Project title:	Apple: Investigation into the relationship between sap, leaf and fruit mineral analysis and the occurrence of diffuse browning disorder (DBD) in Cox.
Project number:	TF 166b
Project leader:	Mr C T Biddlecombe Farm Advisory Services Team Ltd. Experimental Farm North Street Sheldwich Faversham Kent ME13 0LN
Report:	Final report, June 2006
Previous reports:	None
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Grower co-ordinator:	To be advised
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TF 166b

Apple: Investigation into the relationship between sap, leaf and fruit mineral analysis and the occurrence of diffuse browning disorder (DBD) in Cox

Grower Summary

Headline

The results from this trial indicate that there is no link between the occurrence of DBD in Cox and mineral nutrient levels in sap, leaves, fruit pre harvest and post-storage.

Background and expected deliverables

The occurrence of diffuse browning disorder in stored Cox apples has become of increasing concern to the industry. Growers who have orchards that are at risk are restricted to storing fruit short term to avoid the potential development of DBD. This will reduce the potential income from the crop due to the necessity to market the fruit at a time where there is a traditional over supply of dessert apples, resulting in a low market price and in some years a significant financial loss.

The recent HDC project TF 139 “Investigating diffuse browning disorder (DBD) in stored Cox apples” failed to identify the cause of this problem and consequently further research is necessary to determine factors influencing the onset of DBD in Cox.

This project provides an opportunity to determine any link between mineral nutrient levels in sap, leaf and fruit and the occurrence of DBD in Cox. Specifically:

- To determine any relationship between sap mineral content throughout the season and the occurrence of DBD in Cox
- To determine any relationship between leaf mineral content throughout the season and the occurrence of DBD in Cox

- To determine any relationship between fruit mineral content throughout the season and the occurrence of DBD in Cox
- To determine any relationship between fruit mineral content ex-store and the occurrence of DBD in Cox

The potential benefits from this project are threefold. Firstly, greater economic returns are more likely from sales of Cox that has been stored long-term than from fruit that that has to be marketed at a time when dessert apple availability is high. Secondly, there will be a greater confidence in storing Cox from orchards where DBD has not yet been observed. A further significant benefit would be a restoring of confidence through the marketing chain in stored Cox.

Summary of the project and main conclusions

This project assessed four orchard sites to determine the link between mineral analysis and the occurrence of DBD in Cox.

Sap, leaf and fruit analyses were conducted on a fortnightly basis until harvest. Measuring leaf and fruit nutrients by tissue analysis determined the total accumulation of nutrients to that point in time. Sap analysis from the leaf gave information on the nutrient uptake at the point in time when the sample was taken. This can pinpoint periods when nutrient uptake is affected by environmental conditions, crop load or nutrient demand.

Samples were analysed in the laboratory at FAST Ltd for the following:

Sap	P, K, Ca, Mg, Zn, Cu, Mn, Fe, B, S
Leaf	N, P, K, Ca, Mg, Zn, Cu, Mn, Fe, B
Fruit	N, P, K, Ca, Mg, Zn, Mn, Fe, B

Fruit for mineral analysis post storage and for DBD determination was stored at East Malling Research under standard Cox conditions until early February 2006. Results of mineral analysis were then compared with incidence of DBD to determine any links between plant nutrition and incidence of DBD and to provide recommendations for further research and initial recommendations to growers.

Only one of the four sampled sites Orchard 1 showed significant symptoms of DBD post storage (13%). The other sites had little or no occurrence of DBD (0% from Orchard 4; 1% from Orchard 2 and 0% from Orchard 3). Differences between the results for Orchard 1 and the other orchards were then used to determine potential links between mineral analysis and the occurrence of DBD.

Sap, leaf and fruit analysis gave results on the levels of N, P, K, Ca, Mg, Zn, Cu, Mn, Fe, B and S from a range of sample dates in the period of week 17 to week 36. Although there was a range of differing results from the sampled orchards, no specific element was identified at any point in time as being wildly different for Orchard 1when compared to the other sampled orchards.

The results showed no potential link between the occurrence of DBD and the mineral analysis for sap, leaf, fruit prior to harvest and fruit post storage for any of the sample dates. In addition to the results from this trial, post storage fruit from another orchard was separated into fruit with and without DBD. Mineral analysis was then carried out on these two fruit samples and no major differences were observed between samples. This supports the conclusion that there is no link between mineral analysis and occurrence of DBD in Cox.

Financial benefits

There are no financial benefits at this stage.

Action points for growers

There are no action points for growers.

Science section

Introduction

The occurrence of diffuse browning disorder (DBD) in stored Cox apples has become of increasing concern to the industry. Growers who have orchards that are at risk are restricted to storing fruit short term to avoid the potential development of DBD. This will reduce the potential income from the crop due to the necessity to market the fruit at a time where there is a traditional over supply of dessert apples, resulting in a low market price and in some years a significant financial loss.

The recent HDC project TF 139 "Investigating diffuse browning disorder (DBD) in stored Cox apples" failed to identify the cause of this problem and consequently further research is necessary to determine factors influencing the onset of DBD in Cox.

This project provides an opportunity to determine any link between sap, leaf and fruit mineral analysis and the occurrence of diffuse browning disorder (DBD) in Cox.

The potential benefits from this project are threefold. Firstly, greater economic returns are more likely from sales of Cox that has been stored long-term than from fruit that that has to be marketed at a time when dessert apple availability is high. Secondly, there will be a greater confidence in storing Cox from orchards where DBD has not yet been observed. A further significant benefit would be a restoring of confidence through the marketing chain in stored Cox.

Materials and Methods

Although this project was to assess two orchard sites in Kent, one that typically has a high incidence of DBD and one that has a low incidence of DBD, data has been presented from four orchards to better determine the link between mineral analysis and the occurrence of DBD.

The trial orchard sites were located as follows:

Orchard 1	**Anthony's**	Monks Farm, Norton Road, Norton, Sittingbourne, Kent by kind permission of Mr. S. Bray.
Orchard 2	**Hollies**	Hull Farm, Spring Valley Lane, Ardleigh, Essex by kind permission of Mr. C. & R. Fryer.
Orchard 3	**Oast**	Norham Farm, Selling, Faversham, Kent by kind permission of Mr. C. Gaskain.
Orchard 4	**Cherry**	Lee Priory Farm, Littlebourne, Canterbury, Kent by kind permission of Mr. S. Twyman.

Sap, leaf and fruit analyses were conducted on a fortnightly basis until harvest. Measuring leaf and fruit nutrients by tissue analysis determined the total accumulation of nutrients to that point in time. Sap analysis from the leaf gave information on the nutrient uptake at the point in time when the sample was taken. This can pinpoint periods when nutrient uptake is affected by environmental conditions, crop load or nutrient demand.

The soil types of the orchards are as follows:

Anthony's	silty clay loam
Hollies	sandy clay loam
Oast	silty clay loam
Cherry	silt loam

Samples were analysed in the laboratory at FAST Ltd for the following:

Sap	P, K, Ca, Mg, Zn, Cu, Mn, Fe, B, S
Leaf	N, P, K, Ca, Mg, Zn, Cu, Mn, Fe, B
Fruit	N, P, K, Ca, Mg, Zn, Mn, Fe, B

Fruit for mineral analysis post storage and for DBD determination was transported to East Malling Research for storage under standard Cox conditions. Fruit was stored until the 6th February 2006 when the fruit was taken from the store and left at room temperature for one week for DBD symptoms to develop before conducting post storage assessments and fruit analysis

Results of mineral analysis were then compared with incidence of DBD to determine any potential link between mineral nutrient levels and incidence of DBD and to provide recommendations to for further research and initial recommendations to growers.

Results

Total occurrence of DBD

The results for a 100 apple sample from each of the orchards was as follows:

Anthony's	13% DBD
Hollies	1% DBD
Oast	0% DBD
Cherry	0% DBD

Any differences in the results for mineral analysis between Anthony's orchard and the others might indicate a potential link to the causes of DBD.

Sap Analysis

All values for sap analysis have been adjusted to index values so that for each element a value of 500 to 600 represents the optimum. The full data for sap analysis is shown in Appendix I.

When expressed graphically it can be observed that the sap results for P, Ca, Mg, Zn, Cu, Mn, Fe, B and S in the sample from Anthony's orchard generally fall within the range of the other sampled orchards. This trend is also true for K but levels at Oast for week 25 onwards fall rapidly compared to that of Anthony's, Cherry and Hollies. Two examples are presented graphically below in Figures 1 and 2.

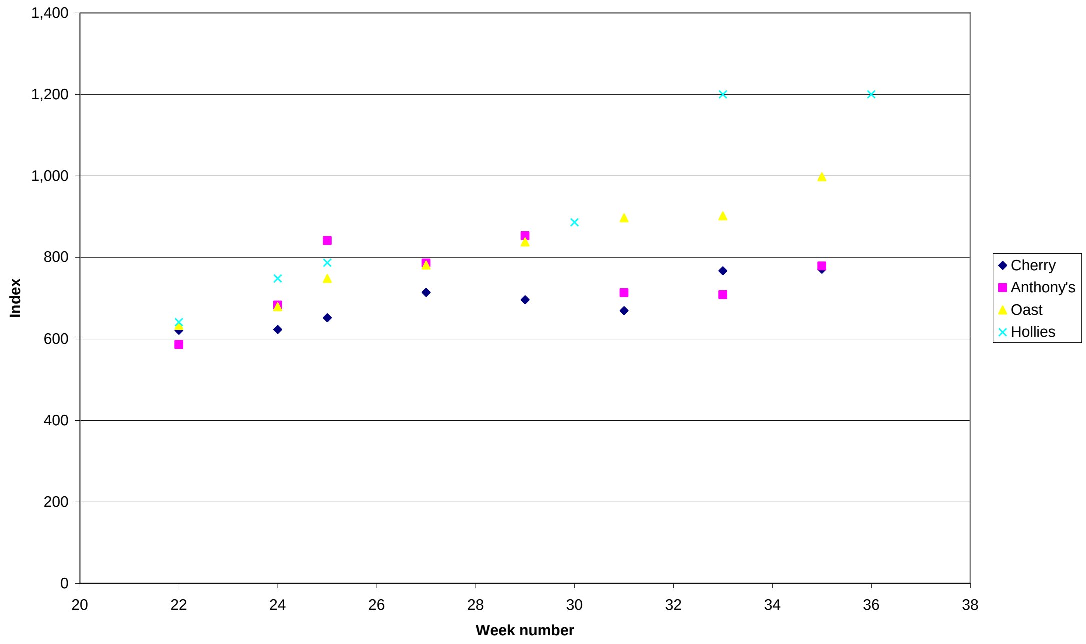

Figure 1. Sap P levels over time.

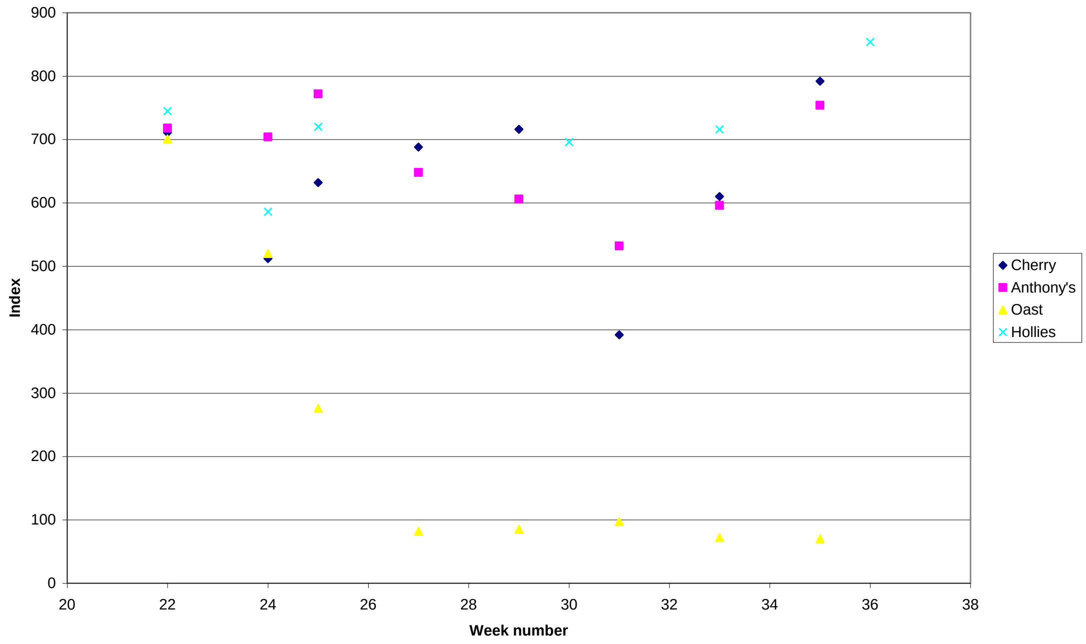

Figure 2. Sap K levels over time.

Leaf analysis

When expressed graphically it can again be seen that the N, P, K, Mg, Ca, Mn, B, Cu, Zn and Fe results from Anthony's Orchard fall around the range of results from the other sampled orchards. Two examples are presented graphically below in Figures 3 and 4; the full data for leaf analysis is contained within Appendix II.

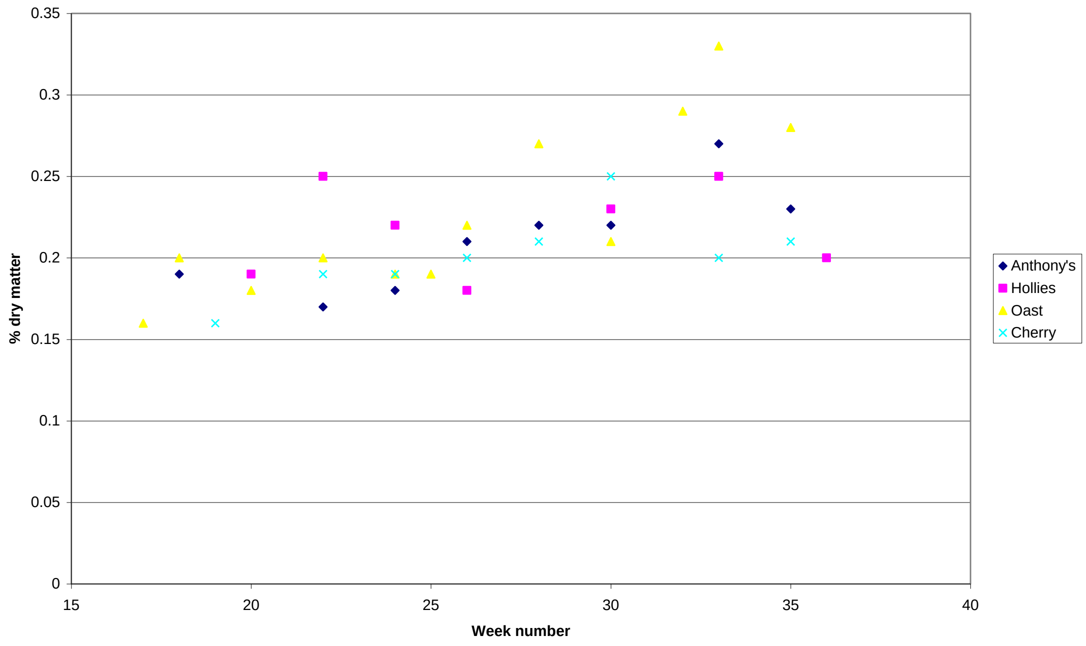

Figure 3. Leaf Mg levels expressed as percentage dry matter.

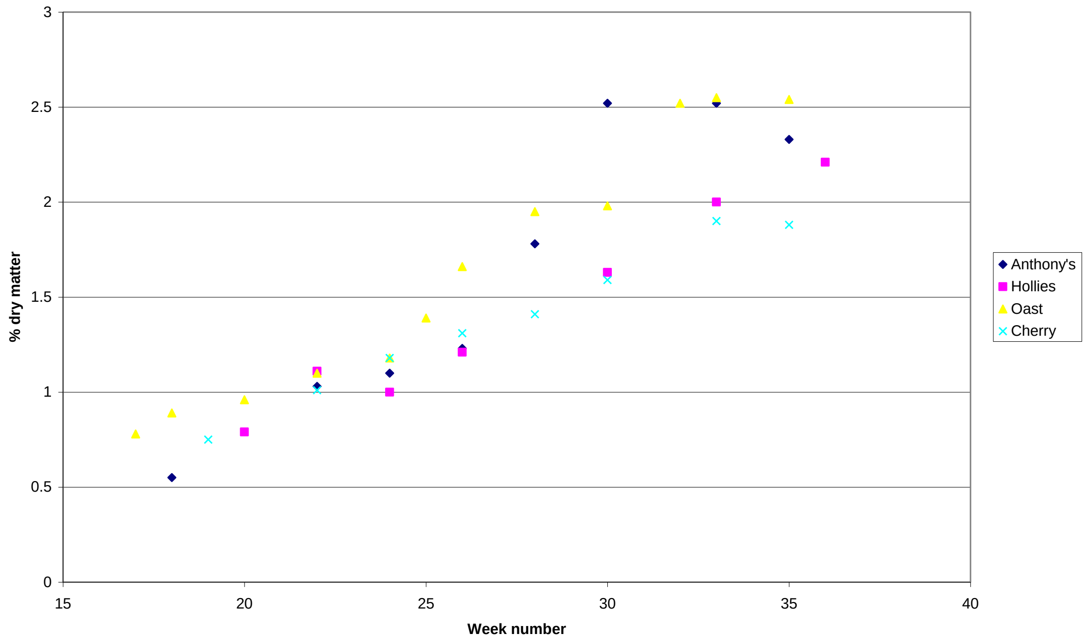

Figure 4. Leaf Ca levels expressed as percentage dry matter.

Fruit analysis prior to harvest

Again when expressed graphically it can be seen that the N, P, K, Mg, Ca, Mn, B, Zn and Fe results from Anthony's Orchard fall around the range of results from the other sampled orchards. Two examples are presented graphically below in Figures 5 and 6, the full data for fruit analysis prior to harvest is contained within Appendix III.

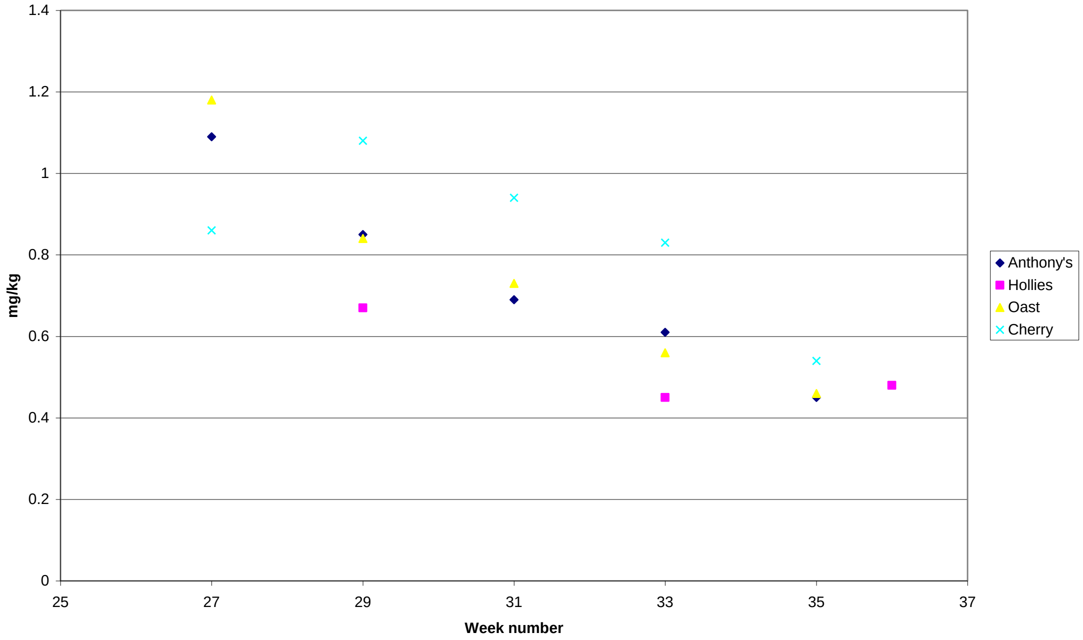

Figure 5. Fruit Mn levels expressed as mg/kg fresh weight.

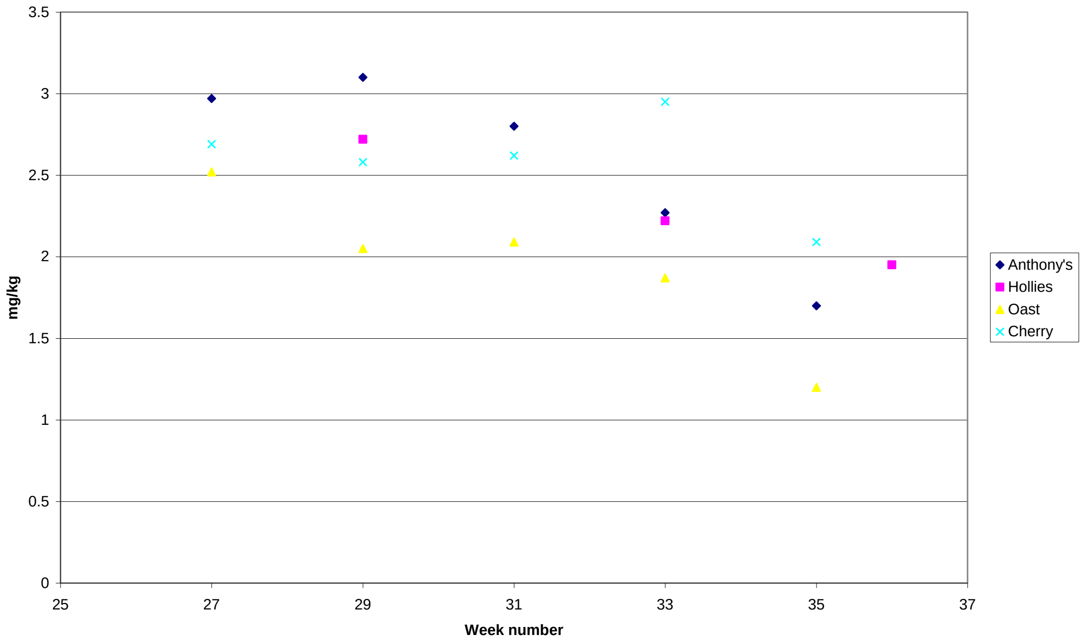

Figure 6. Fruit Fe levels expressed as mg/kg fresh weight.

Fruit analysis post storage

Again when expressed graphically it can be seen that the N, P, K, Mg, Ca, Mn, B, Zn and Fe results from Anthony's Orchard fall around the range of results from the other sampled orchards. Two examples are presented graphically below in Figure 7, the full data for fruit analysis prior to harvest is contained within Appendix IV.

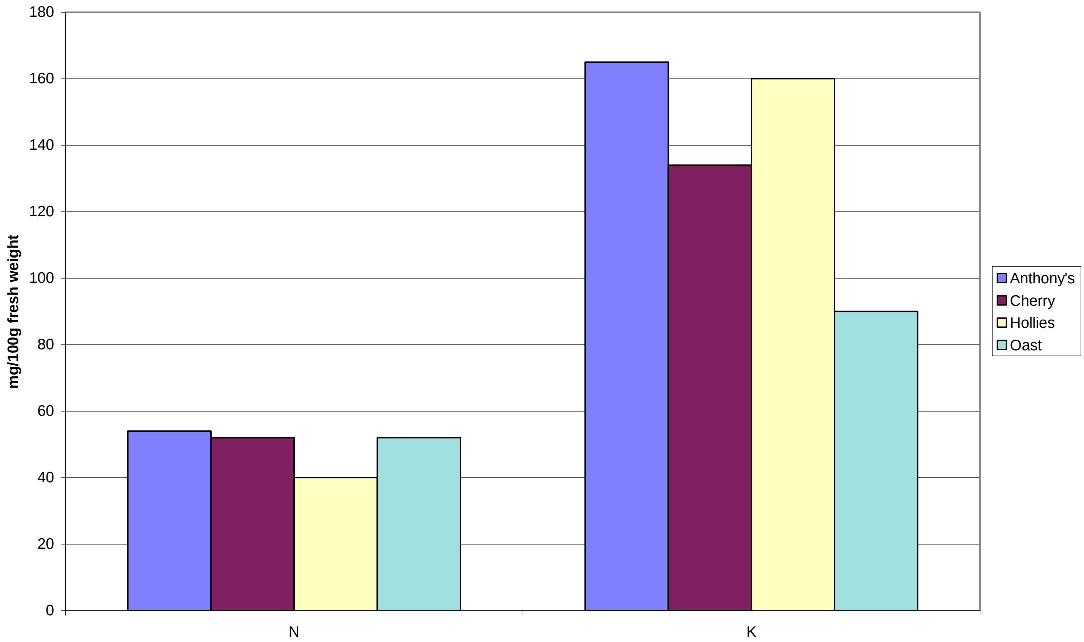

Figure 7. Fruit N and K levels expressed as mg/100g fresh weight.

Discussion

Only one of the four sampled sites (Anthony's) showed significant symptoms of DBD post storage (13%). Potential links between mineral content of sap, leaf, fruit prior to harvest and fruit post storage with occurrence of DBD might be identified from the comparison of data from Anthony's orchard with data from the other three orchards, (Cherry, 0% DBD; Hollies, 1% DBD and Oast, 0% DBD).

Sap analysis gave results on the levels of P, K, Ca, Mg, Zn, Cu, Mn, Fe, B and S from a range of sample dates in the period of week 22 to week 36. Although there was a range of differing results from the sampled orchards, no specific element was identified at any point in time as being very different for Anthony's Orchard when compared to the other sampled orchards.

Analysis of the mineral content of leaves from each orchard from a range of sampling dates in the period of week 17 to week 36 gave similar results to the sap analysis. Again no specific element was identified at any point in time as being particularly different for Anthony's Orchard when compared to the other sampled orchards.

Fruit analysis prior to harvest and post storage revealed that fruit from Anthony's Orchard had similar nutritional levels to fruit from the other orchards.

The above results show that there was no potential link between the occurrence of DBD and the mineral analysis for sap, leaf, fruit prior to harvest and fruit post storage for any of the sample dates. In addition to the results from this trial, post storage fruit from another orchard was separated into fruit with and without DBD. Mineral analysis was then carried out on these two fruit samples and no major differences were observed between samples. This supports the conclusion that there is no link between mineral analysis and occurrence of DBD in Cox.

Conclusions

The results from this trial indicate that there is no link between the occurrence of DBD in Cox and mineral nutrient levels in sap, leaves and fruit both pre harvest and post-storage.

Appendix I.

Raw data: sap analysis

		Index values									
Orchard	Week	P	K	Ca	Mg	Zn	S	Cu	Mn	Fe	B
Cherry	22	621	711	677	523	260	564	505	278	80	122
Cherry	24	623	512	649	356	100	512	426	244	40	501
Cherry	25	652	632	779	507	64	730	510	153	300	425
Cherry	27	714	688	854	570	72	840	367	589	100	329
Cherry	29	696	716	882	575	80	860	500	784	70	281
Cherry	31	669	392	850	534	80	712	433	718	70	61
Cherry	33	767	610	1,039	590	72	745	515	660	380	78
Cherry	35	771	792	812	282	80	720	433	551	80	244
Anthony's	22	586	718	791	535	220	540	510	517	90	88
Anthony's	24	683	704	695	294	87	513	505	324	93	376
Anthony's	25	841	772	787	548	72	760	510	523	180	167
Anthony's	27	786	648	946	581	88	664	433	564	70	71
Anthony's	29	853	606	1,004	638	96	722	525	556	340	98
Anthony's	31	713	532	946	562	52	568	367	528	100	53
Anthony's	33	708	596	1,054	613	64	688	510	592	100	59
Anthony's	35	779	754	1,030	558	80	632	433	502	70	87
Oast	22	633	701	1,060	634	340	484	550	528	70	72
Oast	24	679	520	788	505	153	212	510	428	53	360
Oast	25	748	276	1,050	587	80	660	540	635	90	465
Oast	27	781	82	1,200	716	88	696	515	704	50	103
Oast	29	838	85	1,075	613	76	676	540	776	70	356
Oast	31	897	97	1,046	571	80	596	515	573	60	87
Oast	33	902	72	1,200	742	68	740	510	688	70	66
Oast	35	998	70	1,200	752	80	700	505	545	60	79
Hollies	22	641	745	918	647	420	1,162	510	523	380	96
Hollies	24	748	586	695	500	100	632	505	380	127	510
Hollies	25	787	720	794	540	96	1,088	367	569	512	468
Hollies	30	886	696	861	541	72	1,010	433	519	502	348
Hollies	33	1,200	716	1,007	615	64	1,018	433	473	220	121
Hollies	36	1,200	854	882	450	96	852	515	140	420	313

Appendix II.

Raw data: leaf analysis

Orchard	Week	N	P	K	Mg	Ca	Mn	B	Cu	Zn	Fe
		% dry matter					mg/kg dry matter				
Anthony's	18	3.17	0.35	1.82	0.19	0.55	33	38.2	15.4	28.2	111
Anthony's	22	2.87	0.26	1.91	0.17	1.03	33	26.8	8.9	18.5	88
Anthony's	24	2.67	0.24	1.56	0.18	1.10	24	20.0	7.3	14.2	80
Anthony's	26	3.15	0.25	1.78	0.21	1.23	44	20.2	8.1	18.7	97
Anthony's	28	2.25	0.22	1.47	0.22	1.78	52	17.9	8.2	20.5	92
Anthony's	30	2.07	0.22	1.54	0.22	2.52	37	22.1	7.2	30.7	90
Anthony's	33	2.31	0.22	1.28	0.27	2.52	61	19.3	8.3	18.3	106
Anthony's	35	2.04	0.18	1.34	0.23	2.33	54	21.5	7.9	20.5	104
Hollies	20	2.80	0.33	1.68	0.19	0.79	31	40.9	11.9	19.2	101
Hollies	22	3.02	0.26	1.80	0.25	1.11	34	29.3	10.0	23.7	125
Hollies	24	2.27	0.32	1.66	0.22	1.00	33	23.7	8.9	17.3	90
Hollies	26	2.32	0.24	1.70	0.18	1.21	53	29.3	8.7	23.7	136
Hollies	30	2.38	0.26	1.60	0.23	1.63	45	28.0	8.4	18.5	131
Hollies	33	1.98	0.34	1.72	0.25	2.00	31	26.2	9.5	18.0	140
Hollies	36	1.81	0.40	1.72	0.20	2.21	23	26.8	8.3	18.5	129
Oast	17	3.92	0.59	2.09	0.16	0.78	14	81.2	105.5	62.6	84
Oast	18	3.49	0.44	1.95	0.20	0.89	30	45.8	30.4	49.6	87
Oast	20	3.28	0.28	1.69	0.18	0.96	36	23.0	14.0	26.3	92
Oast	22	3.44	0.28	1.75	0.20	1.10	32	25.4	13.6	20.6	83
Oast	24	3.12	0.24	1.56	0.19	1.18	32	22.5	12.2	27.5	83
Oast	25	2.53	0.26	1.59	0.19	1.39	29	22.9	11.9	18.9	77
Oast	26	3.18	0.22	1.06	0.22	1.66	107	25.0	11.4	21.4	79
Oast	28	2.37	0.23	0.90	0.27	1.95	103	19.2	11.2	19.8	78
Oast	30	2.45	0.23	0.81	0.21	1.98	86	20.3	9.7	18.1	97
Oast	32	2.20	0.30	1.10	0.29	2.52	76	22.3	10.9	25.1	105
Oast	33	2.34	0.28	0.71	0.33	2.55	77	20.9	10.5	17.0	95
Oast	35	1.96	0.26	1.03	0.28	2.54	77	20.9	11.3	48.4	109
Cherry	19	3.33	0.35	1.76	0.16	0.75	23	39.2	14.8	34.3	99
Cherry	22	3.31	0.30	1.66	0.19	1.01	26	25.2	10.4	24.2	87
Cherry	24	2.75	0.22	1.63	0.19	1.18	18	22.0	9.0	31.3	73
Cherry	26	3.07	0.20	1.55	0.20	1.31	20	25.3	9.0	17.3	105
Cherry	28	2.39	0.21	1.65	0.21	1.41	64	23.4	7.6	19.9	123
Cherry	30	2.35	0.20	1.69	0.25	1.59	143	23.0	9.3	20.2	126
Cherry	33	2.15	0.21	1.29	0.20	1.90	95	22.2	9.9	18.9	140
Cherry	35	2.18	0.20	1.47	0.21	1.88	105	24.3	8.5	19.1	131

Appendix III.

Raw data: fruit analysis prior to harvest

Orchard	Week	N	P	K	Ca	Mg	B	Zn	Mn	Fe
		mg/100g fresh weight				mg/kg fresh weight				
Anthony's	27	121	18.73	212	17.94	12.75	2.74	1.12	1.09	2.97
Anthony's	29	101	16.63	193	16.92	10.75	2.26	0.84	0.85	3.10
Anthony's	31	82	12.13	158	11.04	8.14	1.92	1.27	0.69	2.80
Anthony's	33	72	12.79	158	9.73	8.31	2.17	0.53	0.61	2.27
Anthony's	35	59	10.68	133	6.44	6.19	1.72	0.31	0.45	1.70
Hollies	29	74	14.11	162	10.51	8.95	3.63	0.85	0.67	2.72
Hollies	33	53	12.09	131	8.35	7.27	3.88	0.35	0.45	2.22
Hollies	36	42	13.01	145	6.39	6.55	3.74	0.91	0.48	1.95
Oast	27	120	17.92	130	23.82	10.71	3.69	1.14	1.18	2.52
Oast	29	82	13.78	107	13.58	7.56	3.75	0.79	0.84	2.05
Oast	31	78	13.94	117	11.33	7.07	2.74	0.69	0.73	2.09
Oast	33	61	12.32	92	8.75	5.88	2.65	0.56	0.56	1.87
Oast	35	51	10.53	87	6.70	4.97	2.24	0.43	0.46	1.20
Cherry	27	97	14.24	170	13.84	9.43	2.97	0.79	0.86	2.69
Cherry	29	94	13.54	148	10.06	8.30	2.50	0.72	1.08	2.58
Cherry	31	74	12.07	145	8.97	7.22	2.14	0.59	0.94	2.62
Cherry	33	58	9.92	128	7.53	6.25	2.19	0.54	0.83	2.95
Cherry	35	55	8.92	122	5.60	5.12	2.20	0.46	0.54	2.09

Appendix IV.

Raw data: fruit analysis post storage

Orchard	N	P	K	Ca	Mg	B	Zn	Mn	Fe
	mg/100g fresh weight					mg/Kg fresh weight			
Anthony's	54	12.00	165	8.15	7.62	2.28	0.47	0.60	2.41
Cherry	52	11.00	134	5.21	5.96	2.40	0.49	0.62	2.31
Hollies	40	14.10	160	6.79	7.41	3.43	0.39	0.56	2.92
Oast	52	11.80	90	6.69	5.12	2.53	0.35	0.51	1.91