evaluation crop season might explain such a result that jeopardized the trees' performance.

When compared to the control, the chemical sprayings resulted in an increase in budburst on the branches. In comparison to the control, the NF + CN treatments boosted sprouting by 11.45 %, NC by 9.67 %, and HC by 8.79 %. When compared to the chemicals, the poor impact of the control might be explained by inadequate freezing hours to overcome dormancy.

The budburst allowed fresh leaves to grow on the branches. In turn, the resumption of the photosynthetic activity gave the energy required to enhance the fruit growth processes in the upcoming season. Furthermore, the new branches are in charge of ensuring production continuity in the next crop cycle (Ferreira et al., 2019).

Regardless of crop season, HC caused the highest proportion of flowering, that is, 36.42 % open flowers. Based on the intermediate results, spraying with NF + CN resulted in a 26 % flowering rate. The values were lowest in the CN and control treatments. The enhanced effectiveness of the HC in comparison to others is due to the existence of the radical -C≡N, which is thought to be more reactive than the others (Segantini, Leonel, Ripardo, Tecchio, & Souza, 2015).

Furthermore, as compared to CN and the control, NF + CN had lower values than HC but a favourable consequence for flowering. Consequently, it might be regarded as an alternative to HC to trigger budburst in peach plants. Ferreira et al. (2019) validated the product's efficacy on peach trees, where 2.2% NF + 4% CN produced budburst and flowering in the branches to 43.7 %. Nitrogen, carbohydrates, calcium, and diterpenes are among the substances found in NF that work synergistically to restore the bud metabolism, allowing development to continue (VALAGRO, 2021). Nitrogen availability is crucial for initiating nitrogen metabolism, which promotes early and uniform budding (Hernandez et al., 2021); furthermore, during the spring, the synthesis of new chemicals is required for the growth and development of new branches and flowers.

Fruit set was increased by 29.86% and 24.26% with HC and NF + CN, respectively (Table 1). When compared to the control, these products increased fruit fixation by 13.23 % and 7.63 %, respectively. CN did not increase fruit set improvements, yielding results similar to the control. The chemicals' high cost and toxicity are the primary barriers to commercialization. Given the need for novel products with lower toxicity and features of lowering environmental risk profiles, NF + CN might be a viable replacement for HC, especially given its efficiency in breaking bud dormancy.

The 2017 crop season had seen the highest output rates (Table 1). During this time, peach trees produced 100.58 fruits per tree, equivalent to 10.36 kg per tree and a yield of 4.32 t ha^{-1}. The following crop season had a 63.59 % decrease in the amount of fruits and a 60.42 % decrease in plant production. This decrease in crop season in 2018 was caused by greater precipitation and winds, which harmed the plants after pruning and chemical sprayings. Climate change affected flowering, fruit set, and, as a consequence, peach output.

The 2018 crop season had a period of high cumulative chilling hours ≤ 15 °C (114.8 hours), which could have been a positive factor for production, because the effective temperature for chill accumulation varies by cultivar and can be up to 15 °C in cultivars with lower chill demand, such as the Douradão peach.

In terms of the productive factors, the results showed that there were no significant changes for the interaction between chemicals and crop seasons (Table 1). The isolated factors, on the other hand, impacted the number of fruits, output per tree, and yield.

HC increased the amount of fruits (95.05 fruits per tree) in the same way as NF + CN did (75.15 fruits per tree) (Table 1). When the other productive factors were examined; however, the employment of HC produced the greatest results (10.37 kg per tree and 4.32 t ha^{-1}). Trees sprayed with NF + CN performed intermediately in terms of output (6.99 kg per tree) and yield (2.91 t ha^{-1}), both of which were greater than the control plants' averages. There is a need to explore less hazardous substances while thinking about the environment. As a logical consequence, spraying this substance might be regarded an effective option for inducing budburst in peach trees in the region.

Erger®, an alternative to HC, increased the percentage of budbreak and the number of inflorescences per winter bud on commercial kiwifruit output following extreme winter chilling conditions. Even if the reaction relative to the control was always enhanced after medium and moderate winter chilling, the alternatives for HC were less effective than HC (Hernández & Craig, 2016).

In comparison to the control, NF + CN yield increased by 30.92% and HC yield increased by 53.47%. These findings suggested that NF + CN may be used to replace HC since they posed little risk to the employees who used them; nonetheless, the findings supported HC's superior efficacy in subtropical regions with insufficient winter cold temperatures.

The use of hydrogen cyanamide or nitrogen fertilizer + calcium nitrate to trigger budburst in a ‘Douradão’ peach tree that grows in subtropical environment with insufficient chilling accumulation boosted crop performance and yield.

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