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Effects of different pH sprays on the efficiency of prohexadione-Ca in sweet cherry trees

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ABSTRACT

In 2003 and 2004, young 'Kordia' sweet cherry trees were sprayed with prohexadione-Ca (Pro-Ca) to control tree growth and stimulate flower bud setting. A rate of 200 mg Pro-Ca $l^{-1} \times 2$ dissolved in various pH-buffered (6.0-4.5) aqueous solutions was used. Regardless of the acidity of the spray solution applied, the trees treated with Pro-Ca were characterised by reduced shoot and internode length, greater number of shoots (2003) and increased total shoot extension (2004) relative to the control. In both years, Pro-Ca applied in a pH-4.5 buffer solution contributed to an increase of flower bud clusters on current-season shoots. However, there were no significant differences among Pro-Ca/pH treatments either in the vegetative or generative characteristics studied. Two years after Pro-Ca application, no residual effects were found in the studied tree characteristics.

Key words: acidification, bioregulators, current-season shoot, flower bud, growth retardation, Regalis ®

Abbreviations:

Pro-Ca – prohexadione-calcium (active ingredient of Regalis ®)

INTRODUCTION

Prohexadione-Ca is an active ingredient of Regalis ®, a multi-functional plant bioregulator. Fruit species vary in their responses to Pro-Ca (Basak and Rademacher 1998). Apples and pears usually respond well to Pro-Ca with growth reduction even if applied at low rates (Basak 2004, Asin and Vilardell 2006, Cline et al. 2008). Byers and Yoder (1999) found no response in peach trees to Pro-Ca, whereas sweet cherries are somewhat erratic in response, producing short-term, generally transient growth inhibition (Elfving et al. 2003 and 2005). The efficacy of Pro-Ca depends on many factors, amongst which the pH of the water carrier is of paramount importance. Prohexadione-Ca may readily permeate membranes to reach its cellular target, provided that the Pro-Ca is in a non-dissociated form (Rademacher and Kober 2003). Therefore, the velocity and intensity of Pro-Ca uptake is greatly improved by the acidic conditions of the carrier (Rademacher and Kober 2003).

Further growth inhibition in sweet cherries may be achieved by application of ethephon (Facteau and Rowe 1979). Elfving et al. (2003, 2004, 2005) found that a combination of Pro-Ca and ethephon synergistically inhibited the growth of sweet cherries. It is agreed that Pro-Ca sprays are ineffective in floral bud induction in apples

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(Greene 1999), pears (Vanthournout et al. 2006) and sweet cherries (Elfving et al. 2003, 2004, 2005; Guak et al. 2005). However, either using higher concentrations of Pro-Ca above 200 mg l^{-1} (Jacyna and Lipa 2010), increasing the acidity of the Pro-Ca water carrier (Wielgus 2008) or combining Pro-Ca with ethephon (Elfving et al. 2003) may increase flower bud setting on previous-year wood and/or in some instances on older wood in sweet cherry trees.

The study reported here was designed to investigate the retardation effects of Pro-Ca dissolved in different pH buffers applied as sequential sprays to young non-cropping 'Kordia' sweet cherry trees.

MATERIAL AND METHODS

The experiment was conducted from 2003 to 2005 in a commercial orchard in the Lublin area, Poland. The sweet cherry trees of the 'Kordia' cultivar on *Prunus avium* L. rootstock were three years old at the time the experiment began. Tree spacing was 1.5 × 3.0 (m) and the trees were trained as a slender axe canopy. The orchard floor consisted of 50 cm-wide herbicide strips and mowed grass alleyways in between. Cultural and plant protection practices were routine for young non-bearing sweet cherry orchards.

Experimental procedures and treatments: the trees were sprayed to run off using 275 ml per tree of aqueous solution containing 200 mg l^{-1} of Pro-Ca (Regalis ® by BASF, Ludwigshafen, Germany). A non-ionic surfactant, Superam 10AL at 0.75 ml l^{-1}, was added to each spray treatment. The first sprays were performed when new shoots were about 10 cm long, and the second sprays were done 17 days later. Pro-Ca was dissolved in 0.1 M buffered solution of citric acid and sodium nitrate (Mejbaum-Katzenellenbogen and Mochnacka 1966) to set the following treatments (Pro-Ca/pH buffer): 6.0, 5.8, 5.5, 5.0 and 4.5. The control trees were sprayed once with pH 5.5 buffered water solution at the time of the second chemical application. Distilled water was used for all sprays. The pH of the solutions was measured using a Beckman type Ø 12 pH/ISE meter with combined electrodes. At the end of the season, additional trees were chosen and used as non-sprayed control (for internode length measurement).

Data recording and analysis: a randomised complete block design with seven single-tree replications was used in 2003. In 2004, the original experiment design was split into two parts, with the first consisting of four blocks with single-tree replications being chemically treated as in the previous year, and the second part containing three blocks of single-tree replications, which were left intact to observe the residual effects of the 2003 chemical treatment. Upon completion of each growing season, the following data were recorded from three uniform branches of every tree: length and diameter of the branch, length and number of current-season shoots, and the number of flower clusters. To determine internode length, one shoot from each branch was taken and its length and number of nodes were recorded. The data were subjected to analysis of variance. For means separation, the Fisher LSD test at p = 0.05 was used, and the Duncan multiple range test was applied for shoot internode length.

RESULTS AND DISCUSSION

Effect on mean shoot and internode length: in both application years, Pro-Ca reduced shoot length, and in 2003 the internode length (Tab. 1). There were highly significant differences in the shoot and internode lengths between all of the chemical

Table 1. The effects of prohexadione-calcium applied in various pH buffered aqueous solutions on shoot and internode length of 'Kordia' sweet cherry trees

Treatments Pro-Ca [b]/pH buffer	Mean shoot length (cm)			Internode length (cm)
	Year of treatment			Year of treatment
	2003	2004	2005[a]	2003
Control[c]	-	-	-	3.06 b[f]
Control/water[d]	43.5 c[e]	23.3 b	24.2 a	3.22 b
Pro-Ca/6.0	28.2 a	11.7 a	22.4 a	2.22 a
Pro-Ca/5.8	27.9 a	15.2 a	23.8 a	2.17 a
Pro-Ca/5.5	34.7 b	14.5 a	24.4 a	2.47 a
Pro-Ca/5.0	27.9 a	14.5 a	19.4 a	2.23 a
Pro-Ca/4.5	31.0 ab	13.6 a	20.4 a	2.44 a

[a] – residual effect by 2003 treatment; [b] – prohexadione-calcium at 200 mg l^{-1}; [c] – no water sprayed; [d] – sprayed with pH 5.5 buffered aqueous solution; [e] – mean separation by the Fisher LSD test at p = 0.05; [f] – mean separation by the Duncan multiple range test at p = 0.05. Means followed by the same letters are not significantly different for both tests

treatments and the control (P = 0.0000). Yet no differences in these characteristics among Pro-Ca/pH treatments were found. Also, there was no difference in internode length between water-sprayed (pH 5.5) and non-sprayed controls. No residual effects of the 2003 Pro-Ca application on shoot length were noted (P = 0.6027) – Table 1.

Effect on the number of current-season shoots and their total length: Pro-Ca increased the number of current-season shoots in comparison with the control in 2003, but not in the subsequent year. However, no significant differences were noted among the chemical treatments, and no residual effects were found of the 2003 Pro-Ca application measured in 2005 on the number of shoots (Tab. 2). Generally speaking, we did not observe any significant differences in total shoot extension between the control and all chemically treated trees in 2003, except some differences between Pro-Ca/4.5 and either Pro-Ca/5.8 or Pro-Ca/6.0 (Tab. 2). In 2004, the reapplication of prohexadione-calcium, regardless of the type of buffer solution used, caused significant growth suppression as compared with the control trees. Yet no differences in this regard amongst the chemically treated trees were observed. There were no residual effects of the 2003 Pro-Ca treatment on this characteristic (Tab. 2).

Effects on the number of flower clusters in current-season shoots: Pro-Ca dissolved in pH 4.5 buffer significantly increased floral bud setting on previous-season shoots in comparison with the controls in both years (Tab. 3). There were no significant differences in this respect either between the remaining chemical treatments and the controls or amongst the chemical treatments in both 2003 and 2004, except Pro-Ca/5.5 vs. the control in 2004. Consequently, no significant residual effects were detected in the number of flower clusters caused by the 2003-Pro-Ca treatment in 2005 (Tab. 3).

In our experiment, the Pro-Ca-treatments reduced the values of most of the examined characteristics relative to the untreated control. This was most explicitly demonstrated by the lengths of previous-season shoots and internodes. Guak et al. (2005) and Manriquez et al. (2005) reported similar findings for 'Lapins' and 'Bing' sweet cherries, respectively. The number of these shoots was influenced by Pro-Ca only in the first year of treatment. We believe that this response was

Table 2. The effects of prohexadione-calcium applied in various pH buffered aqueous solutions on the number of shoots and total shoot extension growth of 'Kordia' sweet cherry trees

Treatments Pro-Ca [b]/pH buffer	Number of lateral shoots per cm² of branch cross-sectional area			Total length of shoots per cm² of branch cross-sectional area (cm)		
	Year of treatment			Year of treatment		
	2003	2004	2005[a]	2003	2004	2005[a]
Control/water[c]	2.7 a[d]	2.3 a	2.3 a	110.6 ab	54.6 b	55.2 a
Pro-Ca/6.0	3.5 b	2.1 a	2.2 a	97.7 a	24.1 a	48.6 a
Pro-Ca/5.8	3.6 b	2.3 a	1.7 a	97.4 a	35.4 a	40.0 a
Pro-Ca/5.5	3.5 b	1.8 a	1.9 a	114.5 ab	26.2 a	44.8 a
Pro-Ca/5.0	4.0 b	2.2 a	2.3 a	110.8 ab	31.4 a	43.6 a
Pro-Ca/4.5	3.9 b	2.3 a	2.0 a	116.2 b	31.3 a	41.3 a

[a] – residual effect of 2003 treatment; [b] – prohexadione-calcium at 200 mg l^{-1}; [c] – sprayed with pH 5.5 buffered aqueous solution; [d] – mean separation by the Fisher LSD test at p = 0.05. Means followed by the same letters are not significantly different

Table 3. The effects of prohexadione-calcium applied in various pH buffered aqueous solutions on the number of flower clusters of 'Kordia' sweet cherry trees

Treatments Pro-Ca [b]/ pH buffer	Number of flower clusters per cm ² of branch cross – sectional area		
	Year of treatment		
	2003	2004	2005[a]
Control/water [c]	1.28 a[d]	3.59 a	3.68 a
Pro-Ca/ 6.0	1.43 a	4.82 ab	4.72 a
Pro-Ca/ 5.8	1.26 a	4.01 ab	3.92 a
Pro-Ca/ 5.5	1.43 a	6.00 b	5.26 a
Pro-Ca/ 5.0	1.51 ab	5.47 ab	4.37 a
Pro-Ca/ 4.5	1.86 b	6.28 b	4.79 a

[a] – residual effects of 2003 treatment; [b] - prohexadione-calcium at 200 mg l^{-1}; [c] – sprayed with pH 5.5 buffer aqueous solution; [d] – mean separation by the Fisher LSD test at p = 0.05. Means followed by the same letter are not significantly different

most likely cultivar-related. It has been reported that Pro-Ca applied at comparable rates increased shoot number in 'Lapins' but not in either 'Bing', 'Regina' or 'Burlat' sweet cherry cultivars (Elfving et al. 2003, Wielgus 2008, Jacyna and Lipa 2010). After Buban, Basak (2007) reported that Pro-Ca treatment initiated lateral branching in apples in Hungarian trials. There was no evidence of shoot extension reduction by Pro-Ca in the first year, but there was for the subsequent year. It is believed that these year-dependent responses were related to changes in the performance of either shoot number or mean shoot length in both years. These data support earlier findings reported by Basak (2007).

A mutual comparison of chemical treatments showed no effect of the applied pH buffers on the performance of the studied growth characteristics. Rademacher and Kober (2003), and Byers et al. (2004) reported that some improvement in the efficacy of Pro-Ca may be accomplished by the addition of water conditioners or acidifiers to spray solutions. It has been revealed that Pro-Ca is readily absorbed by plant tissues in a non-dissociated form from aqueous solution in the pH range of 4.0 to 5.5 (Rademacher and Kober 2003). Rademacher and Kober (2003), and Wielgus (2008) reported that Pro-Ca at 250 mg l^{-1} dissolved in water acidified with 1 g l^{-1} of citric acid (pH 2.8 – 3.2) reduced the shoot length of barley and sweet cherry to 57 and 40% of control, respectively. Therefore, a low natural responsiveness of 'Kordia' sweet cherry trees to prohexadione-Ca, and an apparently inadequate acidification of the working solutions used in this trial, may explain the partial failure in growth retardation.

Young sweet cherry trees form flower buds on the basal parts of previous-season wood. Jacyna (unpublished) found that Pro-Ca at 250 mg l^{-1} (water carrier of pH 3.2) improved flower bud setting on previous-season wood but not on older spurs. The addition of ethephon to Pro-Ca stimulated a further increase in flower bud formation, including setting flower buds on older wood (Elfving et al. 2003). Generally, the increase in floral bud setting coincides with a simultaneous reduction in shoot length (Elfving et al. 2003, Wielgus 2008). In our experiment, only Pro-Ca applied in the pH-4.5 buffered solution contributed to a significant improvement in flower bud formation in two consecutive years, but it did not reduce the length of shoots as compared with other non-zero treatments. Presumably, this increase in flower cluster number was additionally caused by factors other than the shoot-length-reduction mechanism.

There are few reports on carry-over shoot length reduction in sweet cherries by Pro-Ca. Jacyna and Lipa (2010) reported some residual effects in shoot extension in 'Regina' sweet cherries treated at 125 mg Pro-Ca $l^{-1} \times 2$. Wielgus (2008) found that in the year following Pro-Ca application at 250 mg l^{-1}, internodal length was significantly reduced relative to the untreated control. We did not observe any carry-over effects of Pro-Ca in the studied tree characteristics in this experiment; however, Guak et al. (2005) and Basak (2007) reported some compensatory growth the year following Pro-Ca application on sweet cherries and apples, respectively.

CONCLUSIONS

The results of this research suggest that Pro-Ca may establish an acceptable level of growth control and stimulation of flower bud formation on previous-season shoots in young 'Kordia' sweet cherry trees grown in dense plantings, provided that the compound is applied in a water carrier of pH $\leq$ 4.5 acidity. No Pro-Ca residual effects on growth and flower bud setting may be expected, so the compound ought to be applied every year. A continuation of the research on sweet cherries to match the rates and frequency of Pro-Ca application to tree growth, soil and climatic conditions is suggested.

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WPŁYW ROZTWORÓW O RÓŻNYM pH NA SKUTECZNOŚĆ PROHEKSADIONU-Ca W DRZEWACH CZEREŚNI

Streszczenie: Doświadczenie prowadzono w latach 2003-2005 na młodych nie owocujących drzewach czereśni odmiany 'Kordia'. Drzewa opryskiwano dwukrotnie proheksadionem wapnia (Pro-Ca) w dawce 200 mg l^{-1} rozpuszczonym w roztworach buforowych o różnym pH (od 6,0 do 4,5). Drzewa traktowane Pro-Ca, niezależnie od kwasowości roztworu, charakteryzowały się zredukowaną długością pędów jednorocznych i międzywęźli, większą liczbą pędów (2003) oraz ich większą sumaryczną długością (2004) w porównaniu z drzewami kontrolnymi. Pro-Ca zastosowane w roztworze o pH 4,5 spowodowało istotny wzrost liczby pąków kwiatowych zawiązanych u nasady pędów jednorocznych w stosunku do kontroli. Nie stwierdzono istotnych różnic w wartościach badanych cech wśród kombinacji chemicznych o różnym pH. Dwa lata po zastosowaniu Pro-Ca nie stwierdzono następczego wpływu preparatu na badane cechy drzew.

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