ACTA Acta Sci. Pol., Hortorum Cultus 4(1) 2005, 3-10

EFFECT OF ROOTSTOCK ON CA CONCENTRATION IN DIFFERENT PARTS OF APPLES

Jan M. Ben, Małgorzata Koszorz
Agricultural University of Cracow

Abstract. In the years 1998–2000 an investigation was carried out on 'Jonagold' apples harvested from 6-year old trees grafted on M.9, M.26, P 2, P 22 and P 60. In 1998 and 1999 the average calcium content in fruit was significantly higher than in 2000. The highest calcium was observed in the peel of apples, in each of the year. The effect of the rootstock on the level of calcium in the calyx, core and pedicle part of apples changed, depending on the vegetation season. In each year of the experiment the strongly dwarfing rootstock P 22 had the smallest share in the accumulation of calcium in the different parts of apples.

Key words: rootstock, Jonica cultivar, calcium content, part of apple

INTRODUCTION

The uptake of calcium by the root system of fruit trees depends on its content in the sorptive complex of soil [Jadczuk and Sadowski 1997] and on the environmental conditions [Tromp 1979]. On the basis of long-term field experiments Garnard [1980] showed that although the absorption of mineral constituents frequently depends on the metabolic requirements of the tree, the soil temperature at the level of the root system directly affects its pattern. Shear [1980] and also Neilsen and Neilsen [1997] prove that the constant optimum soil humidity is a significant factor in the uptake of mineral constituents. The excessive humidity or especially its deficiency unfavourably affects the pattern of absorption, particularly of calcium. The kind of the rootstock is another significant factor of the mineral nourishment of fruit trees [Tukey 1933]. Numerous works show that the differentiation in the uptake of mineral constituents from soil is not only due to differences in the morphology of the root system but chiefly to its physiological activity in the given year, manifested by the differentiated uptake of water and food constituents.

Corresponding author – Adres do korespondencji: Jan M. Ben, Małgorzata Koszorz, Katedra Sadownictwa, Akademia Rolnicza w Krakowie, Al. 29 Listopada 56, 31-425 Kraków, e-mail jben@ogr.ar.krakow.pl

The aim of the investigation was to determine the role of the rootstock in the accumulation of calcium in Jonica apple fruit and some of its parts as depending on the pattern of climatic conditions.

MATERIAL AND METHODS

Jonica apples harvested from 6-8 year old trees budded on the rootstocks M.9, M.26, P 2, P 22 and P 60 were investigated in the years 1998-2000. The orchard was fertilized according to the recommendations for commercial apple tree plantations [Sadowski et al. 1990]. In tree rows herbicidal fallow and in inter-rows frequently mowed grass were maintained. The orchard was planted in the design of randomized blocks in four replications. In one replication (plot) 7 trees were grown. The soil of the orchard was classed in group III. The content of humus in the arable horizon was 1.86% and in the sub-arable one 0.41%. The composition of the mechanical soil fraction 1.0–0.1 mm in diameter was 29.0 % and of 0.05–0.02 mm – 25%. In July 1998 pH of soil was measured in 1 n KCl, showing the pH value of 5.1 for the arable horizon and 3.9 for the sub-arable one. In the arable horizon the content of calcium was 39.5 $mg^{-1}.100\ g^{-1}$ of soil and in the sub-arable horizon 44.8 $mg^{-1}.100\ g^{-1}$ of soil (extraction conducted in 1n HCl). For establishing calcium content 56 randomly selected apples of harvest maturity were sampled from each plot from the central and peripheral parts of the tree at a height of 1.5 m. After the stalks, membrane hulls and seeds were removed, separate analyses were conducted of the apple peel (taken off from the whole fruit, rests of the flesh being removed), the flesh with peel, the calyx part, the core part and the stalk (pedicle?) part (apples of uniform size were cut in three equal parts without the peel and separately homogenized). Dried samples of the fruit flesh were reduced to ashes using a "dry" method in a silicon furnace at 550°C. The content of calcium was established in the obtained extract with a 0.1% lanthanum solution (wave length of 422.7 nm) using atomic emission spectrometry with inductively coupled argon plasma ICP – AES. The data given in tables are mean values from the conducted analyses. They were statistically verified using analysis of variance in the UNIANOVA program [Buhl and Zofel 1999]. The conclusions were drawn at confidence level $a = 0.05$.

RESULTS

The content of calcium in whole apples from trees on the investigated rootstocks was related to the vegetation period and was significantly greater in the first two years of the experiment than in the last (tab. 1). In 1998 the lowest level of calcium was found in fruit from trees on M.9 and P 22, while it did not significantly differ in apples from the remaining rootstocks. In the second year of the investigation apples from trees on the rootstocks P 22 and P 60 contained less calcium in comparison with fruit from trees on M.9, M 26 and P 2, which accumulated significantly more calcium however the values did not significantly differ from each other. The greatest content of calcium in the peel of apples (tab. 2) was found in 1999 and 1998 in comparison with the year

2000. In each year of the investigation the lowest level of calcium in the peel was assessed in apples from trees grown on P 22. The rootstocks of British selection M.9 and M.26 did not induce differences in the content of calcium in 1998. In 1999 the greatest content of this element was found in the peel of apples grown on M.26 while its level in apples from trees on M.9 and P 60 was high but the differences between them were non-significant. In 2000 no differentiated effect of the rootstock on the content of calcium in apple peel could be observed.

Table. 1. Calcium content ($mg \cdot 100\ g^{-1}$ f.w.) in apples in relation to the rootstock
Tabela 1. Zawartość wapnia ($mg \cdot 100\ g^{-1}$ ś.m.) w całych jabłkach w zależności od podkładki

Rootstock Podkładka	1998	1999	2000
M.9	4.05 a	5.09 b	3.07 ab
M.26	5.28 b	5.14 b	3.01 ab
P 2	5.14 b	5.18 b	3.32 b
P 22	4.43 a	4.27 a	2.87 a
P 60	5.12 b	4.43 a	3.27 b
Mean Średnia	4.80 b	4.82 b	3.11 a

*Means in columns followed by the same letter do not differ significantly
*Średnie w kolumnach oznaczone tymi samymi literami nie różnią się między sobą istotnie

Table 2. Calcium content ($mg \cdot 100\ g^{-1}$ f.w.) in peel of apple in relation to the rootstock
Tabela 2. Zawartość wapnia ($mg \cdot 100\ g^{-1}$ ś.m.) w skórce jabłek w zależności od podkładki

Rootstock Podkładka	1998	1999	2000
M.9	14.26 b*	18.94 c	11.61 a
M.26	14.58 b	21.65 d	11.98 a
P 2	22.00 d	15.90 b	11.83 a
P 22	11.42 a	15.05 a	11.36 a
P 60	18.50 c	18.92 c	11.65 a
Mean Średnia	16.15 b	18.09 b	11.80 a

*see table 1 – patrz tabela 1

Table 3. Calcium content ($mg \cdot 100\ g^{-1}$ f.w.) in calyx part of apple in relation to the rootstock
Tabela 3. Zawartość wapnia ($mg \cdot 100\ g^{-1}$ ś.m.) w części kielichowej jabłka w zależności od podkładki

Rootstock Podkładka	1998	1999	2000
M.9	3.15 a*	3.94 c	2.64 b
M.26	3.33 ab	4.88 e	2.51 ab
P 2	3.80 b	3.24 b	2.71 b
P 22	3.18 a	2.68 a	2.31 a
P 60	3.58 ab	4.63 d	2.57 ab
Mean Średnia	3.41 b	3.88 b	2.55 a

*see table 1 – patrz tabela 1

In the calyx part of apples the annual average content of calcium (tab. 3) was fairly similar in 1998 and 1999 and exceeded that in the year 2000. In 1999 the greatest content of calcium in this part of apples was recorded in fruit from trees on M.26; it was significantly smaller in apples from trees on P 60, followed by M.9, P 2 and P 22. In 2000 the level of calcium in the calyx part was significantly higher in fruit from trees on M.9 and P 2 than in apples from trees on P 22.

In 1998 and 1999 in the core part of apples the content of calcium was fairly similar, being distinctly lower in 2000 (tab. 4). In 1998 the greatest accumulation was observed in apples from trees on P 2 and in 1999 in fruit from trees on M.9 and P 60, no statistically significant differences in the accumulation being found between them. In the last year of the investigation the greatest calcium accumulation was recorded in apples from trees on P 60. Fruit from trees budded on M.9 and P 22 showed significantly smaller contents.

Table 4. Calcium content (mg·100 g^{-1} f.w.) in core part of apple in relation to the rootstock
Tabela 4. Zawartość wapnia (mg·100 g^{-1} ś.m.) w części środkowej jabłka w zależności od podkładki

Rootstock Podkładka	1998	1999	2000
M.9	4.23 b	5.41 c	3.47 b
M.26	4.00 b	4.88 b	3.76 bc
P 2	5.57 d	4.56 b	3.64 bc
P 22	3.44 a	3.79 a	2.88 a
P 60	4.80 c	5.27 c	3.82 c
Mean Średnia	4.41 b	4.78 b	3.51 a

*see table 1 – patrz tabela 1

Table 5. Calcium content (mg·100 g^{-1} f.w.) in stalk part of apple in relation to the rootstock
Tabela 5. Zawartość wapnia (mg·100 g^{-1} ś.m.) w części szypułkowej jabłka w zależności od podkładki

Rotstock Podkładka	1998	1999	2000
M.9	4.81 b*	5.38 d	3.45 ab
M.26	4.84 b	5.17 cd	3.58 b
P 2	5.85 c	4.99 c	3.81 bc
P 22	4.35 a	4.05 a	3.10 a
P 60	4.93 b	4.67 b	4.03 c
Mean Średnia	4.96 b	4.85 b	3.60 a

*see table 1 – patrz tabela 1

Like in the parts of apples discussed above the accumulation of calcium in the stalk part (tab. 5) distinctly depended on the vegetation period. In 1998 and in 1999 the rootstocks M.9, M.26 and P 60 did not induce significant differences in calcium content. Apples from trees on P 22 contained more calcium. In 1999 its level was high in the stalk part of apples from trees growing on M.9, M.26 and P 2 while the lowest level was noted in fruit from trees on P 22. In 2000 with the relatively lower concentration of calcium in comparison with the preceding years, the rootstocks M.9, M.26 and P 2 did not induce significant differences in calcium content in this part of fruit. However, in apples from trees on P 22 the content was distinctly smaller that that found in apples from trees on P 60.

The mean values for the rootstocks in the investigated three vegetation periods did not manifest statistically significant differences with respect to the whole apple and its separate parts.

DISCUSSION

Considerable differentiation was observed in calcium content in whole apples and their separate parts (apart from the effect of the rootstock) in the three-year period of the investigation. In 1998 and 1999 the concentration of calcium was 4.80 and 4.82 mg·100 g^{-1} d.w., respectively, and in 2000 – 3.11 mg·100 g^{-1}. According to the limit values elaborated by Baab [1997] for whole apples, the content found in fruit in the first two years of the investigation must be regarded as "optimal" and in the third year as "critical". This great differentiation in the level of calcium in the investigated years can be attributed to the climatic conditions of the vegetation period. In the first two years the average total precipitation was high, amounting to 702.9 mm in 1998 and 724.4 mm in 1999 but it was 638.9 mm in the last year of the experiment. Considerable differences were also observed in the distribution of rainfall. The lowest precipitation was recorded in 2000 towards the end of May and early in June with the average air temperature of 12–15°C while in first two years it was at the level of 19–22°C. In 2000 from the last ten days of July to mid-September the drought prevailed as confirmed by a climatodiagram elaborated according to Walter and Lieth [1970]. Such a pattern of climatic conditions of the discussed year could have unfavourably affected the uptake and transport of calcium in apples. The investigations conducted by Atkinson et al. [1995], Cline et al. [1991] and Schlegel and Schonherr [2002] confirmed the occurrence of such close dependences. A very high level of calcium, many times higher than in the flesh, was found in the peel of apples. This can be partly explained by the difference in the content of fresh matter in the flesh and peel, which was the point of reference for the recorded calcium content. However, it was not great, reaching 35.6% on the average. The results obtained by Lang [1990] and also by Canny [1995] suggest that the transport of water and mineral constituents to the tree and fruit chiefly occurs through xylem and is due to the so-called "transpiration duct". Hence the accumulation of calcium in this part of fruit, which has the greater transpiration surface, seems logical. This type of dependence was also suggested by experiments with the protection of apples with bags during the vegetation season. They showed that in wrapped apples the transpiration was poorer and the fruit contained significantly smaller amounts of mineral constituents than those growing without covers [Chen and Lenz 1977]. The above reports do not fully elucidate the reason of increased content of calcium in the apple peel. The present investigation suggests that a not fully clear interaction between the physiological activity of the root system of rootstocks and the pattern of weather conditions plays a significant role in calcium accumulation [Zavalloni et al. 2001, Hong Qiang et al. 2003]. It is distinctly visible in the case of the rootstocks P 2 in 1998 and M.26 in 1999, which contributed to the accumulation of calcium in this part of the fruit to a significantly greater degree than the remaining rootstocks. A similar example is the year 2000 when in the climatic conditions not very favourable for the uptake of calcium, the investigated rootstocks did not induce significant differences in its content in the peel of apples.

The results given in tables 3–5 also indicate the differentiated effect of rootstocks on calcium accumulation in some parts of the apple in the same soil conditions. This can be associated with the mutual effect of the coupled components of the rootstock and the cultivar. The rootstocks of more vigorous growth form crowns of a greater assimilation surface and hence can manifest greater metabolic requirements in respect of calcium than the slower growing rootstocks [Lehman et al. 1990]. In some years the low temperature and water deficiency at the level of the root system can obviously limit the uptake of calcium in spite of its sufficient content in the soil [Himerlick and Walker 1892, Himerlick and McDuffie 1983, Atkinson et al. 1995]. It is also suggested that in spite of the apparently uniform distribution of the root system in soil, its different parts, as depending on the rootstock type, can induce a differentiated uptake and transport of calcium to the tree and fruit from various depths [Fernandes et al. 1995].

In comparing (apart from the rootstock effect) the content of calcium in the calyx, core and stalk part of the apple in separate years, its decreasing concentration in the direction of the calyx was observed. It is surely connected with the poor mobility of calcium not only in the trees but also in the fruit. Faust and Klein [1974] and Webster [1981] reported the occurrence of these dependences. The present studies, however, show that the content of calcium in the analysed parts of apples is distinctly affected by the vegetation period. If the content of calcium in the stalk part of the apple is accepted as 100%, in 1998 the content was smaller by 11.1% in the core part and by 31.3% in the calyx part. In 1999 a minimal differentiation of calcium content of 1.4 and 2.0%, respectively, was observed in the discussed parts. In the year 2000, which was fairly unfavourable for calcium accumulation, this differentiation was 2.5 and 29.2%. Similar relations occurred between the investigated rootstocks in the successive years.

In each year of the experiment the strongly dwarfing rootstock P 22 had the smallest effect on calcium accumulation in the different parts of apples. It could be associated with the poor development of the root system especially in heavy soils of a large content of floatable particles – as is the case in southern regions of Poland. The low absorption potential in relation to the mineral constituents in the sorptive complex of soil could be due to the smaller biomass of roots [Bramlage 1993].

CONCLUSIONS

1. The content of calcium in apples was subjected to changes depending on the vegetation season, being significantly greater in 1998 and 1999 than in 2000.

2. The proportion of calcium accumulation in whole fruit did not manifest uniform tendencies. The rootstocks M.26; P 2 and P 60 in 1998 and M.9; M.26 and P 2 in 1999 contributed to its greatest content in the apples.

3. The greatest content of calcium was found in the peel of apples, the rootstock P 2 in 1998 and M.26 in 1999 inducing its highest accumulation.

4. The content of calcium was decreasing from the stalk part to the calyx. In 1998 and 2000, the average differentiation between these parts of fruit flesh reach reached 30%.

5. The strongly dwarfing rootstock P 22 had the least effect on the accumulation of calcium in the investigated parts of apples in each year of the investigation.

REFERENCES

Atkinson C.J., Taylor R., Taylor J.M., 1995. The influence of temperature and water supply on apple fruit growth and the development of orchard grown trees. J. Hort. Sci. 70 (5), 691–703.

Baab G., 1997. Apfel unterlagen Gestern und Heute. Erwerbsobst. 40, 162–169.

Bühl A., Zőfel P., 1999. SPSS Version 8. Einführung in die moderne Datenanalyse unter Windows. Addison Wesley Longman Verlag GmbH.

Bramlage W.J., 1993. Interactions of orchard factors and mineral nutrition on quality o pome fruits. Acta Hort. 326, 15–28.

Canny M.J., 1995. Apoplastic water and solute movement: new rules for an old space. Annu. Rev. Plant Physiol., Plant Mol. Biol. 46, 9–14.

Chen K., Lenz F., 1997. Effects of training method, shading and fruiting on water consumption of apple trees. Gartenbauwiss. 62 (6), 277–285.

Cline J.A., Hanson E.J., Bramlage W.J., Cline R.A., Kushad M., 1991. Calcium accumulation in 'Delicious' apple fruit. J. Plant Nutrit. 14 (11), 1213–1222.

Faust M., Klein D., 1974. Levels and sites of metabolically active calcium in apple fruit. J. Am. Soc. Hort. Sci. 99, 93–94.

Fernandes R.T., Perry R.L., Ferree D.C., 1995. Root distribution patterns of nine apple rootstocks in two contrasting soil types. J. Am. Soc. Hort. Sci. 120, 6–13.

Garnard J., 1980. Nutrition minèrale et qualitè des fruits des cultures de zono tempèrè. Arboriculture Fruitière 311, 1–27.

Himelrick D.G., Walker C.E., 1982. Seasonal trends of calcium, magnesium, and potassium fractions in apple leaf and fruit tissues. J. Am. Soc. Hort. Sci. 107(6), 1078–1080.

Himelrick D.G., McDuffie R.F., 1983. The calcium cycle: uptake and distribution in apple trees. Hort Sci. 18 (2), 147–154.

Hong Qiang Y., Lian Zhong Z., Jin Liang Q., Yuling J., 2003. The kinetics of calcium uptake in apple rootstock roots. Acta Hort. Sinica 30 (3), 253–257.

Jadczuk E., Sadowski A., 1997. Nutritional status of 'Schattenmorelle' cherry trees in relation to the type of root system and tree age. Acta Hort. 448, 137–144.

Lang A., 1990. Xylem, phloem and transpiration flows in developing apple fruits. J. Exp. Bot. 41, 645–503.

Lehman L.J., Yound E., Unrath C.R., 1990. Growth dynamics of young apple trees as influenced by scion and rootstock vigour. J. Hort. Sci. 65 (2), 123–127.

Neilsen G.H., Neilsen D., 1997. Orchards nutrition to maximize crop quality and minimize environmental degradation. Acta Hort. 448, 365–373.

Palmer J.W., Lai Y.L., Edjamo Y., 1991. Effect of part-tree thinning on fruiting, vegetative growth, and leaf photosynthesis in 'Cox's Orange Pippin' apple. J. Hort. Sci. 66, 319–325.

Sadowski A., Nurzyński J., Pacholak E., Smolarz K., 1990. Określenie potrzeb nawożenia roślin sadowniczych. Zasady, liczby graniczne i dawki nawożenia. Instrukcja upowszechnieniowa.

Schlegel T.K., Schőnherr J., 2002. Penetration of calcium chloride into apple fruits as affected by stage of fruit development. Acta Hort. 594, 527–533.

Shear C.B., 1980. Interaction of nutrition and environment on mineral composition of fruits. [In:] Atkinson D., J.E. Jackson, R.O Sharples and W.M Waller (eds). Mineral nutrition of fruit trees. Butterworths, London, 41–50.
Tromp J., 1979. Influence de la temperature sur la croissance de la pomme et sa composition chinique. Le Fruit Belge 388, 283–298.
Tukey L.D., 1993. Rootstock effects on apple tree growth and fruiting. Research Report for 1992.
Walter H., Lieth H., 1970. Klimadiagramm-Weltatlas, Jena.
Webster D.H., 1981. Mineral composition of apple fruits. Relationships between and within peel, cortex, and whole fruit samples. Can. J. Plant Sci. 61, 73–83.
Zavalloni C., Marangoni B., Tagliavini M., Scudellari D., 2001. Dynamics of uptake of calcium, potassium and magnesium into apple fruit in a high-density planting. Acta Hort. 564, 113–121.

WPŁYW PODKŁADKI NA ZAWARTOŚĆ WAPNIA W RÓŻNYCH CZĘŚCIACH JABŁKA

Streszczenie. Badania prowadzono w latach 1998–2000 na 6-letnich drzewach odmiany Jonagold, okulizowanych na podkładce M.9, M.26, P 2, P 22 i P 60. W latach 1998 i 1999 średnia zawartość wapnia w jabłkach była istotnie wyższa niż w roku 2000. Wysoką zawartość wapnia obserwowano w skórce jabłek, w każdym z badanych lat. Wpływ podkładki na poziom wapnia w części kielichowej, środkowej i szypułkowej jabłka zmieniał się, w zależności od sezonu wegetacyjnego. Jabłka pobrane z drzew okulizowanych na podkładce P 22 gromadziły najmniejszą ilość wapnia w analizowanych częściach.

Słowa kluczowe: podkładka, ‘Jonica’ odmiana, zawartość wapnia, części jabłka

Accepted for print – Zaakceptowano do druku: 2.11.2004