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CROP PRODUCTION
Article

Hydrogened cyanamide promotes dormancy breakage in pear tree grown in a subtropical region

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ABSTRACT: The pear tree (*Pyrus* spp.) is a fruit tree of temperate climate, so it needs a certain number of hours under cold temperatures to overcome its natural dormancy. It can be cultivated in the tropics, but few regions have cold enough winters to overcome the natural dormancy of pear trees. For this purpose, it is necessary to select cultivars with less need for cold conditions combined with the use of bud-inducing to sprouting and flowering products. This study aimed to test doses of hydrogenated cyanamide (Dormex) to break dormancy and induce bud sprouting in different pear cultivars under subtropical conditions. The branches of five pear tree cultivars, 'Cascatense', 'Primorosa', 'Seleta', 'Packham's Triumph', and 'William's', were sprayed with Dormex (a commercial product containing 52% hydrogen cyanamide, CH_2N_2) at 1, 2, 3, 4, or 5% or with water (control). The trees were evaluated at two, four, six, eight, 10, and 12 weeks after the application of the treatments in two consecutive years. The European pear trees 'William's' and 'Packham's Triumph' showed low budding rates compared to hybrid pear trees. Hybrid pear showed better performance in subtropical regions, with higher budding rates, than European pear. CH_2N_2 efficiently induces bud sprouting of pear, with especially 4 and 5% Dormex.

Key words: *Pyrus* spp., Dormex, anticipation of production.

INTRODUCTION

Temperate fruit trees are originated in regions with cold winters (Rohde and Bhalerão 2007). The fruit trees of this group are characterized by the fall of leaves at the end of the productive cycle, stimulated by the lower temperatures and shorter days, and entry into the period known as dormancy (Ruiz et al. 2007). Dormancy is the mechanism that temperate plants use to protect their tissue, which is sensitive to low-temperature conditions (Campoy et al. 2011).

The pear tree (*Pyrus* spp.) is a temperate fruit tree that requires an adequate number of cold hours (CH) with temperatures equal to or lower than 7.2°C to achieve good vegetative and productive development (Rufato et al. 2011).

Most pear tree cultivars have gametophytic self-incompatibility, causing the plant to reject its own pollen (Bisi et al. 2021). Therefore, they depend on cross-pollination for fruit production.

The cultivation of temperate fruit trees has extended to the tropics, where temperatures are mild in winter (Pio et al. 2018). Bud endodormancy lasts until the needed CH are reached and varies in intensity and duration between species and even cultivars (Anzanello et al. 2014). The expansion of pear cultivation to subtropical regions was only made possible by the production of hybrid cultivars obtained from the cross between *Pyrus communis* and *Pyrus pyrifolia* (Curi et al. 2017, Barbosa et al. 2018, Pio et al. 2023). This combination is interesting because it combines the quality of European pear trees (*P. communis*) with the low need for winter cold of Asian pear trees (*P. pyrifolia*) (Barbosa et al. 2018). Low fruit fixation, linked to the unevenness of bud sprouting, is one of the limiting factors of the expansion of pear cultivation in subtropical regions, especially of European pear trees (Bettiol Neto et al. 2014). In the subtropics, there are few regions with periods of winter that are cold enough for long enough for the cultivation of European pear trees (Pio et al. 2018).

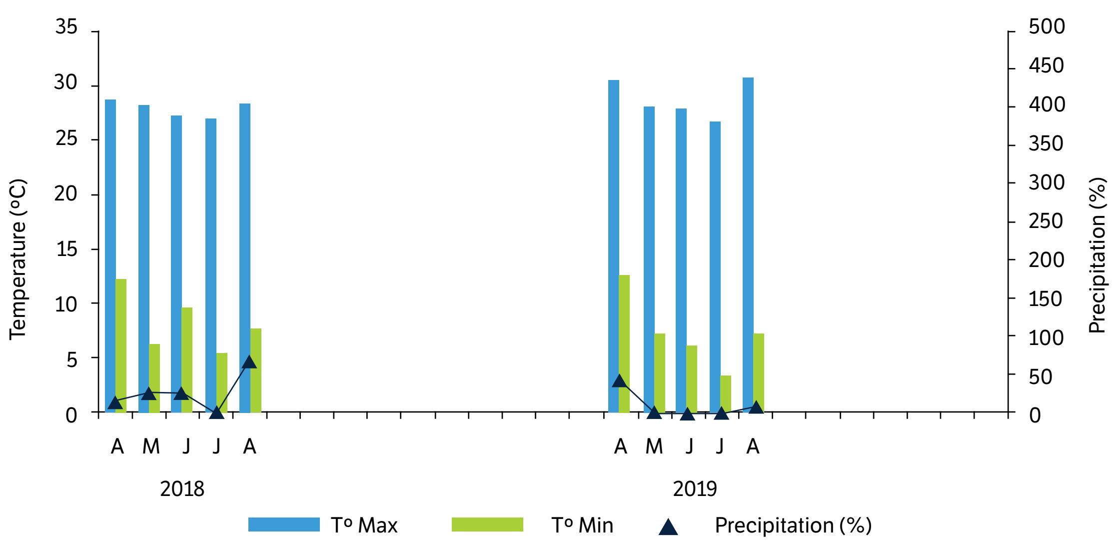
The bud-inducing products that are used to compensate for the absence of cold are only able to overcome dormancy if a minimum amount of cold was previously achieved (Pio et al. 2018). The application of hydrogen cyanamide (CH_2N_2) is a well-established technique to mitigate the shortage of CH, break bud dormancy, and promote uniform budding (Chen and Beckman 2019). The responses of temperate fruit trees to this chemical vary between cultivars and cultivation regions and depend on the chemical concentration and application time (Kuroki et al. 2013). In the case of pear cultivation in subtropical regions, of either hybrid or European cultivars, the dosage of hydrogenated cyanamide for the artificial breaking of buds is unknown (Pio et al. 2018).

This study aimed to determine the effects of hydrogenated cyanamide (Dormex) on breaking the dormancy of buds and the uniformity of budding in pear trees grown in a subtropical region.

MATERIALS AND METHODS

The experiment was conducted at a site located in the south of the state of Minas Gerais, Brazil. The Köppen climate classification for this region is Cwa: subtropical climate, with cold, dry winters and hot, humid summers (Alvares et al. 2013). This region is located at 21°14'S, 45°00'W, and 918 m altitude. The experiment was conducted between August and November of both 2018 and 2019. Before the beginning of the experiment, the lowest (5 a.m.) and the highest temperature (2 p.m.) temperature of the day were recorded daily, as was the daily accumulated precipitation (Fig. 1).

These air-temperature data came from April–August, the second half of autumn and the first half of winter, when the temperatures are mild.



Source: Principal Climatological Station of Lavras (UFLA/INMET).

Figure 1. Climate data from April to August 2018 and 2019 in Lavras, Minas Gerais, Brazil.

Three hybrid pear cultivars of the *P. communis* × *P. pyrifolia* cross were studied: 'Cascatense', 'Primorosa', and 'Seleta' (Table 1), besides two European pear cultivars of *P. communis*: 'Packham's Triumph' and 'William's'.

The seedlings were grafted onto a *Pyrus calleryana* rootstock and taken to the field in October 2010, with 3 × 4-meter spacing between plants (833 plants·ha^{-1}). The plants were grown in a modified central leader system. The orchard management practices were standardized, especially regarding fertilization and phytosanitary control using chemicals recommended for cultivation.

The experiment began in August of each year, when the plants were 8 years old. Four plants of each cultivar were used, and on each of them 30 branches were marked, which had the same pattern regarding the number of buds and the dimensions. The branches were sprayed with Dormex (a commercial product containing 52% CH_2N_2) at the dose of 1, 2, 3, 4, or 5% or with water (negative control). The applications were performed early in the morning on days without wind to avoid drift, and no precipitation was recorded in the following 48 hours. Five replicates were applied to each plant, and all Dormex concentrations were given to each plant. The experimental design was completely randomized in a 5 × 5 × 6 factorial scheme (five evaluations over time, five cultivars, and six doses) with 20 replicates (five branches × four plants), with bud sprouting as the variable.

Table 1. Cultivars and their genealogy and origin (Bisi et al. 2019).

Cultivars	Genealogy	Origin
'Cascatense'	'Packham's Triumph' × 'Le Conte'	Instituto Agronômico, Brazil
'Primorosa'	'Hood' × 'Packham's Triumph'	Empresa Brasilera de Pesquisa Agropecuária, Brazil
'Seleta'	'Hood' × 'Packham's Triumph'	Instituto Agronômico, Brazil

The branches were evaluated weekly, from which the percentage of total bud sprouting was estimated. Bud sprouting was estimated at two, four, six, eight, 10, and 12 weeks after treatment application.

The data were transformed to meet the assumptions of analysis of variance (ANOVA). To achieve data normality, bud sprouting was subjected to square root transformation, after which normality was again verified by the Shapiro-Wilk's test. Data were subjected to ANOVA, and significant interactions were subjected to regression. All analyses were performed in R statistical software with the significance threshold of 5%.

RESULTS AND DISCUSSION

The triple interaction of cultivar × time × dose ($p = 0.9947$) and the double interaction of cultivar × time ($p = 0.4747$) were not significant. The double interactions cultivar × dose ($p < 0.001$) and time × dose ($p < 0.001$) were significant.

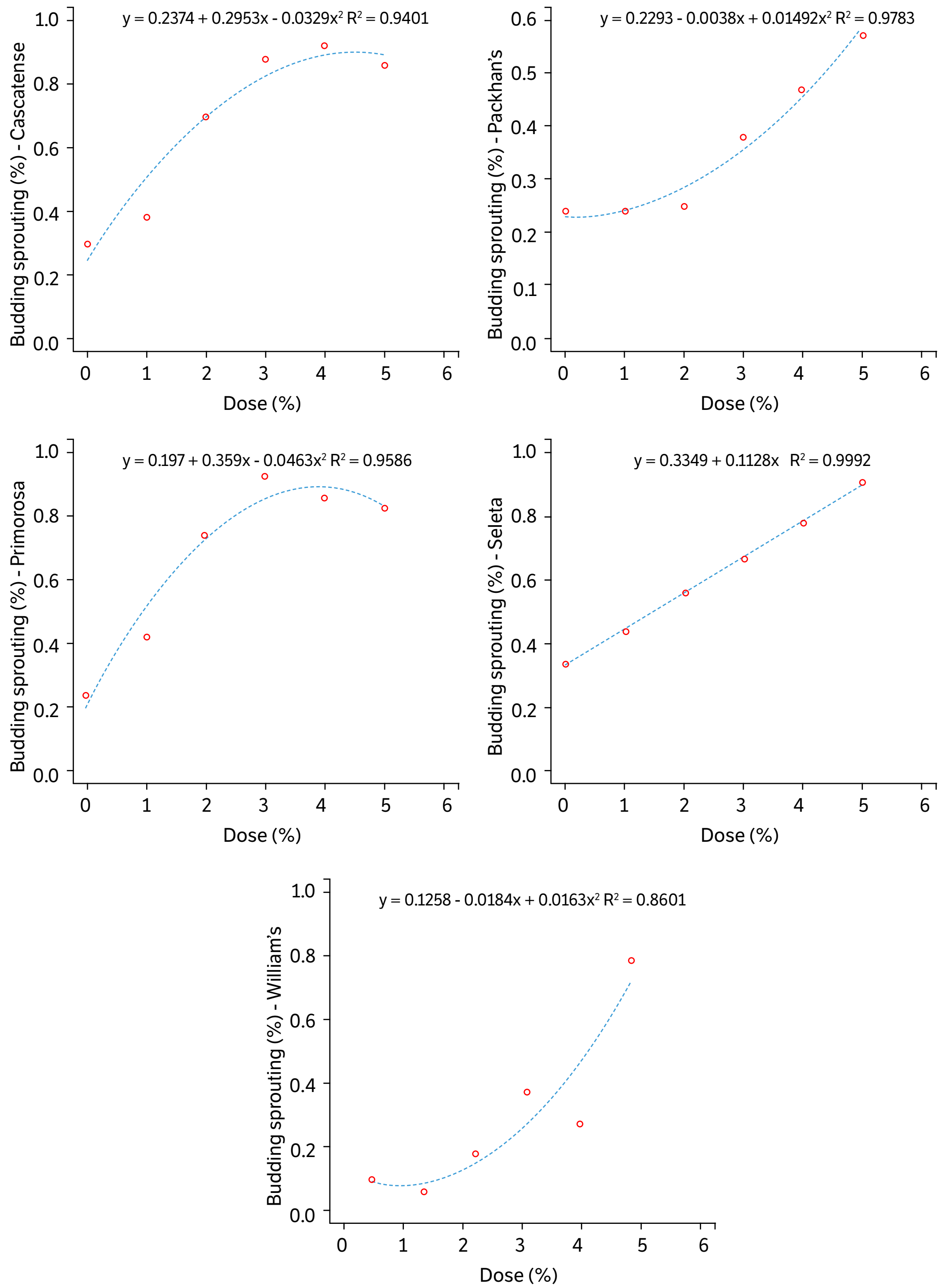
All the comparisons between doses within each cultivar were significant ($p < 0.001$), requiring regression modeling. Quadratic linear regression was the most appropriate to describe the bud sprouting of the cultivars 'Cascatense', 'Primorosa', 'Packham's Triumph', and 'William's'. The first two cultivars showed an increase in bud sprouting rate up to doses of 4 and 3% of Dormex, respectively, followed by stabilization and a decrease in sprouting at the higher dose(s).

The 'Primorosa' cultivar showed higher bud sprouting with a lower dose of Dormex than the 'Cascatense' cultivar (Fig. 2). A dose of 5% to the 'Primorosa' cultivar caused bud abortion, demonstrating an antagonistic effect.

The 'Packham's Triumph' and 'William's' cultivars showed different behaviors than those above, with low bud sprouting at lower doses and peak budding at doses of 4 and 5%, without budding rate stabilization. They also showed lower budding rates at the end of the evaluations, with 45 and 60% of buds sprouted, respectively. In contrast, the other cultivars (hybrids) showed high budding rates (~90%).

Bud sprouting of the 'Seleta' cultivar was best described by first-degree linear regression, i.e., its budding increased with the dose of Dormex.

All time comparisons within each dose were also significant for 2018 ($p < 0.001$), requiring the regression study. Bud sprouting at the 0- and 3%-doses was best described by first-degree (linear) regression, i.e., the buds showed linear growth of bud sprouting rates over time. The other doses (1, 2, 4, and 5%) were better described by quadratic linear regressions, demonstrating accelerated sprouting at the beginning of the evaluations, stabilization, and then a decrease in bud sprouting (bud abortion) (Fig. 3).

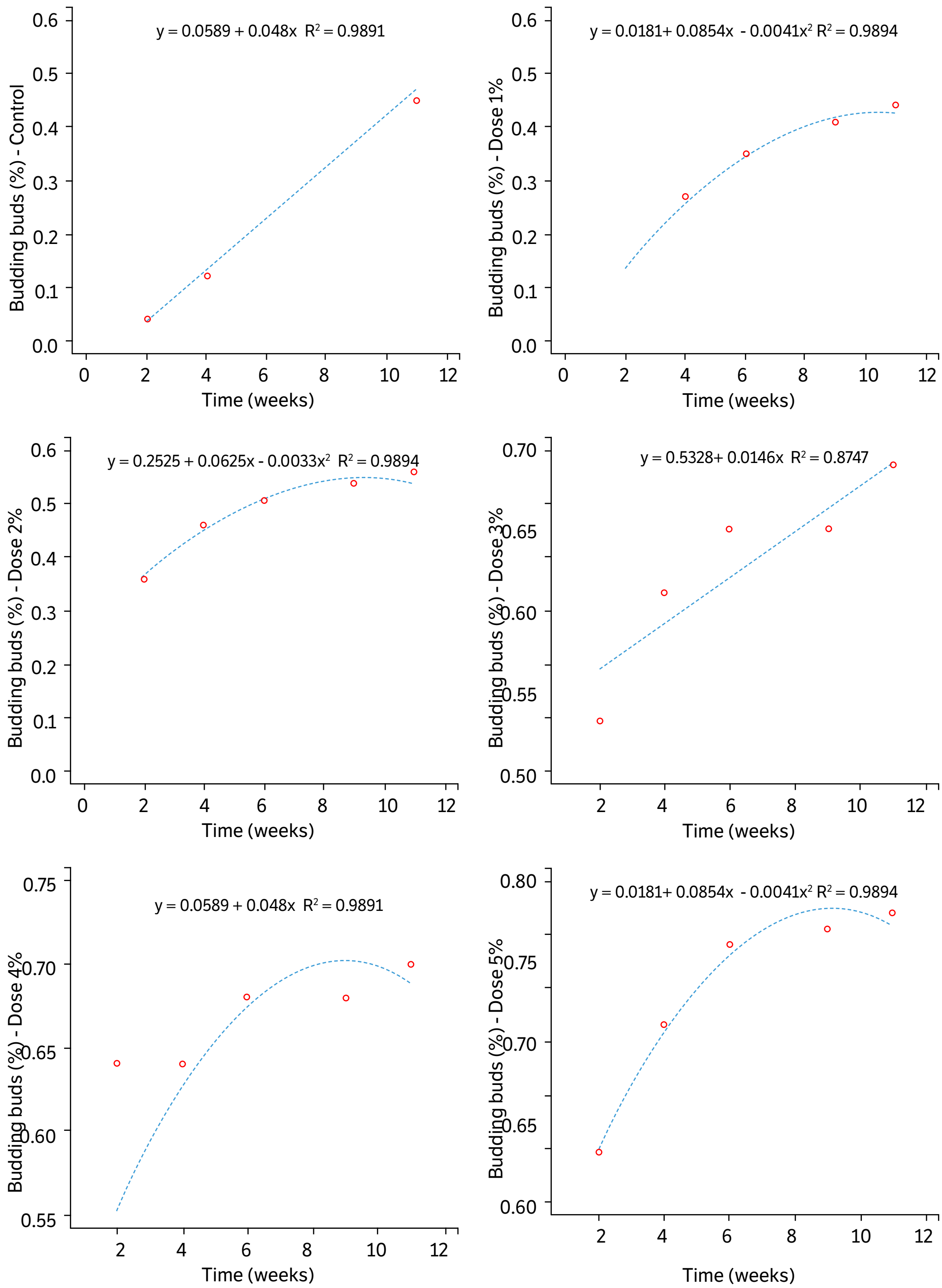


Source: Elaborated by the authors.

Figure 2. Equation for the regression of bud sprouting percentage on Dormex dose (0, 1, 2, 3, 4, and 5%) within each cultivar ('Cascatense', 'Packham's Triumph', 'Primorosa', 'Seleta', 'William's') for the year 2018.

Despite showing similar behavior, with stabilization of budding rates, the 4- and 5%-doses showed higher bud sprouting (70–80%) than lower doses (40–50%). The 3% dose also achieved high bud sprouting rates (~70%), but the 4- and 5%-doses anticipated bud sprouting by approximately four weeks (stabilization point).

All cultivars already showed budding in the first two weeks, especially at the 5%-dose, with a 62% budding rate.

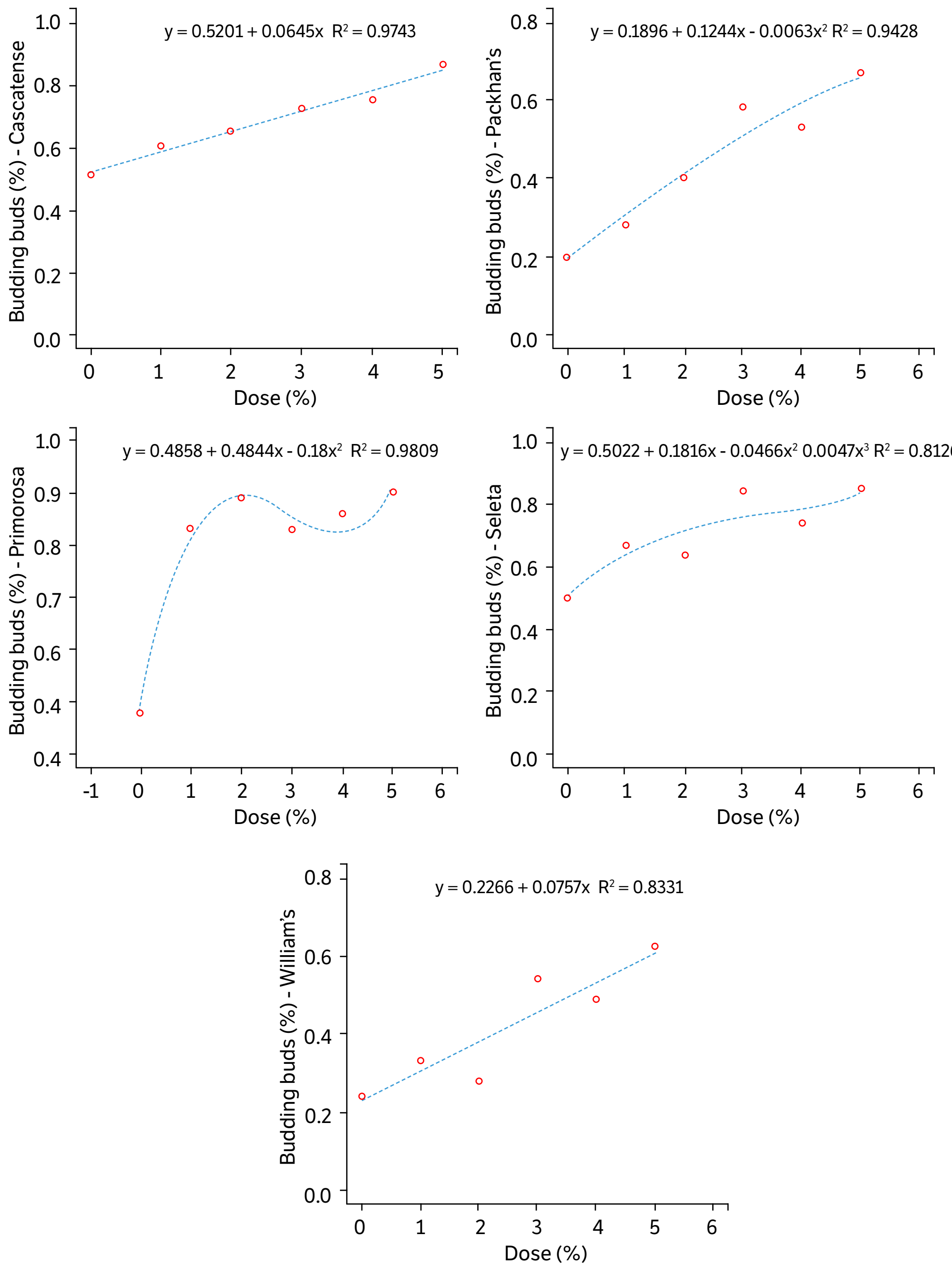


Source: Elaborated by the authors.

Figure 3. Equation for the regression of bud sprouting percentage on time (two, four, six, eight, 10, and 12 weeks) within each dose (0, 1, 2, 3, 4, and 5%) for 2018.

In 2019, the triple interaction time × dose × cultivar ($p = 0.9606$) and the double interaction cultivar × time ($p = 0.0589$) were not significant. The double interactions cultivar × dose ($p < 0.001$) and time × dose ($p < 0.001$) were significant.

All the comparisons of the doses within each cultivar were significant ($p < 0.001$), so regression modeling was necessary. The bud sprouting of the 'Cascatense' and 'William's' cultivars was best described by first-degree (linear) regressions, i.e., budding increased linearly with the dose of Dormex (Fig. 4). The bud sprouting of 'Packham's Triumph' was best modeled by quadratic linear regression, showing increased bud sprouting rates with increasing doses followed by a tendency to stabilize. The ‘Primorosa’ and ‘Seleta’ cultivars were best described by cubic linear regressions. The ‘Primorosa’ cultivar showed high budding rates at 2% Dormex (88%), with a subsequent fall and stabilization at doses of 3 and 4% (85%), indicating bud abortion, followed by resumption of growth (new shoots) at the dose of 5% (90%). The ‘Seleta’ cultivar showed a nonlinear increase in budding rates up to the 5% group (83%). The ‘William’s’ and ‘Packham’s Triumph’ cultivars showed lower budding rates at the end of the evaluations, with 60 and 65% bud sprouting, respectively. The other cultivars (hybrids) showed high budding rates (85–90%).

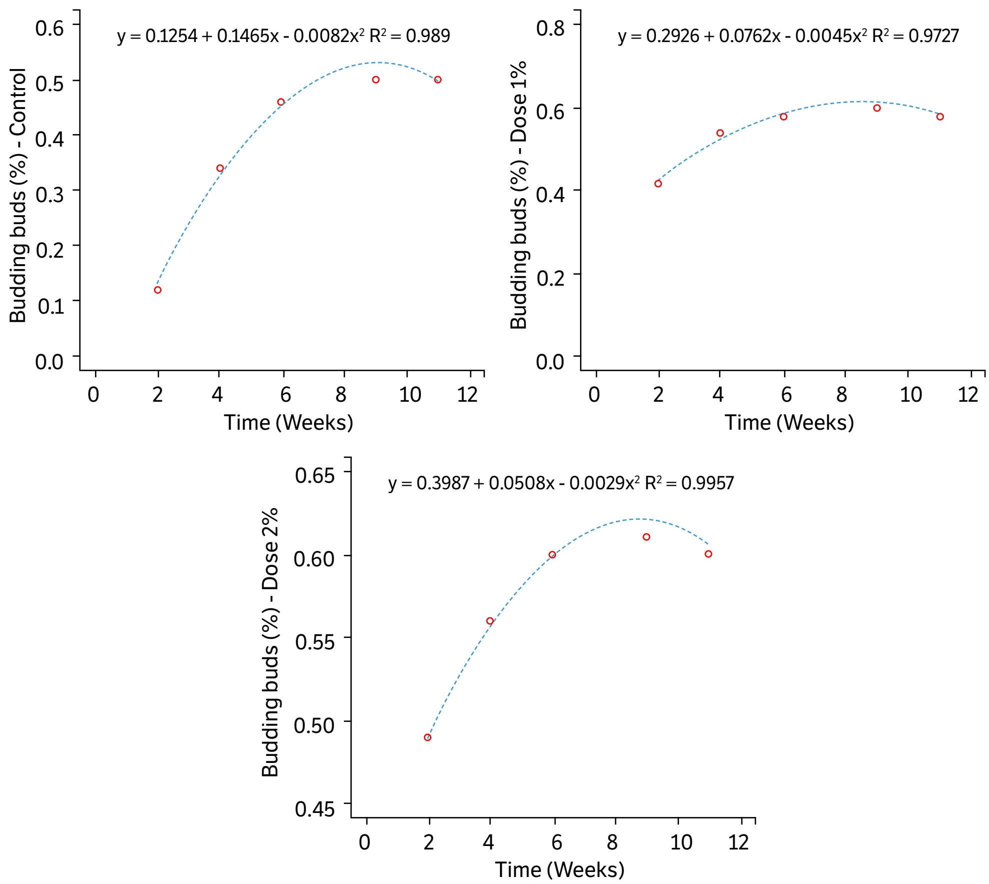


Source: Elaborated by the authors.

Figure 4. Equation for the regression of bud sprouting percentage on the Dormex dose (0, 1, 2, 3, 4, and 5%) within each cultivar (‘Cascatense’, ‘Packham’s Triumph’, ‘Primorosa’, ‘Seleta’, ‘William’s’) in 2019.

The time comparison was significant only within the 0, 1, and 2% doses ($p < 0.001$) in 2019. Quadratic linear regression was the most appropriate model to describe bud sprouting at these doses, as there were accelerated sprouting at the beginning of the evaluations, stabilization, and a decrease (bud abortion) (Fig. 5).

Despite showing similar behavior, with budding stabilization at approximately eight and nine weeks, the 1- and 2%-doses showed higher bud sprouting (60%) than the control (50%). This demonstrates the efficiency of the application of Dormex in pear bud sprouting. Despite these low budding rates, they were still higher than the rates at the same doses in 2018.

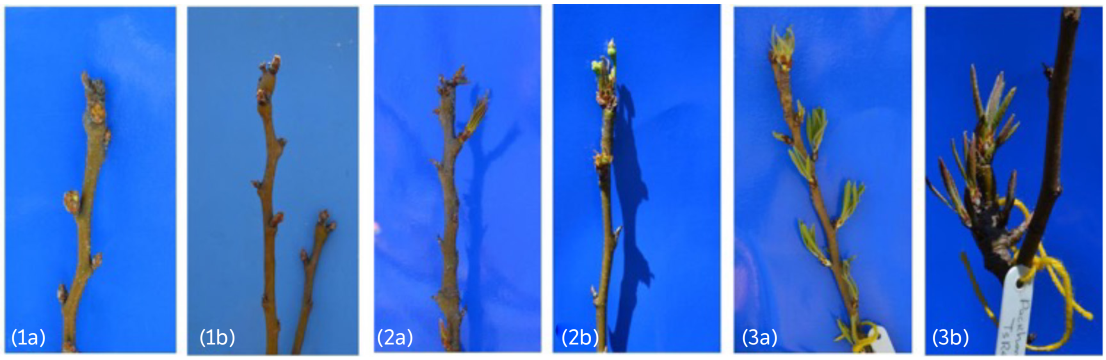


Source: Elaborated by the authors.

Figure 5. Equation for the regression of bud sprouting percentage on time (two, four, six, eight, 10, and 12 weeks) within each dose (0, 1, and 2%) in 2019.

Figure 6 shows the branches of a hybrid cultivar ('Seleta') and a European cultivar ('Packham's Triumph') when only water (1.a and 1.b), 2%- (2.a and 2.b), or 5%-Dormex was added (3.a and 3.b), at six weeks after treatment application. The difference in bud sprouting capacity was visible as the dose increased. The bud sprouting capacity of the hybrid cultivar was the highest.

The 'William's' and 'Packham's Triumph' cultivars showed lower budding rates than the other cultivars. This is due to the greater requirement for CH at temperatures equal to or lower than 7.2°C (> 150 hours) to overcome dormancy (Pio et al. 2018). Figure 1 shows that the minimum average temperatures recorded before the application of Dormex were low, but not sufficient, even with the exogenous application of bud-inducing products. Several problems related to dormancy occur in temperate fruit trees grown in regions with mild winters. One way to overcome the limitations imposed by environmental conditions is to use cultivars with low cold requirements that are adapted to the climatic conditions of the region (Rahemi and Pakkish 2009), in addition to the application of bud-inducing products (Kuroki et al. 2013).



Source: elaborated by the authors.
Figure 6. Pear cultivars that received only water (0%) (1.a 'Seleta' and 1.b 'Packham's Triumph'), 2%-Dormex (2.a 'Seleta' and 2.b 'Packham's Triumph'), or 5%-Dormex (3.a 'Seleta' and 3.b 'Packham's Triumph'), at six weeks after treatment application.

The lack of adequate environmental conditions for the development of temperate fruit trees can cause numerous physiological anomalies in plants, such as low budding rates and low productive potential of orchards (Maguylo et al. 2012). The 'Cascatense', 'Primorosa', and 'Seleta' cultivars, obtained through hybridization between Asian and European pear (*P. communis* × *P. pyrifolia*), are therefore more adapted to mild winter conditions, explaining their higher bud sprouting rates than the European ones had.

Doses of 1, 2, 4, and 5% showed accelerated budding at the beginning of the evaluations, with subsequent stabilization and a decrease (bud abortion) in 2018, indicating that the evaluated period was long enough to describe the behavior of the doses over time, except for the 0- and 3%-doses, which induced a linear behavior. Besides the 0- and 3%-doses, no dose showed stabilization and a decrease for 2019. Therefore, bud sprouting could increase even more with a longer evaluation period.

Only the 'Cascatense' and 'Primorosa' cultivars in 2018 showed stabilization of the bud sprouting rate, with doses of 4 and 3% of Dormex, which provided greater sprouting. However, very high doses can cause antagonistic effects, impairing bud sprouting and effective fruiting (Petri et al. 2014), reinforcing the importance of finding an ideal dose.

In 2018, the 3-, 4-, and 5%-doses showed higher bud sprouting (70–80%) than lower doses (40–50%); however, the 4- and 5%-doses promoted high budding rates in a shorter time (anticipation of bud sprouting by approximately four weeks). Budding indices above 70% are considered satisfactory to end endodormancy in temperate fruit trees (Anzanello et al. 2018).

The effect of CH_2N_2 on pear dormancy breaking depends on the concentration (applied dose), accumulated refrigeration, and cultivar (Kuroki et al. 2013). The application of 4- and 5%-CH_2N_2 was the most indicated for better pear budding, similar to that found for blackberry cv. Tupy, in which the 4.5%-dose showed greater anticipation, uniformity, budding, and fruit production (Fernández et al. 2011).

Marchi et al. (2017) also observed that, regardless of the cultivar, the location of the bud, and the evaluation period, the highest percentages of budding of apple tree buds were obtained with the use of CH_2N_2 (2%) + mineral oil compared to the absence of CH_2N_2. Although other products, such as vegetable and mineral oil, showed a significant increase in budding percentage, Marchi et al. (2017) observed that the use of oils did not reach half of the gains obtained (bud sprouting) with the use of CH_2N_2. Chen and Beckman (2019) observed budding approximately four times higher in peach tree branches sprayed with CH_2N_2 than in untreated branches. Thus, the use of hydrogenated cyanamide efficiently induces budding. In addition, the efficacy, anticipation, and uniformity of budding favor its use (Kuroki et al. 2013).

CONCLUSION

CH_2N_2 efficiently induces bud sprouting of pear, with especially 4- and 5%-Dormex. Hybrid pear showed better performance in subtropical regions, with higher budding rates, than European pear.

AUTHORS' CONTRIBUTION

Conceptualization: Suárez, N. F., Abreu, R. A. A., Peche, P. M. and Pio, R.; **Data curation:** Suárez, N. F. and Pio, R.; **Formal analysis:** Silva, A. D. and Silva, E. M.; **Funding acquisition:** Suárez, N. F. and Pio, R.; **Investigation:** Suárez, N. F., Abreu, R. A. A., Peche, P. M., Silva, A. D. and Pio, R.; **Methodology:** Suárez, N. F. and Pio, R.; **Investigation:** Suárez, N. F., Abreu, R. A. A., Peche, P. M., Silva, A. D. and Pio, R.; **Software:** Silva, A. D. and Silva, E. M.; **Visualization:** Silva, A. D. and Silva, E. M.; **Project administration:** Pio, R.; **Resources:** Pio, R.; **Supervision:** Pio, R.; **Validation:** Pio, R.; **Writing – original draft:** Pio, R; **Final approval:** Pio, R.

DATA AVAILABILITY STATEMENT

All dataset were generated and analyzed in the current study.

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