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DRESSING OR SPRAYING CALCIUM FOR BITTER PIT CONTROL

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Introduction

Bitter pit in apples can be controlled partly and sometimes entirely by intensive spraying with a solution of calcium nitrate or chloride during the growing season (Naumann, 1974; Van Goor, 1971). However, from a practical point of view, it would be more economic and convenient to replace frequent spraying, if possible, by a single soil dressing and a study was therefore made of the comparative effectiveness of four levels of liming, gypsum dressing and spraying with calcium nitrate on the incidence of bitter pit and breakdown to determine whether these measures could replace or supplement one another.

Materials and Methods

The trial was carried out in an orchard on sandy soil. In January 1969 the required amounts of lime were ploughed into the soil in the 0–30 cm layer. Cox's Orange Pippin and James Grieve on M.9 rootstock were planted on 1 April. The treatments were factorial combinations of:

(1) four pH–KCl levels (5.0, 5.5, 6.0 and 6.5)
(2) gysum ($CaSO_4 \cdot 2H_2O$) dressing (4, later 2 t ha^{-1})
(3) spraying with 0.75 per cent calcium nitrate solution, 10–12 times a year, beginning at the end of May.

The orchard was grown in grass strip culture. The soil beneath the trees was kept free from weeds by herbicides without tillage, so that, in combination with a high rate of potassium dressing, the development of bitter pit was stimulated (Delver, 1978). The trial was arranged as three replicated blocks with four or five trees of each variety per plot. Records were obtained throughout the period from 1970 to 1977.

Leaf samples consisted of the third and fourth leaf from the base of annual shoots. Fruit samples were composed of fruits of average size or, at picking time, of three size grades: the fruits were analysed with skin and without stalks.

. After harvest the apples were stored at 3–4 °C as long as possible to stimulate the development of physiological disorders. After a week of ripening at room temperature, the incidences of bitter pit and breakdown were assessed.

Results

EFFECT OF TREATMENTS

Soil analysis

In the 0–30 cm layer of the clean-cultivated soil beneath the trees the desired pH values were generally obtained for the two lower lime rates. However, the highest dose raised the pH to only 6.3 in 1976. In the 40–70 cm layer there was no effect of liming on pH. Exchangeable calcium in the 0–30 cm layer was increased by liming from 3.8 to 6.4 mEq/100 g air-dried soil; in the deeper layer there was only a very small effect of liming. Gypsum produced an additional average increase of 0.3 mEq/100 g.

Wood and bark composition

Wood and bark analysis of annual shoots in winter 1978/1979 showed an increase in calcium concentration as a result of gypsum dressing. The calcium content of the bark had also increased by spraying with calcium nitrate solution, either the result of direct application or of redistribution of calcium from the leaves. An enhanced calcium concentration of the xylem sap in spring (Bollard, 1953; Bradfield, 1975) following gypsum dressing and a non-significant increase after spraying indicate that, early in the season, soil dressing provides a better supply of calcium to the developing organs than spraying during the preceding growing seasons.

Leaf and fruit composition

Differences in fruit composition between years were connected with crop size. With higher yields the calcium concentration of the fruit was higher and, more clearly, the (K + Mg)/Ca ratio lower (*Figure 47.1*).

Liming did not have any consistent effect on the calcium content and the (K + Mg)/Ca ratio in leaf and fruit. Gypsum dressing increased leaf calcium and decreased the cation ratio of the leaf, these effects being statistically significant in most years (*Table 47.1*). Frequent spraying with calcium nitrate during the growing season had the same effects, but these were more distinct than those of gypsum and were significant in all years. However, the calcium concentration in the fruit was either scarcely or not affected by dressing with calcium sulphate. In all eight years, the effect of spraying on fruit calcium content was highly significant (probability level of at least p = 0.01).

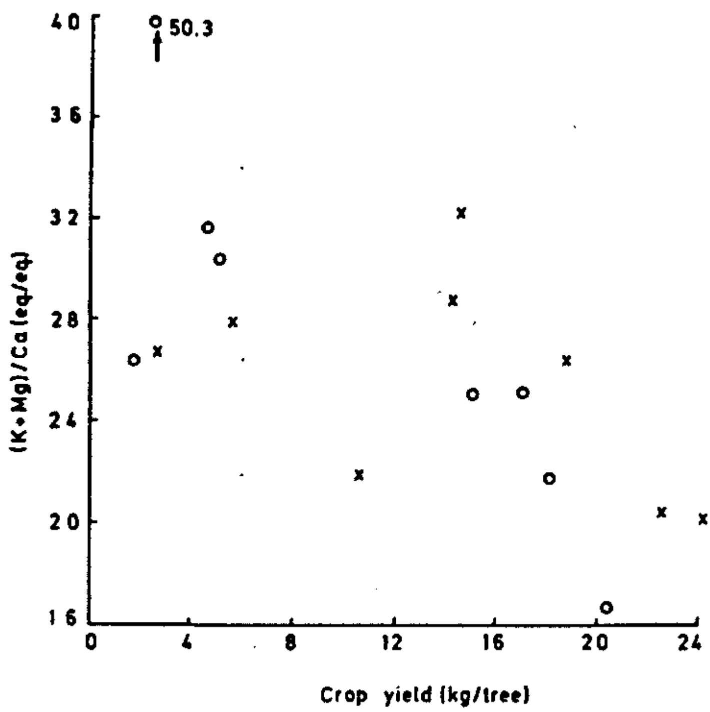

Figure 47.1 Relationship between (K + Mg)/Ca ratio in fruit of unsprayed plots and the weight of crop from the tree. ○, *Cox's Orange Pippin;* ×, *James Grieve*

Table 47.1 EFFECT OF GYPSUM DRESSING AND SPRAYING WITH CALCIUM NITRATE SOLUTION ON THE AVERAGE CALCIUM CONTENT AND (K + Mg)/Ca RATIO IN LEAF AND FRUIT FOR EIGHT SUCCESSIVE YEARS (1970–1978). THE FIGURES IN PARENTHESES REPRESENT THE NUMBER OF YEARS IN WHICH TREATMENT MEANS DIFFERED SIGNIFICANTLY ($p<0.05$)

Nutrient content	*Gypsum* –	+	*Spraying* ($Ca(NO_3)_2$) –	+
*Leaf composition**				
	James Grieve			
Ca (% DM)	1.35	1.50 (8)	1.30	1.57 (8)
(K + Mg)/Ca (Eq/Eq)	0.99	0.85 (7)	1.03	0.81 (8)
	Cox's Orange Pippin			
Ca (% DM)	1.10	1.21 (5)	0.99	1.31 (8)
(K + Mg)/Ca (Eq/Eq)	1.25	1.09 (5)	1.38	0.96 (8)
Fruit composition				
	James Grieve			
Ca (mg/100 g DM)	24	25 (1)	22	27 (8)
(K + Mg)/Ca (Eq/Eq)	23.5	22.7 (0)	25.7	20.6 (8)
	Cox's Orange Pippin			
Ca (mg/100 g DM)	26	26 (0)	23	30 (8)
(K + Mg)/Ca (Eq/Eq)	25.3	24.5 (1)	28.5	21.4 (8)

*DM = dry matter

Bitter pit and breakdown

The incidences of bitter pit and breakdown were more serious in James Grieve apples than in Cox's Orange Pippin. Except in the first year of cropping, when yields were very low, a negative relation between these physiological disorders and crop size was found, especially for James Grieve. Liming had no effect on fruit quality but, on the plots treated with gypsum, the incidence of bitter pit and breakdown was generally less (with one exception in 1974 on Cox's Orange Pippin). In certain of the eight experimental years when the trees bore a crop, the beneficial effect of gypsum was found to be statistically significant (*Table 47.2*). Spraying gave

Table 47.2 EFFECT OF GYPSUM DRESSING AND SPRAYING WITH CALCIUM NITRATE SOLUTION ON MEAN INCIDENCES OF BITTER PIT AND BREAKDOWN IN JAMES GRIEVE AND COX'S ORANGE PIPPIN APPLES STORED IN AIR AT 3–4 °C. THE DATA ARE THE MEANS FOR EIGHT SUCCESSIVE YEARS (1970–1977) AND THE FIGURES IN PARENTHESES REPRESENT THE NUMBER OF YEARS IN WHICH TREATMENT MEANS DIFFERED SIGNIFICANTLY ($p<0.05$)

	Gypsum		*Spraying* $Ca(NO_3)_2$	
Variety	–	+	–	+
Bitter pit (%)				
James Grieve	24.5	19.8(4)	32.5	11.8(8)
Cox's Orange Pippin	5.2	3.3(5)	7.2	1.3(8)
Breakdown (%)				
James Grieve	15.6	11.8(5)	22.0	5.4(8)
Cox's Orange Pippin*	2.8	2.2(2)	4.4	0.5(4)

*Breakdown incidence exceeded 1 per cent in Cox's Orange Pippin in only five of the years.

an even greater reduction than gypsum; bitter pit incidence was decreased to less than half, the beneficial effect on breakdown being even greater. After spraying, Cox's Orange Pippin developed an average of less than 2 per cent breakdown. In most years lowest incidences of bitter pit and breakdown were recorded in fruits from plots treated with gypsum and sprayed with calcium nitrate. Although there was a tendency for gypsum dressing to be less effective on plots with sprayed trees, statistically significant interactions were rare and it seems unlikely that any one of the treatments can be replaced by another.

Relationship between fruit quality and leaf and fruit composition

Leaves and fruits were sampled from each of the 16 treatments. Since all the experimental trees were growing in the same orchard under similar conditions and only the calcium status was varied, the relationship between fruit quality and leaf composition was as close as that with fruit composition (*Table 47.3*). Early sampling in July gave the lowest correlations for both leaf and fruits with both types of disorder. The fruit size grade which showed the highest relation between composition and total bitter pit or breakdown varied from year to year and for practical purposes it

Table 47.3 CORRELATION COEFFICIENTS (MEANS FOR 1970–1977) BETWEEN THE PERCENTAGES OF BITTER PIT AND BREAKDOWN IN JAMES GRIEVE APPLES AND LEAF AND FRUIT COMPOSITION (PERCENTAGE DRY MATTER)

	Leaf composition		*Fruit composition*			*Harvest fruit size* (mm)		
	Mid-July	*Mid-Aug.*	*Mid-July*	*Mid-Aug.*	*Mid-Sept.*	*65–70*	*70–75*	*75–80*
Bitter pit (%)								
Ca	−0.63	−0.78	−0.60	−0.73	−0.71	−0.85	−0.79	−0.85
(K + Mg)/Ca	0.62	0.78	0.63	0.73	0.76	0.84	0.80	0.83
Breakdown (%)								
Ca	−0.67	−0.84	−0.57	−0.81	−0.76	−0.79	−0.74	−0.82
(K + Mg)/Ca	0.71	0.84	0.62	0.83	0.83	0.80	0.77	0.82

is recommended that the medium size grade fruit should be used to predict the incidence of bitter pit.

A low bitter pit incidence of 10 per cent or less can be expected if the calcium concentration of the fruit is higher than 32 mg/100 g dry matter (*Figure 47.2*), or if the (K + Mg)/Ca ratio is less than 17.5 (Eq/Eq). These threshold levels are at the extreme of the range of measured values and they were difficult to obtain, even by means of the most favourable spraying treatment. The extent to which bitter pit occurred at any given calcium level below the threshold of the fruit varied from year to year. If other factors which affect the appearance of bitter pit, such as size of crop and weather conditions, are not taken into account, the prediction of bitter pit incidence on the basis of fruit analysis figures is only of limited value (Van der Boon

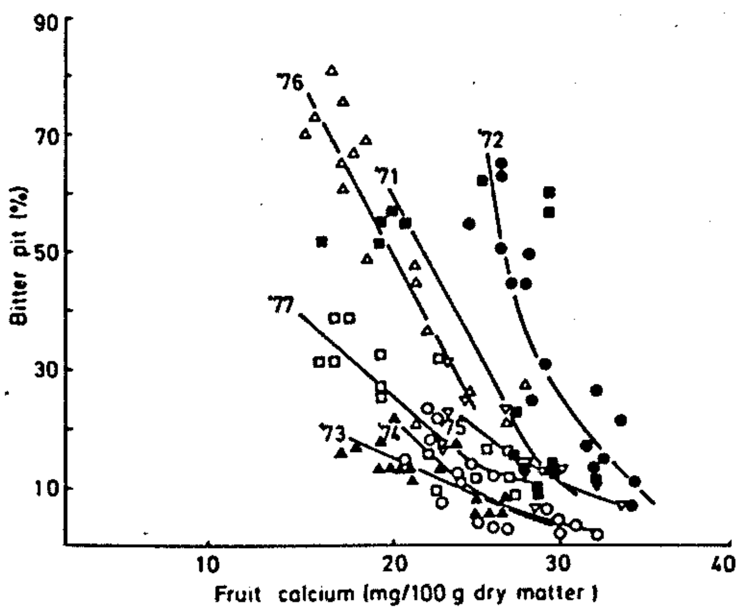

Figure 47.2 Relation between the percentage of bitter pit in James Grieve apples and the calcium concentration in the fruit (size 70–75 mm). Averages of 16 treatments for 1971–1977. ■, *1971;* ●, *1972;* ▲, *1973;* ○, *1974;* ▽, *1975;* △, *1976;* □, *1977*

and Das, 1977). Only fruit with high calcium contents or low cation ratios can be safely regarded as unlikely to develop the disorder.

Discussion

Bitter pit and breakdown in apples are related to a low calcium concentration in the fruit flesh. The results obtained in the literature with soil applications of calcium are contradictory (Naumann, 1974). On the basis of mass flow theory, a shortage in the calcium suply via the soil would not be anticipated. The low adsorption capacity and low pH of sandy soils make these the most likely to respond favourably to calcium application. Furthermore high availability of potassium for trees growing in sandy soils may also be detrimental to the quality of the fruit. In five experimental trials in existing orchards liming resulted, after a few years, in a small decrease in bitter pit incidence; gypsum was more effective (Van der Boon and Das, 1977). The small effect was attributed to the fact that calcium did not penetrate far enough into the soil but in the trial reported here, where calcium carbonate was ploughed into the soil before planting, gypsum dressing was no more effective and liming was ineffective. It seems that soil application of gypsum provides sufficient calcium to the tree in spring only, increasing the calcium concentration in the wood, bark and leaf. Later in the season, soil application hardly improves the calcium status of the fruit presumably because it fails to provide the small but continuous supply of calcium which is required to maintain fruit free from disorders as is achieved by routine calcium nitrate sprays. The most effective control of bitter pit was achieved by gypsum application to the soil in combination with spraying with calcium nitrate but there was no indication that spraying could be omitted or diminished in frequency where gypsum had been applied. Sadowski and Świderska (1977) also recommended both measures. A disadvantage of gypsum dressing is that it results in a reduction in the magnesium concentration in the leaf (Van der Boon and Das, 1977). This decrease was observed again in these trials, especially in the leaves of Cox's Orange Pippin. Gypsum dressing should therefore be supplemented with magnesium sulphate.

Bitter pit incidence varied in the experiment from year to year. High yield per tree was accompanied by a lower average fruit weight, lower (K + Mg)/Ca ratio, higher calcium level and a lower incidence of bitter pit. However, when the calcium level or cation ratio in the fruit is unfavourable, bitter pit levels remain low if the fruit/leaf ratio is high (Van der Boon and Das, 1976). Since a sufficiently high concentration of calcium in the fruit is difficult to achieve, even with spraying, it is necessary to gain a better insight into the other factors which diminish or increase bitter pit in the presence of low calcium levels, such as fruit/leaf ratio and weather conditions (Van der Boon and Das, 1977; Delver, 1978).

References

BOLLARD, E.G. (1953). The use of tracheal sap in the study of apple tree nutrition. *J. exp. Bot.* 4, 363–368

BRADFIELD, E.G. (1975). Calcium complexes in the xylem sap of apple shoots. *Pl. Soil* 44, 495–499

DELVER, P. (1978). Stip in appels. Wilhelminadorp, Mededelingen Proefstation voor de Fruitteelt, No. 17

NAUMANN, G. (1974). Second discussion meeting on bitter pit in apples. *Acta hort.* 45

SADOWSKI, A. and ŚWIDERSKA, S. (1977). Studies on bitter pit of apples. 7. Effect of calcium fertilization applied to the soil. *Zeszyty Naukowe Szkoly Glownej Gospodarstwa wiejskiego 'Ogrodnictwo'* 10, 105–117

VAN DER BOON, J. and DAS, A. (1976). Mogelijkheid van voorspellen van stip en zacht in Cox's. *Fruitteelt* 66, 632–634

VAN DER BOON, J. and DAS, A. (1977). Stip en zacht in appels op zandgrond en calciumbemesting. *Bedrijfsontwikkeling* 8, 971–977

VAN GOOR, B.J. (1971). The effect of frequent spraying with calcium nitrate solutions on the mineral composition and the occurrence of bitter pit of the apple Cox's Orange Pippin. *J. hort. Sci.* 46, 347–364

Discussion

Sharples. You obtained an increase in calcium uptake following the application of gypsum. How general is such a response likely to be?

Van der Boon. We only see this type of response on sandy soils which have a low adsorption capacity and an unfavourably high potassium–calcium balance. I doubt if you would get such good results on clay soils.