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Beyond-root calcium fertilization of apple trees

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Abstract

Investigations were performed in the period 1977-1979 on the apple tree cultivar 'Fantazja', on rootstock A 2, M 7 and MM 106 on the effect of spraying with solution containing calcium on the incidence of bitter pit, breakdown, calcium content in the fruit flesh and other features of the fruits. Threefold spraying with calcium nitrate, calcium chloride or Anti-Stipp significantly limited the appearance of bitter pit and breakdown.

INTRODUCTION

The interest in the significance of calcium in the supply of minerals to fruit trees has greatly increased since in the thirties it was found that one of the most frequent physiological apple diseases, bitter pit, is connected with a low content of this element in the fruits. Intensive research led to the establishment of numerous relations between the chemical composition of fruits and the incidence of still other physiological diseases of apples. It appeared that the traditional liming of soil is not sufficiently effective in the control of these diseases. The results of numerous investigations in many countries in the sixties (Martin et al., 1960; Jackson, 1962; Schreven et al., 1963; Beyers, 1963; Drake and Weeks, 1967 and many others) and in later years (Bangerth, 1973; Słowik and Legespi, 1974; Sharples and Johnson, 1977; Mason, 1979; Perring, 1979; Sharples, 1979; Terblanche et al., 1979; Waller, 1979) and within a much smaller range in Poland (Ostrowski, 1965; Sadowski, 1967) demonstrated the high effectiveness of beyond-root fertilization with calcium nitrate or calcium chloride in the prevention of development of physiological apple diseases in storage.

Bangerth (1973) reports a negative correlation between calcium content in apples and bitter pit incidence, 'Jonathan' spot, breakdown and watercore in apples. An increased incidence of apple scald was also noted on

fruit with low calcium content. The view prevails that a better supply of calcium to the fruits can reduce these diseases. The reactions of various apple cultivars, however, show wide differences, as noted by numerous authors, among them Ostrowski (1965) and Sadowski (1967), Sharples and Johnson (1977). The causes of these diseases may be diverse, they do not result solely from poor supply of calcium to the fruits, and as regards bitter pit, they are not fully elucidated.

Calcium uptake by plants is affected by a number of factors such as: soil aeration and compactness, moisture, pH (Terblanche et al., 1979), the presence of other ions, especially NH_4^+, K^+, Mg^{++} and Al^{+++} (Kirkby, 1979; Kotze, 1979; Słowik, 1979). Excessive concentrations of these ions inhibit the process of Ca uptake by the roots.

It is generally believed that soils contain a sufficient amount of calcium to satisfy nutritional requirements of plants and that the symptoms of deficit of this element are rather due to a poor uptake and transport than to a lack of Ca in the soil. The weak mobility of Ca in plants and its translocation almost exclusively along vessels (Ferguson, 1979b) would cause local Ca deficits (Ferguson, 1979a).

Rapid accumulation of calcium in fruits occurs in the first weeks after their setting (Ferguson, 1979b; Tromp, 1979) and lasts to about mid July. Tromp (1979) suggests that calcium transport to fruits in the second half of the vegetation season is balanced by calcium excretion with water from the fruit. This occurs under conditions of water stress occurring in the course of daytime. Goode et al. (1978) reduced the occurrence of bitter pit of apples by watering the trees from June to mid September. Trials undertaken to apply antitranspirants in order to limit bitter pit in apples gave controversial results (Schumacher et al., 1976; Terblanche et al., 1979).

The most effective methods for increasing Ca content in fruits are: balanced fertilization, summer pruning, appropriate irrigation, and, above all, calcium salts supply by other pathways than the roots.

Spraying with calcium compounds is applied 3-8 times beginning with June and up to apple harvest, with the use of $Ca(NO_3)_2$ or $CaCl_2$. The efficacy of these compounds in prevention of development of physiological apple diseases is rather similar (Słowik and Legaspi, 1974), and it largely depends on the natural calcium content in the fruits (Sharples, 1979). For immersion of apples after the harvest only $CaCl_2$ is used, usually in a 3-4 per cent concentration (Mason, 1979) and it does not cause impairment of the fruits, in spite of the high concentration used, contrary to calcium nitrate (Sharples, 1979). It has also been tried to increase calcium content in apples by its infiltration into the fruits under conditions of hypotension (Johnson, 1979).

The research conducted in the Institute of Pomology and Floriculture, concerning calcium nutrition of fruit trees was concentrated mainly on tests of new fertilization technologies which would increase the calcium content in the fruits, and at the same time effectively counteract the development of physiological diseases of apples in storage or cold storage.

MATERIAL AND METHODS

The experiments were started in 1977 and carried on for three years in an apple orchard with the cultivar 'Fantazja' at the Research Station Dąbrowice near Skierniewice. The experimental trees grow on three kinds of rootstock A 2, M 7 and MM 106 at a spacing of 800 trees/ha.

Before the fruit harvest the trees were sprayed three times at two-week intervals with calcium nitrate solution ($Ca(NO_3)_2 \cdot 4\,H_2O$) calcium chloride ($CaCl_2 \cdot 6\,H_2O$) and Anti-Stipp (Chemie Linz, Austria). All these chemicals were used in an equal concentration of 0.75 per cent. In the control combination the trees were not sprayed with calcium compounds at all.

For investigations on apple storage samples were taken in three replications. One replication consisted of a sample comprising about 120-150 fruits collected from three trees. The fruits were stored in a cold store at 0°C and relative air humidity 88-90 per cent for three months. Then the apples were inspected and the appearance of physiological diseases and rotting were recorded. In 20 randomly chosen applies flesh firmness was determined (with a Magness-Taylor penetrometre), the colour was evaluated (percentage of fruit surface flushed red) and the basic colour of the skin (according to the colour scale). These fruits also served as material for chemical analyses.

After the period of storage 20 fruits were taken from each replication, free from any noticeable symptom of physiological disease and rotting and they were placed for five days at +15°C. After this period the flesh firmness of the apples, the basic colour and development of physiological diseases and rotting were once more determined.

The results were submitted to statistical analysis. For establishing the statistical significance Duncan's test was used at a 5 per cent significance level.

RESULTS

The severity of physiological diseases on the fruits of the cultivar 'Fantazja' depended to a high extent on the weather conditions in the particular years. The incidence of bitter pit was highest in the dry year 1979 (Table 1). The rootstock on which the trees were grafted exerted a much less conspicuous influence on the occurrence of bitter pit. The incidence of the latter was much lower on M 7 rootstock as compared with that on A 2 and MM 106 (Table 1).

Table 1

Incidence of bitter pit and breakdown on fruits of the 'Fantazja' cultivar in relation to the rootstock and year

Rootstock	Year							
	1977		1978		1979		Mean for rootstock	
	bitter pit %	breakdown %	bitter pit %	breakdown %	bitter pit %	breakdown %	bitter pit %	breakdown %
A 2	7.0 bc	3.3 e	2.2 a	1.1 cd	18.0 d	0.1 ab	7.9 b	1.1
M 7	2.0 a	1.6 cda	3.0 ab	3.0 de	9.0 c	0.0 a	4.3 a	1.0
MM 106	2.7 ab	0.8 bc	9.0 c	1.7 cde	13.2 cd	0.03 a	7.9 b	0.6

Table 2

Some features of fruits of the 'Fantazja' cultivar sprayed with calcium solution in the successive years, means for three kinds of rootstock (A 2, M 7 and MM 106)

Year	Feature					
	Ca content in flesh mg/100gf.wt.	K:Ca ratio	bitter pit %	breakdown %	fruit firmness pounds	red flush on fruits % of area
1977	2.1 b	40.1 b	3.6 a	1.8 b	9.1 a	56 b
1978	1.9 a	45.1 c	4.5 a	1.9 b	10.3 b	46 a
1979	2.8 c	26.2 a	13.2 b	0.02 a	9.4 a	53 b

Table 3

Some features of fruits of 'Fantazja' cultivar, sprayed with calcium solution. Means for three kinds of rootstock (A 2, M 7 and MM 106) and for 3 years (1977, 1978 and 1979)

Combination	Feature					
	Ca content in flesh mg/100gf.wt.	K:Ca ratio	bitter pit %	breakdown %	fruit firmness pounds	red flush on fruits % of area
Control	1.9 a	42.6 c	14.9 b	2.8 c	9.6	54 b
$Ca(NO_3)_2$ 3x	2.4 c	33.9 a	5.4 a	0.8 b	9.6	48 a
$CaCl_2$ 3x	2.4 c	34.9 ab	3.5 a	0.2 a	9.5	53 b
Anti-Stipp 3x	2.2 b	37.1 b	4.7 a	0.5 ab	9.4	51 ab

Table 4

Influence of spraying with calcium solution on Ca content and K:Ca ratio in fruits of 'Fantazja' cultivar on various rootstock, means for 3 years

Combination	Rootstock						Mean Ca content	Mean K:Ca ratio
	A 2		M 7		MM 106			
	Ca content mg/100 g f. wt.	K:Ca ratio	Ca content mg/100 g f. wt.	K:Ca ratio	Ca content mg/100 g f. wt.	K:Ca ratio		
Control	1.99 ab	41.0 de	1.81 a	45.6 e	2.00 ab	41.2 de	1.93 a	42.6 c
$Ca(NO_3)_2$ 3 ×	2.29 c	39.6 cd	2.41 cd	31.7 ab	2.53 d	30.5 a	2.41 c	33.9 a
$CaCl_2$ 3 ×	2.43 cd	35.8 bc	2.33 cd	34.8 abc	2.41 cd	34.0	2.39 c	34.9 ab
Anti-Stipp 3 ×	2.08 b	44.1 de	2.32 cd	33.7 ab	2.30 c	33.7	2.23 b	37.1 b

The most important features of fruits of the 'Fantazja' cultivar in the particular years are shown in Table 2. Calcium content in the fruit flesh was found to be lowest in 1978 and highest in 1979. The K:Ca ratio, on the contrary, was highest in 1978 and lowest in 1979, although in the latter year symptoms of bitter pit were most severe.

Spraying with calcium solution significantly raised the calcium level in the fruit flesh (Table 3). All solutions used for spraying significantly restricted the occurrence of bitter pit and breakdown. The colouring of fruits was significantly impaired by spraying with calcium nitrate as compared with fruits sprayed with calcium chloride or the control ones.

Calcium content significantly increased in the flesh of fruits sprayed with calcium nitrate or chloride on all three tested of rootstock as compared with that in the control (Table 3). This was particularly noticeable in the mean values for all the three kinds of rootstock (Table 4). Differences were not found in calcium content in fruits sprayed with calcium nitrate or chloride. The K:Ca ratio was highest in all cases in the control combinations, the fruits sprayed with Anti-Stipp from rootstock A 2 excepted.

CONCLUSIONS

1. The investigations confirmed the usefulness of applying calcium beyond the roots for controlling the occurrence of bitter pit and breakdown.

2. The influence of the weather in the given season was more pronounced than that of the rootstock on the incidence of physiological diseases on the fruits of the cultivar 'Fantazja'.

3. Calcium content in the flesh of fruits sprayed with calcium nitrate or chloride increased significantly as compared with that in the control combination.

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Nawożenie pozakorzeniowe jabłoni wapniem

Streszczenie

W latach 1977-1979 przeprowadzono badania nad wpływem opryskiwania jabłoni odmiany 'Fantazja' roztworami zawierającymi wapń: azotanem wapnia ($Ca(NO_3)_2 \cdot 4H_2O$), chlorkiem wapnia ($CaCl_2 \cdot 6H_2O$) i preparatem Anti-Stipp na występowanie chorób fizjologicznych na jabłkach, zawartość wapnia w miąższu owoców oraz innych cech owoców. Badania prowadzono na trzech podkładkach: A 2, M 7 i MM 106, przy czym drzewa we wszystkich przypadkach rosły w zagęszczeniu 800 drzew/ha. Trzykrotne opryskiwanie azotanem wapnia, chlorkiem wapnia lub preparatem Anti-Stipp istotnie ograniczało występowanie gorzkiej plamistości podskórnej i rozpadu. Istotne pogorszenie wybarwienia się wystąpiło na owocach opryskiwanych azotanem wapnia w porównaniu z kombinacją kontrolną lub opryskiwaną chlorkiem wapnia. Nie stwierdzono różnic w zawartości wapnia w owocach opryskiwanych azotanem wapnia lub chlorkiem wapnia.