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Evaluation of garlic extract on bud dormancy release of 'Royal Gala' apple trees

R. V. Botelho[A,B] *and M. M. L. Müller*[A]

[A]Departamento de Agronomia, UNICENTRO, R. Simeão Varella de Sá no. 03, Guarapuava-PR 85040-080, Brazil.
[B]Corresponding author. Email: rbotelho@unicentro.br

Abstract. This study aimed to examine the effects of garlic extract (Bioalho) on bud break of 'Royal Gala' apple trees compared with the effects of the conventionally used hydrogen cyanamide (H_2CN_2). In the southern region of Brazil, immediately after winter pruning on 19 September 2005, the following treatments were sprayed at dormant bud stage using a hand sprayer: (1) control (untreated); (2) 1% garlic extract (GE); (3) 5% GE; (4) 10% GE; (5) 2% mineral oil (MO); (6) 1% GE + 2% MO; (7) 5% GE + 2% MO; (8) 10% GE + 2% MO; (9) 0.4% H_2CN_2 + 4% MO. GE at 1 or 5% + 2% MO showed similar effects compared with H_2CN_2 alone, achieving ~80% bud sprouting, whereas 2% MO and the untreated control attained 53 and 18% bud sprouting, respectively. The 10% GE + 2% MO treatment was superior to the others treatments, reaching 95% bud sprouting at 50 days after treatments. The application of 10% GE + 2% MO was also the most effective in advancing bloom. Unfortunately, in this experiment, this also contributed to reduced fruit yield, since the early anthesis coincided with an atypical rainfall in the beginning of spring.

Additional keywords: *Malus domestica*.

Introduction

Deciduous fruit trees usually enter dormancy during the winter, affording the trees better survival under low temperature conditions. To begin the next year's growth flush in spring, trees need to be exposed to a chilling period. This period is variable for each species and cultivar (Petri *et al*. 1996).

The principal apple cultivars grown in Brazil, namely Gala and Fuji, do not meet their full chilling requirements (Petri 1997), even at the higher elevations of the southern region (Iuchi *et al*. 2002). Therefore, the use of chemicals for breaking bud dormancy is essential.

Many compounds have an effect on bud dormancy release. These compounds include mineral oil (MO), hydrogen cyanamide (H_2CN_2), dinitro-o-cresol, calcium cyanamide and thidiazuron. Presently, however, only MO and H_2CN_2 are recommended for sprouting induction of deciduous fruit trees in Brazil (Petri *et al*. 2002). Similarly, H_2CN_2 is used in other countries. In 2001, an estimated 112 491 kg were used in California and 36 287 kg were used in Italy, primarily on grapes (Settimi *et al*. 2005).

Increasing restrictions on the use of synthetic substances in orchards, as recommended by groups supporting sustainable systems (e.g. Integrated Fruit Production and Organic Fruit Production), means the lack of alternatives for inducing bud dormancy break of deciduous fruit trees, may become an important limitation for deciduous fruit production in warm climate regions (McArtney and Walker 2004).

Another issue of concern is the toxicity of H_2CN_2. Adverse health effects from contact with H_2CN_2 include severe irritation and ulceration of the eyes, skin and respiratory tract, in addition to causing acetaldehyde syndrome (Settimi *et al*. 2005). The USA Environmental Protection Agency classifies this compound in the highest toxicity category (category I); it is currently under regulatory review by European Union authorities (Settimi *et al*. 2005).

In searching for alternatives that could be used to induce early budbreak, Kubota and Miyamuki (1992) reported that garlic paste applied to cane cut surfaces of 'Muscat of Alexandria' grapevines immediately after pruning was more efficient than calcium cyanamide. Satisfactory results were also obtained by using 20% garlic oil in 'Pione' and 'Thompson Seedless' grapevines (Kubota *et al*. 2000). In 'Santa Rosa' plum trees, mixtures of 4% MO and 2, 4 or 8% garlic extract (GE) were effective for releasing bud dormancy (Sanchez 1992). According to Kubota *et al*. (1999), the active substances in garlic responsible for breaking bud dormancy are volatile compounds containing sulfur and an allyl group, such as diallyl mono-, di- and tri-sulfides.

The purpose of the present study was to compare the effects of using GE (with or without the use of MO) on bud break of 'Royal Gala' apple trees with the standard treatment using H_2CN_2.

Material and methods

The experiment was carried out in a 3-year-old commercial orchard of 'Royal Gala' apple trees on EM.9 rootstock located in Guarapuava, Paraná, Brazil (25°33′S, 51°29′W, 1095 m a.s.l.), spaced 0.9 by 3.6 m and trained to a central leader. During the winter, from May to September 2005, trees accumulated 268

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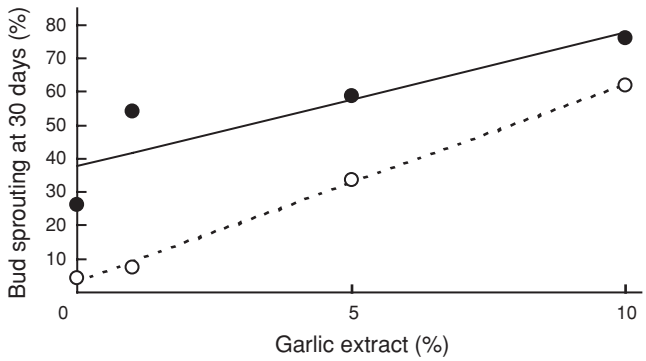

Fig. 1. Bud sprouting (%) of 'Royal Gala' apple trees treated with different garlic extract doses combined (● y = 37.6697 + 4.0169x, r^2 = 0.7759, P < 0.001) or not combined (○ y = 3.1145 + 5.9214x, r^2 = 0.9979, P < 0.001) with 2% mineral oil at 30 days after treatments.

chilling hours (≤7.2°C) or 902.2 chilling units according to the North Carolina Method (Shaltout and Unrath 1983).

Treatments were composed of the following commercial products: Bioalho (GE, Natural Rural Co.), Attach (75% MO, Bayer Cropscience Co.) and Dormex (490 g/L H_2CN_2, Basf Co.). Bioalho is a water-soluble natural product obtained from the cold-pressing of garlic cloves.

Immediately after winter pruning, on 19 September 2005, the following treatments were sprayed to 'drip point' at dormant bud stage using a hand driven sprayer: (1) control (untreated); (2) 1% GE; (3) 5% GE; (4) 10% GE; (5) 2% MO; (6) 1% GE + 2% MO; (7) 5% GE + 2% MO; (8) 10% GE + 2% MO; (9) 0.4% H_2CN_2 + 4% MO. The reason for the use of a lower dose of MO in GE mixtures was to avoid a possible risk of plant toxicity.

The trial was laid out using a randomised block design with five whole-tree replications. Each apple tree was examined for bud sprouting percentage and number of opened flowers at 30, 37, 43 and 50 days after treatments (DAT). Bud break was considered positive when a green tinge was seen beneath the bud scales. Fruit harvest took place on 31 January 2006, at which time the number of fruit and their total weight were recorded.

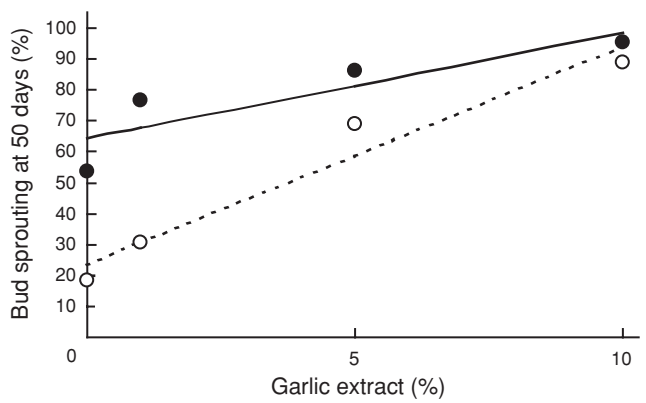

Fig. 2. Bud sprouting (%) of 'Royal Gala' apple trees treated with different garlic extract doses combined (● y = 64.2383 + 3.431x, r^2 = 0.7631, P < 0.01) or not combined (○ y = 23.4506 + 7.057x, r^2 = 0.9532, P < 0.001) with 2% mineral oil at 50 days after treatments.

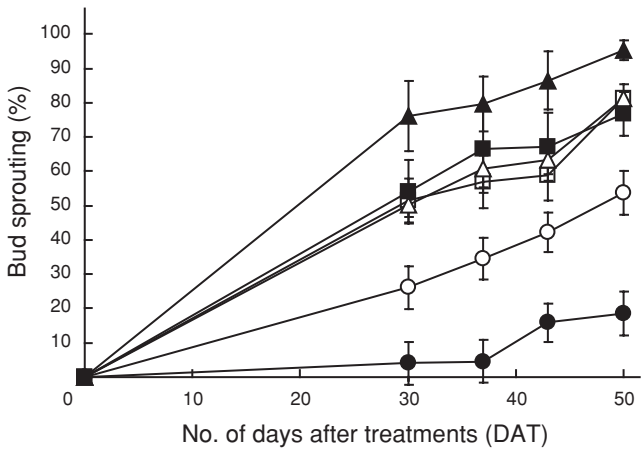

Fig. 3. Bud sprouting (%) of 'Royal Gala' apple trees treated with different garlic extract doses and 2% mineral oil or 0.4% cyanamide hydrogen and 4% mineral oil (● control, ○ 2% MO, ■ 1% GE + 2% MO, □ 5% GE + 2% MO, ▲10% GE + 2% MO, △ 0.4% H_2CN_2 + 4% MO) at various evaluation dates. Vertical bars indicate standard deviations (n = 5).

All data were analysed statistically using the ANOVA and factorial analysis methods in the SANEST statistical package (UNESP, Jaboticabal-SP, Brazil). Meaningful comparisons were generated using Tukey`s test (1% level) and regression analysis.

Results and discussion

At 30 DAT, bud break of 'Royal Gala' apple trees increased linearly with increasing doses of GE. The addition of MO to GE further increased sprouting, especially when mixed at a 1% dilution (Fig. 1). In this evaluation, fewer than 5% of buds had sprouted in untreated plants, compared with ~55% with 1% or 5% GE + 2% MO and 75% with 10% GE + 2% MO.

At 50 DAT, the GE doses showed a linear effect on bud break. The MO also promoted bud sprouting and improved the GE effect, mainly when used at a 1% dilution (Fig. 2). The most

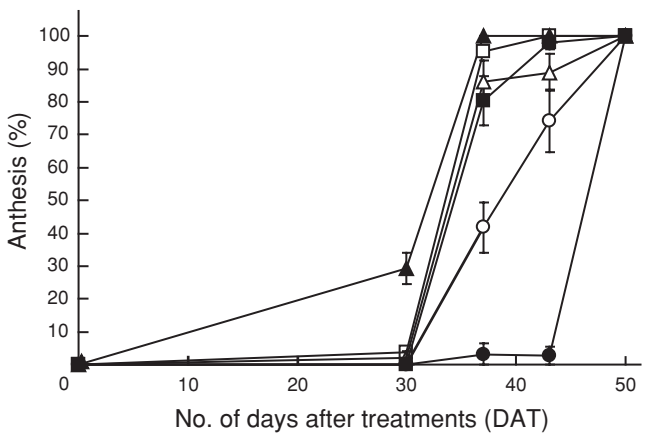

Fig. 4. Anthesis (%) of 'Royal Gala' apple trees treated with different garlic extract doses and 2% mineral oil or 0.4% cyanamide hydrogen and 4% mineral oil (● control, ○ 2% MO, ■ 1% GE + 2% MO, □ 5% GE + 2% MO, ▲10% GE + 2% MO, △ 0.4% H_2CN_2 + 4% MO) at various evaluation dates. Vertical bars indicate standard deviations (n = 5).

Table 1. Number of fruit, fruit weight (g) and yield (g/plant) of 'Royal Gala' apples treated with different substances for bud break
Mean separation within each column by Tukey's test ($P = 0.01$)

Treatment	No. of fruit	Fruit weight (g)	Yield (g/plant)
Control (untreated)	3.5b	93.5	318b
1% garlic extract (GE)	8.5ab	104.3	876ab
5% GE	16.2a	115.2	2026a
10% GE	15.2a	111.0	1019a
2% mineral oil (MO)	11.0ab	103.3	1114ab
1% GE + 2% MO	6.8ab	116.8	802ab
5% GE + 2% MO	3.0b	104.0	329b
10% GE + 2% MO	2.5b	115.0	306b
0.4% H_2CN_2 + 4% MO	7.2ab	114.0	824ab
Significance of *F*-value	0.001	0.416	0.001
l.s.d. ($P = 0.01$)	10.2859	13.77	1389.8

effective treatments were those using the Bioalho and MO mixtures, which obtained between 76% to 95% bud sprouting.

The use of 10% GE + 2% MO was significantly superior to all other treatments, reaching 95% bud sprouting at 50 DAT. Standard treatment (0.4% H_2CN_2 + 4% MO) and 1% or 5% GE + 2% MO, showed similar trends, achieving ~80% bud sprouting, athough 2% MO and the control, obtained only 53 and 18% bud burst, respectively (Fig. 3).

The treatments with GE and MO advanced anthesis, as did the standard treatment with H_2CN_2. The use of 10% GE + 2% MO was the most effective treatment in the acceleration of blooming of 'Royal Gala' apple trees (Fig. 4). Unfortunately, in this experiment, this also contributed to reduced fruit yield, since the early anthesis coincided with an atypical rainfall period at the beginning of the spring. Between 19 September to 18 October, rainfall was ~339 mm.

In general, fruit yield was very low due to this higher than average rainfall. Although treatments with GE and MO had improved bud burst, they also advanced flowering (Fig. 4), contributing to yields and number of fruit similar to the control (Table 1). The treatments with 5% or 10% GE had higher yields and numbers of fruit because, in these cases, the sprouting was irregular, thus allowing a partial escape from the rainfall period. Fruit weight was not affect by treatments, although the untreated plants had shown slightly lower fruit weight (Table 1).

In 2005, 'Royal Gala' apple trees did not have their chilling requirements fulfilled in the Guarapuava region. This apple cultivar needs 1115 chilling units (by the North Carolina Method) for bud dormancy release (Chariani and Stebbins 1994) and, during the winter of 2005, only 902.2 chilling units were accumulated. For this reason, untreated plants showed a poor sprouting, with only 18% bud burst, at 50 DAT.

The effectiveness of H_2CN_2 and MO mixture on bud dormancy release of 'Royal Gala' apple trees verified in this trial was to be expected, considering it is the standard treatment for this purpose in Brazil. However, the role H_2CN_2 played in break dormancy was not completely elucidated, and this could be related to its effects on the cell respiratory system and interference in some enzymatic processes that control plant rest, such as catalase inhibition and peroxidases activation (Taylorson and Hendricks 1977; Shulman *et al*. 1986; Perez and Lira 2005).

Nevertheless, the search for new bud break agents is essential due to the high toxicity of H_2CN_2 (Settimi *et al*. 2005). The abovementioned alternative, Bioalho, is a natural product recommended for organic production systems according to actual Brazilian legislation.

In this experiment, GE and MO mixtures were equal or better than the standard treatment for break dormancy of 'Royal Gala' apple trees. Similar results were verified with garlic-based compounds in grapevines (Kubota and Miyamuki 1992; Kubota *et al*. 2000) and plum trees (Sanchez 1992). According to Kubota *et al*. (1999) the active substances in garlic responsible for breaking bud dormancy are volatile compounds containing sulfur and an allyl group, especially the diallyl dissulfide, which is the most abundant sulfide in garlic. Exposure of grapevine cuttings to volatiles from grated garlic and commercial garlic promoted budbreak. However, the effect of diallyl disulfide on the breaking bud dormancy in grapevines that were not chilled was not established (Kubota *et al*. 2000).

The most effective treatment was 10% GE + 2% MO, which conferred 95% bud burst and anticipated anthesis of 'Royal Gala' apples. Economically, this treatment is too expensive and in order to be competitive, GE should be used in doses similar to that of H_2CN_2. The results with 1% GE + 2% MO were analogous to the standard treatment with H_2CN_2 and, therefore, GE is more economically viable. Nevertheless, further investigations using higher MO doses probably will permit a reduction in the Bioalho dose and thus increase the effectiveness and the competitiveness of GE use for bud dormancy release of apple trees. Additionally, the toxicity of GE in sprouted buds should be examined, as toxicity has been a major problem with the use of H_2CN_2 when the dormancy break is delayed.

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