

# Effects of calcium and/or phosphorus sprays with different commercial preparations on quality and storability of Šampion apples

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**ABSTRACT:** Investigations on the effect of spraying trees with various calcium, phosphorus and calcium-phosphorus preparations were carried out in 1999–2001. Effects of sprays depended on the type of preparation. Foliar calcium fertilization increased Ca concentration in apples; however, the effectiveness of the used fertilizer also depended on the season. A high calcium content in apples was measured when treated with the new Polish preparation Kalcisal. This effect was observed in all years of investigations. A better calcium supply affected the appearance of apples (usually more green background peel colouring, reflected in the chlorophyll content). In storage these fruits ripened later and lost less of their firmness than apples from control trees. With the higher calcium content in fruits the share of apples with physiological disorders decreased. The lowest losses of apples related to physiological disorders were observed when trees were sprayed with the solutions of Kalcisal or Rosacal.

**Keywords:** Šampion apple; calcium and phosphorus sprays; quality and storability

The results of the investigations point to a close relationship between the storability of apples and the contents of mineral components in fruit (FAILLA et al. 1990). The most frequently observed is the dependence between physiological disorders and apple calcium content (BEN 1995; BRAMLAGE et al. 1985; TOMALA 1995). SHARPLES and LITTLE (1970) presented an opinion that apart from calcium, a high content of phosphorus also limited the incidence of bitter pit. The proofs confirming the relationship between calcium content and the incidence of many physiological disorders were found in numerous experiments on spraying apple trees with calcium salt solutions and especially calcium chloride. Resulting from such treatments a significant decrease in the incidence of, among others, bitter pit (HEWETT, WATKINS 1991), breakdown (GUZEWSKA 1980) and core flesh (RESNIZKY, SIVE 1991) was reported. Although calcium foliar fertilization nearly always limited the incidence of physiological disorders, they were totally eliminated only in some, not numerous, experiments.

The aim of the present study was to evaluate the effects of various calcium and/or phosphorus preparations used for foliar fertilization on the quality and storability of Šampion apples.

## MATERIAL AND METHODS

The experiment was set up in 1999 in a commercial orchard in Central Poland on two-year-old apple trees of Šampion cultivar on M.26 planted at 4 × 1.5 m spacing. The soil was kept in the herbicide strips in tree rows with grass between rows. The investigations were carried out in three storage seasons: 1999/2000, 2000/2001

and 2001/2002. The experiment was set in four replications: one replication comprised 15 trees in a field. Trees were sprayed 7 times (each fortnight from mid-June) using 10 different fertilizers (the list of fertilizers is presented in Table 1). In all years of the investigations the same trees were sprayed with the Sleza type spraying apparatus using 1,000:1 of solution per ha. The control comprised fruits from trees that were not sprayed. The time of optimal apple harvest was established on the basis of the induced ethylene method. Apples were picked on 22 September 1999, 16 September 2000 and 18 September 2001. From each replication, about 16 kg of fruits were taken for storage and 15 apples for the investigations directly after harvest. Immediately after harvest the mean apple weight was determined, background colour (using a Minolta spectrophotometer), internal ethylene concentration (using gas chromatography), fruit flesh firmness (using a penetrometer by Instron) and the soluble solid content (using an Abbe refractometer). Fruit flesh and peel were collected for mineral analysis. Sample preparations for mineral analysis and determination of mineral elements were performed in accordance with the procedure presented by TOMALA (1995).

Apples were stored at the temperature of 2–3°C and relative air humidity of 90–95%. After 2 and 4 months of storage the background colour intensity of ethylene production was determined on a sample of 15 apples. After 4 months of storage the firmness and soluble solid content were determined, and the occurrence of storage disorders was identified. For the final evaluation of the results, the two-factor analysis of variance was used. This analysis for the percentage of apples with storage disorders was performed on the values transformed according to the Bliss formula. The Newman-Keuls test

Table 1. Calcium and phosphorus contents in Šampion apples depending on the preparation used for foliar fertilization

Preparation, Ca and/or P concentration	Ca (mg/kg d.m.)			P (% d.m.)		
	1999	2000	2001	1999	2000	2001
Control	263 a	192 a	283 a	0.087 a	0.086 ab	0.053 a
Calcium chloride (5 kg CaCl <sub>2</sub> /ha)	408 bc	264 abc	317 c	0.081 a	0.099 bc	0.072 ab
Kalcisal (5 l/ha) (concentrated CaCl <sub>2</sub> )	460 c	309 c	322 c	0.091 a	0.080 a	0.064 ab
Rosacal (5 l/ha) (22.4% CaO)	363 abc	261 abc	322 c	0.094 ab	0.084 ab	0.060 ab
Rosatop Calcium (5 l/ha) (22.5% CaO)	373 abc	255 abc	320 c	0.095 ab	0.089 ab	0.067 ab
Calcium nitrate (5 kg/ha) (26.5% CaO)	414 bc	275 abc	303 abc	0.092 ab	0.100 bc	0.064 ab
Wuxal Calcium (5 l/ha) (24% CaO)	358 abc	246 abc	316 c	0.092 ab	0.087 ab	0.061 ab
Kalcifos (5 l/ha) (concentrated CaCl <sub>2</sub> + P)	387 bc	248 abc	315 c	0.113 c	0.089 ab	0.082 b
Kalcisal/Kalcifos	355 abc	289 bc	307 bc	0.095 ab	0.089 ab	0.066 ab
Rosafos (5 l/ha) (5.8% CaO, 314 g/l P <sub>2</sub> O <sub>5</sub> )	352 abc	231 ab	319 c	0.116 c	0.096 b	0.081 b
Seniphos (5 l/ha) (5.6% CaO, 310 g/l P <sub>2</sub> O <sub>5</sub> )	328 ab	286 bc	307 bc	0.113 b	0.099 bc	0.070 ab
Wuxal Top P (5 l/ha) (26% P <sub>2</sub> O <sub>5</sub> )	352 abc	249 abc	304 abc	0.105 ab	0.110 c	0.076 b

Means marked with the same letter do not differ at the level of  $\alpha = 0.05$

was applied to evaluate the significance of differences between the means, at the significance level of 5%.

## RESULTS AND DISCUSSION

Foliar fertilization of trees significantly affected the amount of calcium detected in the apple flesh with peel. The highest value of this element was characteristic of fruits from trees that were sprayed with Kalcisal solutions. It should be stressed that in the remaining combinations of fertilization, apples were characterized by a significantly higher calcium content than the fruits from the control combination. Similarly like in the case of calcium, the phosphorus content also differed statistically. As compared to the control, a significantly higher content of this element was measured in the apples obtained from trees that were sprayed with solutions of the

following preparations: Rosafos, Seniphos, Wuxal Top P and Kalcifos (Table 1).

In many papers dealing with fruit storability, special attention is paid to the importance of the physiological status of apples during harvest. The present experiment revealed that all the tested preparations significantly slowed down the degree of starch hydrolysis in fruits as compared to apples from the control combination. It means that fruits from trees sprayed with calcium salt solutions can ripen later, which should be included in decisions concerning the time of apple harvest. Another indicator of the evaluation of the apple physiological status and, at the same time, one of the most important parameters of fruit quality is their firmness. In the case of this indicator, the foliar calcium and/or phosphorus fertilization appeared to limit the decrease in apple firmness significantly although differences between the

Table 2. The value of starch index at harvest and firmness of Šampion apples after two months of storage depending on the preparation used for foliar fertilization

Preparation	Starch index (1–10)			Firmness after 2 months of storage (N)			
	1999	2000	2001	1999	2000	2001	1999–2001
Control	7.7 c	5.0 c	6.1 a	39.5 a	33.4 a	38.6 a	37.2 a
Calcium chloride	5.6 a	4.9 bc	5.0 a	40.4 a	35.9 a	40.5 a	38.9 b
Kalcisal	6.6 b	4.3 abc	5.8 a	43.4 a	36.8 ab	42.2 a	40.8 b
Rosacal	5.8 ab	4.0 a	5.2 a	43.4 a	37.1 ab	41.9 a	40.8 b
Rosatop Calcium	5.7 a	4.1 ab	5.6 a	41.7 a	36.3 ab	41.7 a	39.9 b
Calcium nitrate	5.4 a	4.7 abc	5.0 a	39.9 a	37.2 ab	40.1 a	39.0 b
Wuxal Calcium	5.6 a	3.9 a	5.5 a	43.5 a	37.6 b	41.4 a	40.8 b
Kalcifos	6.2 b	4.3 abc	5.1 a	41.2 a	36.8 ab	41.7 a	39.9 b
Kalcisal/Kalcifos	5.8 ab	4.3 abc	6.0 a	43.7 a	36.5 ab	41.0 a	40.4 b
Rosafos	6.0 ab	4.2 abc	4.6 a	41.5 a	36.7 ab	40.5 a	39.6 b
Seniphos	5.9 ab	4.2 abc	4.8 a	40.3 a	37.2 ab	41.7 a	39.7 b
Wuxal Top P	5.9 ab	4.3 abc	5.5 a	40.3 a	37.0 ab	41.8 a	39.7 b

Means marked with the same letter do not differ at the level of  $\alpha = 0.05$

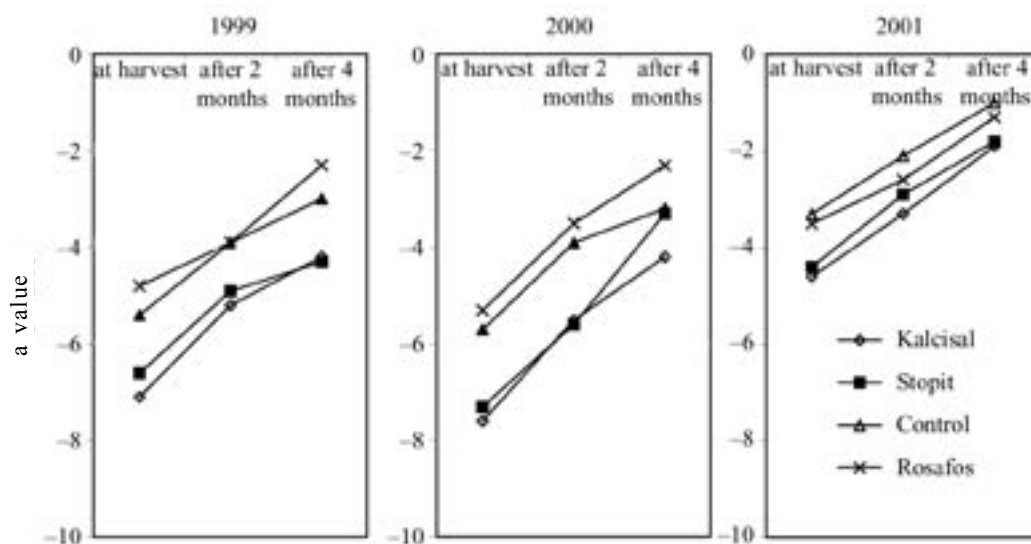


Fig. 1. Change of the peel background colour of Šampion apples during storage

particular combinations of spraying were not significant (Table 2).

In the literature referring to the physiological status of fruits, a lot of attention is paid to the fruit background colour. The present experiment revealed that the fruits from combinations favourable for higher calcium content lost the green colour of the peel at a slower rate than the fruits from combinations with lower calcium content. The results from combinations that were most differentiated are presented in Fig. 1. The greenest peel was characteristic of fruits from trees sprayed with calcium nitrate solutions while the least green peels were found in apples from the control combination. A significant effect of tree spraying on the background colour of apples revealed itself only after fruit storage. On the other hand, the chromatometric measurements taken after the end of storage always pointed to the proven relationship between the background colour and the type of fertilizer used for tree spraying. A greener peel colour

resulted above all from a higher content of chlorophyll that converged with higher calcium content. However, the effect of particular fertilizers on the rate of chlorophyll degradation, similarly like in the case of calcium content, largely depended on the season of the investigation. It should be stressed that the foliar fertilization of trees never showed any proven effect on the content of chlorophyll b. However, it can be stated generally that the change of the background colour from green to yellow took place much more slowly in apples with higher calcium content than in fruits containing lesser amounts of this element. More greenish peel colour after storage was observed in fruits obtained from trees sprayed with calcium nitrate or Rosacal.

The high calcium content was also connected with ethylene production during storage. In the case of this index, it proved that apples which were characterized by a higher calcium content produced ethylene in smaller amounts. This dependence was observed in all terms and

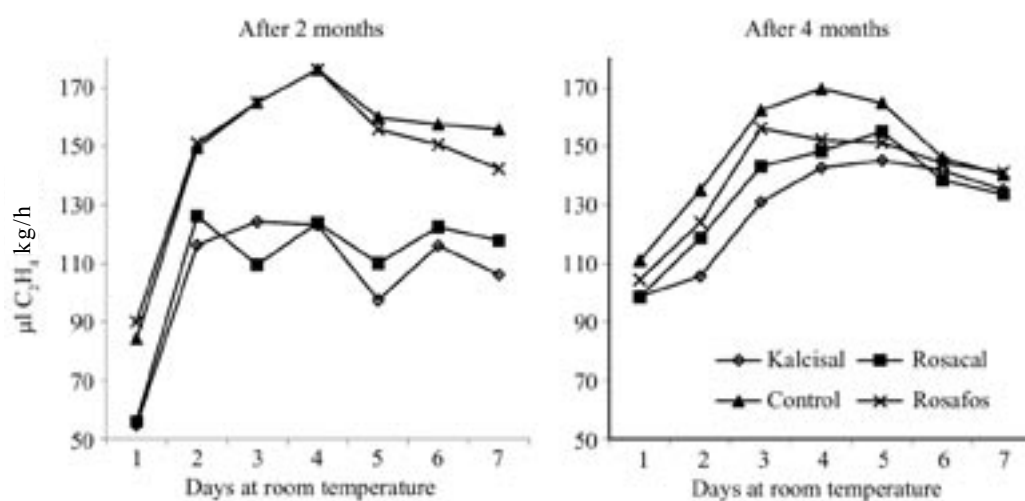


Fig. 2. Ethylene production by Šampion apples after 2 and 4 months of storage

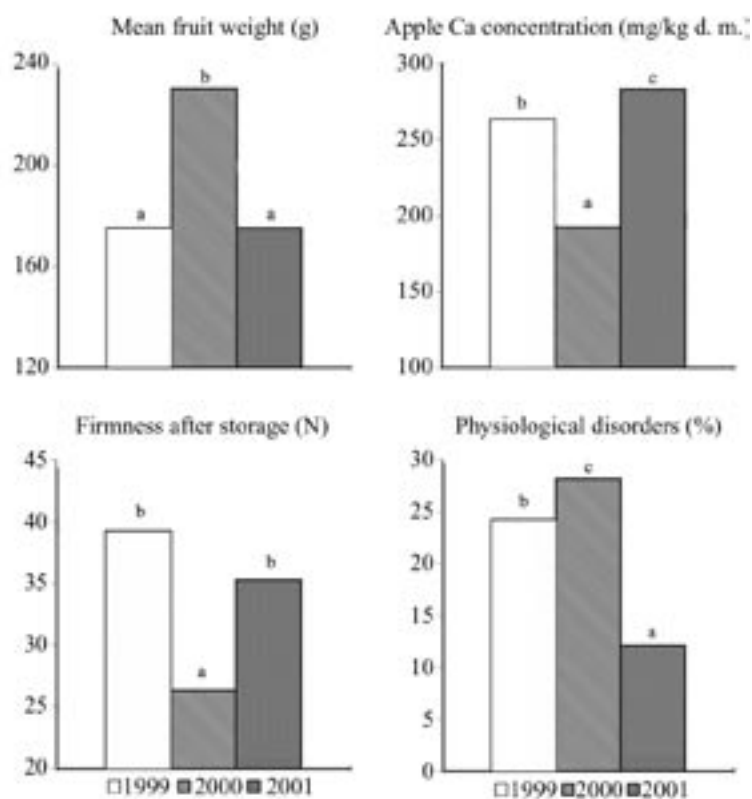


Fig. 3. The effect of years on some investigated traits of Šampion apples on the basis of the control combination

years of investigations. Fig. 2 presents the results for the most differentiated combinations from 1999. It agrees with the data in literature according to which fruits containing more calcium produced ethylene in smaller amounts (CONWAY, SAMS 1987) and their respiration was slower (SONG, BANGERTH 1993).

In the experiment, a significant effect of years on a majority of the investigated traits was observed. Fruits from the year 2000 as compared to the other years of the investigation were characterized by a significantly higher weight, which was connected with poorer fruiting

of trees resulting from spring frost. The consequence of a higher mean fruit weight was a lower calcium content. The higher the mean fruit weight, the lower the calcium content and the lower the apple firmness after storage, all of which showed convergence with a higher percentage of fruits with physiological disorders (Fig. 3).

Apart from the effect of years, the incidence of physiological disorders also showed a significant dependence on the type of preparation used for tree spraying. Generally speaking, fruits characterized by a high calcium content were susceptible to physiological disorders with

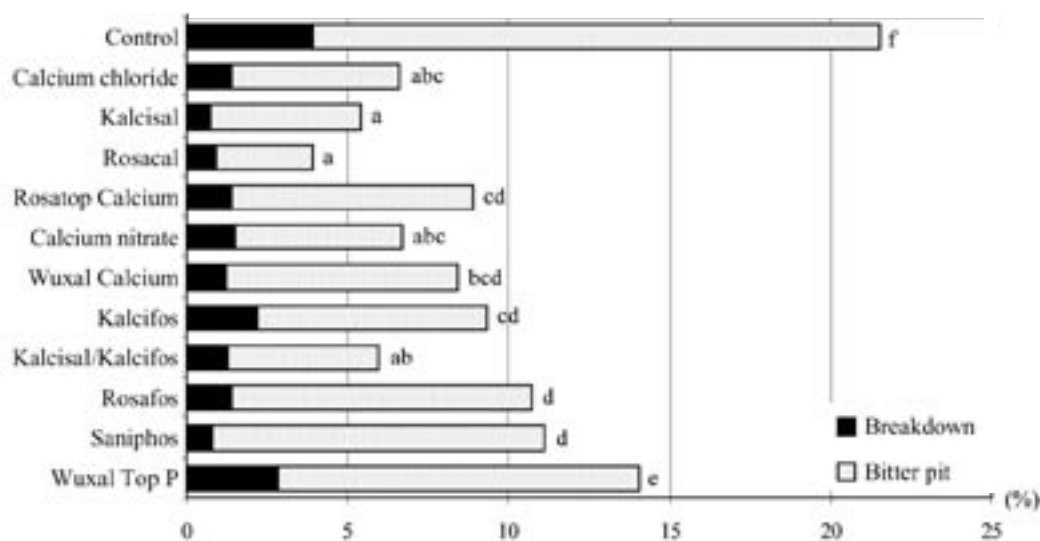


Fig. 4. The incidence of physiological disorders in Šampion apples depending on the preparation used for foliar fertilization (mean for three years of investigation)

lesser frequency. The lowest number of apples showing physiological disorders was observed in the combination with Kalcisal and Rosacal, and the highest number in the control combination (Fig. 4). It should be mentioned that in the experiment, mainly the bitter pit was observed. It agrees with the common opinion that the incidence of most physiological disorders largely depends on the calcium content in apple flesh (BEN 1995; TOMALA 1997).

## CONCLUSIONS

1. Spraying young apple trees with calcium solutions improves apple calcium content, and thus it decreases the incidence of physiological disorders. A clear decrease in the percentage of apples with physiological disorders is possible using Kalcisal or Rosacal. However, atmospheric conditions during the vegetation period can modify the effect of the fertilizers used.
2. Apples sprayed with calcium and/or phosphorus solutions have a tendency of later ripening on the tree, which should be considered while determining the optimal date for fruit harvesting.
3. Apples with higher calcium content are, as a rule, firmer during storage and, at the same time, they produce less ethylene and become yellowish more slowly. It can affect the length of storage and also determine their assessment by consumers.

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## Vlivy postřiků vápníkem nebo fosforem při použití různých komerčních přípravků na kvalitu a skladovatelnost jablek odrůdy Šampion

**ABSTRAKT:** Výzkum vlivu postřiků stromů různými přípravky obsahujícími vápník, fosfor nebo jejich kombinace byl proveden v letech 1999–2001. Účinnost těchto postřiků byla ovlivněna typem přípravku. Listové aplikace vápenatých hnojiv zvyšovaly obsah vápníku v plodech, nicméně účinnost těchto použitých hnojiv závisela také na průběhu vegetačního období. Vysoký obsah vápníku v jablkách byl zjištěn po ošetření novým polským přípravkem Kalcisal. Jeho příznivý účinek se projevil ve všech sledovaných letech. Vyšší obsah vápníku ovlivňoval vzhled plodů, které měly zelenější slupku, což souviselo s obsahem chlorofylu. Během skladování tyto plody dozrávaly později a pomaleji ztrácely pevnost dužniny než plody z kontrolních stromů. Čím byl obsah vápníku v plodech vyšší, tím více se snižoval podíl jablek postižených fyziologickými poruchami. Nejnižší ztráty v důsledku výskytu fyziologických poruch byly pozorovány u stromů, které byly ošetřovány postřikem roztoků přípravků Kalcisal nebo Rosacal.

**Klíčová slova:** jablko Šampion; postřiky vápníkem a fosforem; kvalita a skladovatelnost plodů

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