Project title:	Apple: Determining the effectiveness of novel calcium products to increase fruit calcium, increasing storage potential and potentially reducing bitter-pit
Project number:	TF 200
Project leader:	Gary Saunders, East Malling Research
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Date project commenced:	01 April 2011
Date project completed (or expected completion date):	30 September 2012

Disclaimer:

The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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Report authorised by:

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28 September 2012

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GROWER SUMMARY

Headline

- There were no clear advantages of any of the applied calcium products over the untreated control in this one year trial

Background and expected deliverables

Calcium concentrations in apple are known to be associated with fruit storage potential and the development and expression of bitter pit. The potassium to calcium ratio is also known to have an influence over storage potential, the greater the ratio of potassium to calcium, the less the potential storage period. This one year project was undertaken to determine the relative efficacy of existing and new calcium based products at increasing calcium concentrations within Bramley Seedlings fruit. Seven foliar calcium products were evaluated along with a standard calcium chloride treatment and an untreated control to determine their effectiveness at increasing fruit calcium and storage duration and their effectiveness at reducing bitter-pit.

Summary of the project and main conclusions

The treatments included consisted of:

1. Control – Untreated
2. Control – Calcium chloride flake ($CaCl_2$)
3. Pi212
4. Coded – HDC P001
5. Yara Vita Stopit
6. Carnival
7. CaB
8. Wuxal
9. Coded – HDC P002

All of the above products were applied according to manufacturer's recommendations for best practice in terms of timing, rate and water volume, subject to weather conditions at the time of application. These treatments started at bud burst and continued throughout the season.

Fruit firmness was determined and mineral analysis recorded from samples of fruit at harvest. The resulting storage potential was predicted. Another sample was stored for post-storage assessment to determine the effect on bitter-pit.

Fruit firmness was recorded above 9.5 kg for all treatments, although Treatments 3 (Pi212) and 7 (CaB) were significantly lower than the $CaCl_2$ control, Treatment 5 (Stopit) and Treatment 9 (coded product). Pi212

The fruit mineral analysis showed no evidence of significant differences in calcium concentrations between treatments. All levels were reasonably high, with concentrations above the figure of 4.5 mg/100g fresh weight- the level recommended by the Quality Fruit Group for long-term storage. This indicates that this was a good year for calcium uptake. Storage potential varied a little but all fruit was predicted to store medium to long-term.

The post-storage assessments showed no significant treatment differences in the development of bitter-pit, although the lowest levels were found in the CaB and Pi212 treated fruit.

In summary, 2011 was a reasonably good year for calcium uptake with the untreated control having a good concentration of calcium in the fruit. If calcium uptake had been poor it would probably have been easier to determine differences between treatments. However, in this trial, there were no significant differences in calcium concentrations between the treatments.

The cost of treatment applications varied, but with no clear benefits arising from any of the treatments, no clear conclusions can be drawn as to recommendations for particular products. This is a potential problem when carrying out short-term agronomy experiments with perennial crops.

Financial benefits

No financial benefits could be identified from this one year project..

Action points for growers

- No action points have arisen from this project.

SCIENCE SECTION

Introduction

This project evaluated seven foliar calcium products against a calcium chloride treatment and an untreated control on cv. Bramley Seedling to determine their ability to increase fruit calcium and storage potential and their ability to reduce bitter pit.

Calcium concentrations in apple are known to be associated with fruit storage potential and bitter pit and the potassium to calcium ratio is known to be specifically associated with storage potential, the greater the ratio of potassium to calcium, the less the storability. Potassium is preferentially taken up over calcium, so in soils where potassium is present in more than the required quantities, fruit quality can suffer. This is also often the case where composted green waste has been applied as a mulch because it is rich in potassium. Foliar calcium sprays are applied to redress the balance, however new technologies are available in recently introduced calcium formulations which require evaluating. This project determined the effectiveness of increasing fruit calcium concentration and associated cost of these new products.

The specific objectives were:

- To determine the nutrient analysis (including calcium) and firmness of the fruit at harvest
- To calculate fruit storage potential
- To determine the level of physiological disorders of the fruit ex-store post-Christmas
- To determine the cost of application

Materials and methods

The trial was conducted at East Malling Research, East Malling, Kent, in plot number EE193: a 0.58 ha plot of Bramleys Seedling on M9 planted in 2000 and known to be an orchard with a history of bitter-pit.

The treatments shown in Table 1 were applied according to the manufacturer's recommendations for best practice in terms of timing, rate and water volume, subject to weather conditions at the time of application. These treatments started at bud burst and continued throughout the season. The cost of application of each treatment was recorded.

Table 1. Treatment applications

	Treatment	Rate (amount or volume/ha)	Water volume (l/ha)	Application dates (week of the year)
1	Control – Untreated	-	-	-
2	Control – Calcium chloride flake ($CaCl_2$)	4 kg increasing to 6 kg	200	18, 19, 21, 22, 23, 25, 26, 27, 29
3	Pi212	1.5 L	200	16, 18, 19, 22, 25, 29
4	Coded – HDC P001	2 L	200	16, 18, 21, 25
5	Yara Vita Stopit	5 L pre-flower 10 L post-flower	200	16, 18, 19, 21, 22, 25, 26, 27, 29
6	Carnival	10 L	500	18, 21, 22, 25, 26, 29
7	CaB	5 L	500	18, 21, 22, 25, 26, 27, 29
8	Wuxal	4 L post-flower 5 L June July	200	18, 21, 22, 25, 26, 29
9	Coded - HDC P002	0.6 kg	200	23, 25, 26, 29
10	Control – Untreated	-	-	-

This experiment was designed as a randomised complete block experiment with five blocks of 10 treatments. However, treatment 10 did not materialise so plots allocated this treatment t the same as treatment 1 i.e. an untreated control. This was used in the analyses giving the untreated control double replication. All the recorded data variates have been analysed accordingly using ANOVA.

At harvest two samples of fruit were taken:

- a sample of 20 fruit per plot was used for fruit firmness, simple mineral analysis and storage potential prediction. This was carried out by Fast Ltd and done blind as one of their products (CaB) was used in the trial.
- a sample of 150 fruit per plot were taken, netted and air stored at East Malling Research. The fruit was removed from store post-Christmas, after bitter pit had been observed in fruit harvested from guard rows of the orchard, and subject to post-storage assessment for bitter-pit and other physiological disorders

Results

Fruit size

There was no evidence for any differences of fruit weight or diameter in the harvested fruit between treatments (Table 2).

Table 2. Average fruit weight and diameter

	Treatment	Mean fruit weight (g)	Mean fruit diameter (mm)
1	Untreated	167.2	71.99
2	$CaCl_2$	178.0	73.48
3	Pi212	151.5	70.90
4	HDC P001	154.3	70.56
5	Stopit	188.3	74.16
6	Carnival	159.8	70.92
7	CaB	171.0	73.16
8	Wuxal	166.1	69.16
9	HDC P002	164.2	72.08
	F-prob	0.444	0.701
	SED(1)	13.96	2.365
	SED(2)	16.12	2.731
	LSD(1)	28.3	4.79
	LSD(2)	32.7	5.53

SED(1) and LSD(1) are for comparing the control (1) with any of the other 8 treatments; SED(2) and LSD(2) are for comparing any two treatments.

Fruit firmness

Treatments 3 (Pi212) and 7 (CaB) appear to be less firm than the untreated control; they were also significantly lower than the $CaCl_2$ control and treatments 5 (Stopit) and 9 (HDC P002) (Table 3).

Table 3. Fruit firmness

	Treatment	**Pressure (kg)**
1	Untreated	10.638
2	$CaCl_2$	10.773
3	Pi212	9.692
4	HDC P001	10.456
5	Stopit	10.869
6	Carnival	10.112
7	CaB	9.907
8	Wuxal	10.557
9	HDC P002	10.939
	F-prob	0.042
	SED(1)	0.3598
	SED(2)	0.4155
	LSD(1)	0.729
	LSD(2)	0.842

SED(1) & LSD(1) are for comparing the control (1) with any of the other eight treatments; SED(2) & LSD(2) are for comparing any two treatments.

Fruit mineral analysis

N: there was a small overall difference between control and treated (p=0.066) with all but one treatment being higher than the controls but no individual treatment was significantly different from the untreated control (Table 4).

Ca: there was no evidence of any treatment differences in fruit calcium concentration (Table 4).

K/Ca ratio: there was very slight evidence of differences present between treatments 3-8,

with treatments 3 (Pi212) and 6 (Carnival) being low and treatment 5 (Stopit) high; no individual treatment was significantly different from the untreated control (Table 4).

Cu: there was some overall evidence of a difference between control and treated (p=0.027); treatments 4 (HDC P001), 5 (Stopit) and 9 (HDC P002) are significantly higher than the untreated control 1 (Table 4).

Fe: there was some very slight evidence of differences between treatments 3-9 (p=0.073); treatment 8 (Wuxal) seems particularly high but this is due mainly to one value. This difference should therefore be treated with extreme caution (Table 4).

Table 4. Fruit mineral analysis, N, Ca, K/Ca ratio, Cu and Fe, values per unit fruit fresh weight

	Treatment	N (mg/100g)	Ca (mg/100g)	K/Ca Ratio	Cu (mg/100kg)	Fe (mg/100kg)
1	Untreated	37.2	4.91	24.1	0.314	1.55
2	$CaCl_2$	37.1	5.21	23.6	0.318	1.65
3	Pi212	42.0	5.59	18.0	0.320	1.73
4	HDC P001	44.8	5.46	24.8	0.354	1.76
5	Stopit	44.8	4.17	31.2	0.357	1.69
6	Carnival	41.2	5.99	17.2	0.326	1.47
7	CaB	40.9	4.85	20.3	0.312	1.46
8	Wuxal	38.8	5.05	24.3	0.347	2.18
9	HDC P002	38.0	4.79	26.8	0.359	1.95
	F-prob	0.507	0.348	0.159	0.086(*)	0.096(*)
	SED(1)	4.04	0.605	4.25	0.01838	0.2128
	SED(2)	4.67	0.698	4.90	0.02122	0.2458
	LSD(1)	8.2	1.23	8.6	0.0372	0.431
	LSD(2)	9.5	1.42	9.9	0.0430	0.498

SED(1) & LSD(1) are for comparing the control (1) with any of the other 8 treatments; SED(2) & LSD(2) are for comparing any two treatments.

K: there are no significant differences (Table 5).

Mg: there are no significant differences (Table 5).

Mn: there is strong evidence of differences present (p=0.003), both between controls and treated (p=0.026) and between treatments 3-9; treatments 4 (HDC P001), 6 (Carnival) and 8 (Wuxal) are significantly greater than the untreated control, and also all other treatments except treatment 3 (Pi212) (Table 5).

P: there are no significant differences (Table 5).

Zn: there are no significant differences (Table 5).

B: there are no significant differences (Table 5).

Table 5. Fruit mineral analysis, K, Mg, Mn, P, Zn and B, values expressed as fresh apple weight

Treatment		**K (mg/ 100g)**	**Mg (mg/ 100g)**	**Mn (mg/ 100kg)**	**P (mg/ 100g)**	**Zn (mg/ 100kg)**	**B (mg/ 100kg)**
1	Untreated	111.9	4.37	0.33	9.96	0.27	2.41
2	$CaCl_2$	116.6	4.29	0.31	11.14	0.58	2.39
3	Pi212	99.3	4.35	0.37	10.03	0.40	2.37
4	HDC P001	112.7	4.53	0.40	10.91	0.42	2.33
5	Stopit	120.5	4.40	0.32	11.46	0.51	2.69
6	Carnival	96.9	4.48	0.39	9.80	0.44	2.31
7	CaB	93.6	3.94	0.31	9.08	0.36	2.52
8	Wuxal	119.1	4.58	0.39	10.39	0.42	2.69
9	HDC P002	116.4	4.48	0.30	10.51	0.29	2.58
	F-prob	0.127	0.064(*)	0.003**	0.117	0.667	0.632
	SED(1)	9.62	0.160	0.0253	0.692	0.157	0.197
	SED(2)	1.11	0.185	0.0293	0.799	0.181	0.227
	LSD(1)	9.5	0.32	0.051	1.40	0.32	0.40
	LSD(2)	22.5	0.38	0.059	1.62	0.37	0.46

SED(1) and LSD(1) are for comparing the control (1) with any of the other 8 treatments; SED(2) and LSD(2) are for comparing any two treatments

Predicted storability

This was predicted as having long, medium or short term potential. Greatest to least predicted storage potential is:

- $CaCl_2$ – long-term store
- Pi212, Carnival, Wuxal – mid- to long-term store
- Untreated, HDC P001, HDC P002 – mid- to long-term store
- CaB – mid- to long-term store
- Stopit – short- to mid-term store

Post storage assessment

There was no evidence of any significant treatment differences present for any of the analysed variates – in no case does any individual treatment (2-9) give a significant difference from the untreated control (1). As can be seen from the relative magnitude of the LSDs, the % data is rather variable.

Table 6. Post storage assessment.

	Treatment	% bitter pit	% rots	% scald
1	Untreated	14.37	5.92	2.26
2	$CaCl_2$	9.52	6.01	2.41
3	Pi212	6.68	1.16	4.23
4	HDC P001	12.46	8.30	4.94
5	Stopit	17.63	8.58	4.79
6	Carnival	7.23	3.74	2.09
7	CaB	6.44	3.81	5.87
8	Wuxal	16.08	10.31	3.90
9	HDC P002	7.14	7.88	1.54
	F-prob	0.526	0.265	0.576
	SED(1)	5.857	3.088	2.121
	SED(2)	6.763	3.566	2.449
	LSD(1)	11.87	6.26	4.30
	LSD(2)	13.70	7.23	4.96

SED(1) and LSD(1) are for comparing the control (1) with any of the other 8 treatments; SED(2) and LSD(2) are for comparing any two treatments

Cost of treatment application

The costs were based on number of treatment applications throughout the season and spray volume.

Table 7. Cost of treatment application

	Treatment	Cost of application £/ha
1	Untreated	£0
2	$CaCl_2$	£180
3	Pi212	£120
4	HDC P001	£80 *
5	Stopit	£180
6	Carnival	£150
7	CaB	£175
8	Wuxal	£120
9	HDC P002	£80 *

* No chemical cost was available for these coded products and so just the cost of application is noted

Discussion

Fruit firmness was good for all the treatments even though pressures were lower for Pi212 and CaB treated fruit. There was no evidence of any significant differences in calcium concentration between treatments but all concentrations were reasonably high. The untreated control had 4.91 mg/100g fresh weight, well above the figure of 4.5 mg/100g fresh weight, recommended by the Quality Fruit Group for long-term storage. This indicates that this was a good year for calcium uptake, a year when treatment effects would be difficult to determine. Predicted storability varied little but all fruit was predicted to store mid- to long-term. With the post-storage assessments again there are no significant treatment differences although the lowest percentage bitter pit figures (although not significant), were found in the CaB and Pi212 treated fruit. The elevated Ca concentrations in the untreated fruit also make it difficult to determine if any of the applied product was actually taken up by the fruit.

The cost of applications varied, consisting of a combination of chemical cost and application cost. Several of the products were coded and therefore no chemical cost could be determined for these, therefore to enable comparisons to be made between treatments just the cost of application was noted.

Conclusions

It must be remembered that this is only a one-year trial and that 2011 was a reasonably good year for calcium uptake with the untreated control having a good concentration of calcium in the fruit. If calcium uptake had been poor it might have been easier to determine differences due to treatment application. As it was there were no significant differences in calcium concentrations within the fruit of different treatments, so it is difficult to determine even if the product calcium was taken up by the fruit.

There was some variation in predicted storability but no statistically different results from the post storage assessments. Cost of treatment applications varied, but with no clear benefits arising from any of the treatments, no clear conclusions can be made as to recommendations for particular products.

It would not normally be expected with this type of experiment on a perennial crop to make any recommendations solely on one year's worth of data, so the conclusions from this work must be considered as only very preliminary and the interpretation must be taken with caution.