Scientia Horticulturae 168 (2014) 51–57

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

# Impacts of preharvest fall sprays of calcium chloride at high rates on quality and 'Conference' pear storability

P. Wójcik*, A. Skorupińska, J. Filipczak

*Research Institute of Horticulture, ul. Konstytucji 3 Maja 1/3, 96-100 Skierniewice, Poland*

ARTICLE INFO

*Article history:*
Received 20 November 2013
Received in revised form 8 January 2014
Accepted 10 January 2014

*Keywords:*
'Conference' >pears
Fall Ca sprays
Fruit storability

ABSTRACT

The aim of the study was to examine effects of preharvest fall sprays of calcium chloride ($CaCl_2$) at high rates on quality and 'Conference' pear (*Pyrus communis* L.) storability. The experiment was carried out during 2011–2013 in central Poland, on mature pear trees grafted on Quince S1 (*Cydonia oblonga* Mill.), planted on a coarse-textured soil with low level of organic mater. The trees were sprayed with $CaCl_2$ six times during a growing season. The first spray treatment was made 6 weeks after full bloom and the last one - 7 days before harvest. The doses of $CaCl_2$ in the first fifth spray measures (summer sprays) were 2–5 kg $ha^{-1}$, whereas in the last treatment (fall spray): 5, 10, 15, 20 or 25 kg $ha^{-1}$. The trees unsprayed with Ca served as the control. The results showed that fall sprays of $CaCl_2$ at increased rates (10, 15, 20 and 25 kg $ha^{-1}$) injured leaves. The most intensive leaf burn was recorded as a result of fall spray of $CaCl_2$ at a rate of 25 kg $ha^{-1}$. The above spray treatment caused also defoliation; however, it did not affect cold damage of flower buds. $CaCl_2$ sprays had no influence on yield, mean fruit weight, russeting and peel color, and flesh firmness, soluble solids concentration (SSC) and titratable acidity of fruit at harvest. >Pears sprayed with >$CaCl_2$ had increased Ca status; the most Ca was found in fruit treated with $CaCl_2$ in the summer and in the fall at doses of 20 and 25 kg $ha^{-1}$. All spray treatments of $CaCl_2$ inhibited production rates of ethylene ($C_2H_4$) and carbon dioxide ($CO_2$) by fruit at harvest. After storage, pears sprayed with $CaCl_2$ in the summer and the fall at rates of 20 and 25 kg $ha^{-1}$ produced less $C_2H_4$ and $CO_2$, contained more organic acids, and were firmer, greener and less sensitive to internal browning than the control fruit. It is concluded that fall sprays of $CaCl_2$ at a rate of 20 or 25 kg $ha^{-1}$ should be recommended in 'Conference' pear orchards, as supplement of summer Ca sprays, to improve fruit storability.


## 1. Introduction

Deficiency of calcium (Ca) occurs commonly in major growing regions of fleshy fruit, particularly of apples (Shear, 1975). This phenomenon is observed even on calcareous soils (Malakouti et al., 1999). A significant Ca importance in fruit production results from the fact that this nutrient plays a critical role in quality and fruit storability (Fallahi et al., 1997; Kader, 1992; Shear, 1975). For example, apples (*Malus domestica* Borkh.) with low Ca status are sensitive to sunburn, splitting, some physiological disorders (e.g. bitter pit, water core, internal and senescence breakdown), and decay during storage (Conway and Sams, 1983; Conway et al., 2002; Ferguson and Watkins, 1989; Wójcik, 2004). In case of pears (*Pyrus communis* L.), low Ca concentrations in tissues of flesh/skin are related to the incidence of some pre- and postharvest disorders, such as alfalfa greening (Raese et al., 1979), hard-end (Ackley, 1954), black end (Woodbridge, 1971), cork spot (Mason and Welsh, 1970), and internal browning (Zerbini and Sozzi, 1980).

For improvement of quality and pear storability, in some countries preharvest Ca sprays are recommended (Raese, 1994; Wójcik, 2012). Those Ca sprays are necessary since liming and/or soil application of Ca-containing fertilizers (e.g. Ca-nitrate) do not guarantee an increase of fruit Ca (Sadowski, 1967; Wójcik, 2009). This phenomenon results from the fact that Ca taken up by roots is transported preferentially to transpiring leaves and the shoot apices (Faust and Shear, 1973). Summer-fall Ca sprays at low rates (up to 1.4 kg Ca $ha^{-1}$ per spray treatment) are not always successful in obtaining pears rich in Ca (Wójcik, 2004, 2012). Thus, it seems that for winter pear varieties apart from summer-fall Ca sprays at low rates, spray treatments of this nutrient, just before harvest at high rates, would be justified. This result from the fact that increase in fruit Ca status as a result of preharvest sprays of this nutrient corresponds in general to the amount of used Ca-containing fertilizer (Świetlik and Faust, 1984; Wójcik, 2004). The efficiencies of

*Abbreviations:* SSC, soluble solids concentration; TA, titratable acidity; IB, internal browning.

* Corresponding author. Tel.: +48 46 8345233.
*E-mail addresses:* pawel.wojcik@inhort.pl (P. Wójcik), anna.wawrzynczak@inhort.pl (A. Skorupińska), jacek.filipczak@inhort.pl (J. Filipczak).

0304-4238/$ – see front matter © 2014 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.scienta.2014.01.017

**Table 1**
Physico-chemical parameters of the soil prior to initiation of the study.

| Parameter | Value |
|---|---|
| Density ($g\,cm^{-3}$) | 1.3 |
| pH | 5.9 |
| Sand (%) | 65 |
| Silt (%) | 20 |
| Clay (%) | 15 |
| Surface area ($m^2\,g^{-1}$) | 71 |
| Organic matter ($g\,C\,kg^{-1}$) | 13 |
| Exchangeable Ca ($cmol\,kg^{-1}$) | 16 |
| Available P ($mg\,kg^{-1}$) | 68 |
| Available K ($mg\,kg^{-1}$) | 121 |
| Available Mg ($mg\,kg^{-1}$) | 42 |
| Available B ($mg\,kg^{-1}$) | 4.1 |
| Available Fe ($mg\,kg^{-1}$) | 1454 |
| Available Mn ($mg\,kg^{-1}$) | 191 |
| Available Zn ($mg\,kg^{-1}$) | 6.1 |
| Available Cu ($mg\,kg^{-1}$) | 5.8 |

**Table 2**
Schema of preharvest sprays of calcium chloride in 'Conference' pear orchard.

| Weeks after full bloom | The spray combinations | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| | A rate of $CaCl_2$ ($kg\,ha^{-1}$) | | | | |
| 6* | 2 | 2 | 2 | 2 | 2 |
| 8 | 3 | 3 | 3 | 3 | 3 |
| 10 | 3 | 3 | 3 | 3 | 3 |
| 12 | 4 | 4 | 4 | 4 | 4 |
| 14 | 5 | 5 | 5 | 5 | 5 |
| 16 | 5 | 10 | 15 | 20 | 25 |

* Dates of spray treatments for 6, 8, 10, 12, 14 and 16 weeks after bloom were: 19 June, 3 and 17 July, and 1, 15 and 29 August of 2011, and 29 June, 13 and 27 July, 10 and 25 August and 8 September of 2012, respectively.

preharvest fall sprays of $CaCl_2$ at high rates in improving quality and apple storability have been examined in Poland by Wójcik (2001a), in Turkey by Wójcik et al. (2010), and in Washington State, USA, by Peryea and Neilsen (2006). In those studies, fall Ca sprays (applied ca. one week before harvest) at high rates (up to 24 kg Ca $ha^{-1}$) increased apple Ca status and improved their storability. However, there is no study assessing the efficiency of fall Ca sprays at high doses in pear production. Therefore, the aim of this experiment was to examine impacts of fall Ca sprays at high rates, as supplement of summer Ca sprays, on quality and 'Conference' pear storability.

## 2. Materials and methods

### 2.1. The study localization, plant material, and growth conditions

The study was carried out during 2011-2013 at an Experimental Orchard in Dąbrowice (central Poland), belonging to Research Institute of Horticulture in Skierniewice. The mean annual temperature and the sum of precipitation in this region are 8.3 °C and 490 mm, respectively. Average temperature and rainfall in vegetation period (May–October) are 14.9 °C and 302 mm, respectively.

The experimental field was established on a coarse-textured soil (Albic Luvisols). Basic physico-chemical properties of the soil are given in Table 1. Soil sample for analysis was taken prior to initiation of the study (fall 2010) from the surface layer (0–20 cm) of herbicide strips along tree rows, ca. 1 m from trunks. A composite soil sample, consisting of seven subsamples, was dried at room temperature and sieved through a plastic sieve with aperture size of 2 mm. A bulk density of soil was determined according to the core method (Tisdall, 1951); reaction (pH) was measured potentiometrically in 1:2.5 soil/1 M KCl suspension after shaking for 24 h (Mercik, 2004); particle contribution of sand (1–0.1 mm), silt (0.1–0.02 mm) and clay (<0.02 mm) by the aerometric method of Casagrande and Prószynski (described by Ostrowska et al. (1991)); soil surface area by ethylene glycol monoethyl ether adsorption procedure (Carter et al., 1965); status of organic matter according to the chromic and titration procedure (Allison, 1965); contents of available phosphorus (P) and potassium (K) by means of solution of Ca-lactate (at pH 3.6) and of available magnesium (Mg) by solution of 0.0125 M Ca-chloride (Ostrowska et al., 1991); amount of exchangeable Ca by means of 1 M $NH_4$-acetate solution (Ostrowska et al., 1991); status of available iron (Fe), manganese (Mn), zinc (Zn), copper (Cu) and boron (B) as a result of extraction with 1 M HCl (Mercik, 2004). Amounts of K, Mg, Ca, Fe, Mn, Cu, Zn and B in the soil were determined by an inductively coupled plasma spectroscopy (Thermo Jarrell Ash, Franklin, MA, USA), and of P by a spectrophotometer (Cintra 916, GBC, Dandenong, Australia), using the molybdenum blue reaction (Ostrowska et al., 1991).

Mature 'Conference' pear (Pyrus *P. communis* L.) trees grafted on dwarfing rootstock Quince S1 (*Cydonia oblonga* Mill.) were the subject of the experiment. Selection of this cultivar resulted from the fact that it is grown commonly in the European Union. The experimental trees were planted at a spacing of 4 × 2 m (1250 plants per ha) in the north–south oriented rows. Trees were trained as a spindle to a height of 3 m. To keep the canopy size within allotted space, the trees were pruned annually at the stage of swollen–burst of buds. Soil moisture from May to September was maintained nearly field capacity by drip irrigation; emitters were placed every 70 cm, delivering 4.1 L of water per ha. The trees grew in a 1.5-m-wide herbicide strips maintained by applications of Roundup 360 SL (glyphosate) in mid May and late July at a rate of 5 L $ha^{-1}$ in each treatment and of Basta 150 SL (ammonium glufosinate) in late August at a dose of 3 L $ha^{-1}$. The sod in the interrows was mowed 6–8 times per season.

To obtain most marketable fruit, hand fruitlet thinning was made. This measure was performed just after "June drop" and one month later. Control of pathogens and pests of the experimental trees was performed according to the standard recommendations for commercial orchards (Olszak and Bielenin, 2010).

Because prior to initiation of the study, soil contents of available/exchangeable nutrients were within optimal (Ca, B, Fe, Mn, Zn) or high (P, K, Mg, Cu) range, recommended by Sadowski et al. (1990) and Mercik (2004), only nitrogen (N) was applied annually over whole period of the examination. Nitrogen was used as ammonium nitrate (34-0-0), at the swollen buds, uniformly over entire orchard soil surface at a rate of 100 kg N $ha^{-1}$ (according to the recommendations of Wójcik (2009) for integrated pear production under conditions of coarse-textured soils, poor in organic matter). With exception of Ca, the trees were not supplied with mineral nutrients via foliar sprays.

'Conference' pears were harvested on 5 and 15 September of 2011 and 2012, respectively. Only fruit from trees were picked.

### 2.2. The studied treatments and the experiment layout

In 2011 and 2012, the trees were sprayed with Ca-chloride (commercial flake, 78% $CaCl_2$) six times in each growing season. Selection of $CaCl_2$ as Ca source resulted from the high efficiencies of sprays of this salt in improving fruit Ca status of different plant species (Raese and Drake, 1995; Świetlik and Faust, 1984; Wójcik, 2001b). The first spray treatment of $CaCl_2$ was made 6 weeks after full bloom, and the last one - 7 days before harvest. Intervals between Ca sprays were 14 days. The rates of $CaCl_2$ used in the given sprays depended on the tree growth stage (Table 2). In the first fifth treatments (summer sprays) doses of $CaCl_2$ varied from 2 to 5 kg $ha^{-1}$; those rates were in accordance to the recommendations of Wójcik (2009) for pear trees grown under polish conditions. In the last spray