

<b>Project Title</b>	Apple: Continued investigation into fruit position in relation to tree structure and the occurrence of diffuse browning disorder (DBD) in Cox
<b>Project number:</b>	TF 166f
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<b>Project coordinator:</b>	TBA
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The results and conclusions in this report are based on a series of experiments 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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# Grower Summary

## Headline

- The occurrence of DBD was not linked to fruit position or number of seeds
- The occurrence of DBD within an orchard appears to centre around localised positions within specific trees

## Background and expected deliverables

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 desert apples, resulting in a low market price and in some years a significant financial loss.

This project provides an opportunity to determine the link between fruit position in relation to the canopy and associated tree characteristics and the occurrence of diffuse browning disorder (DBD) in Cox.

Although the occurrence of DBD in HDC project TF 166c was too low to show links between DBD and fruit tree characteristics the data did show that fruit with DBD appeared to occur in clusters within the orchard and within the tree. If these findings are confirmed it will give a clear lead to further investigations to understand the causes of DBD. This project proposes to investigate this localised occurrence further.

This project will build upon the findings of the recently funded HDC project TF 139: Investigating diffuse browning disorder (DBD) in Cox, TF 166a: Investigating the link between spray programme characteristics and the occurrence of diffuse browning disorder (DBD) in Cox, TF 166b: Investigation into the relationship between sap, leaf and fruit mineral analysis and the occurrence of diffuse browning disorder (DBD) in Cox and TF 166c: Investigation into fruit position in relation to tree structure and the occurrence of diffuse browning disorder (DBD) in Cox.

This project provides an opportunity to determine the link between fruit position in relation to the canopy and associated tree characteristics and the occurrence of DBD in Cox. Specifically to determine the relationship between the occurrence of DBD in Cox and:

- fruit position in sun or shade
- fruit number in a cluster
- the age of fruiting wood
- the proximity to a strong shoot
- the number of seeds in the fruit

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 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**

54 of the 1,028 fruit picked and recorded at Farm A (5.25%) developed symptoms of DBD. This incidence of DBD was greater than the previous year (0.74%) and was more typical of fruit stored in previous years which had developed high levels of DBD. In contrast only 17 of the 2,352 fruit picked and recorded at Farm B (0.72%) developed symptoms of DBD.

As a whole sample, and as in HDC project TF 166c, fruit within the selected trees was either found singly or in clusters of two to five fruit, predominantly as one, two or three fruit. In the samples showing DBD, fruit was predominantly held singly or in clusters of two.

Across the whole sample fruit was found around all sides of the tree but within the DBD sample the greater proportion of fruit was found on the East sides whereas in HDC project TF 166c most affected fruit was found on the North and West sides of the tree. These conflicting results indicate that there is no relationship between fruit orientation in the tree and the incidence of DBD.

The occurrence of DBD at differing heights in the canopy followed a similar pattern to total yield as did the pattern for age of wood and presence of a strong shoot arising from the fruit cluster i.e. there is no relationship between these factors and the incidence of DBD.

There also appears to be no correlation between number of viable seeds and occurrence of DBD as the proportion of number of seeds follows that of the whole sample.

The results showed no links between the occurrence of DBD and any of the measured characteristics and hence no practical grower recommendations can be made from these results.

However as in HDC project TF 166c, the occurrence of DBD centred around specific trees although not always the same trees year on year. Occurrence within trees was again typically localised to specific points within the canopy, often on the same or adjacent branch, but not linked to the measured parameters.

### **Financial benefits**

There are no financial benefits.

### **Action points for growers**

- There are no action points for growers

## **Science Section**

### **Introduction**

The occurrence of diffuse browning disorder in stored Cox apples has become of increasing concern to the UK apple industry. Growers who have orchards that are at risk are restricted to storing fruit short term to avoid the potential development of DBD. This reduces 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 projects TF 139 “Investigating diffuse browning disorder (DBD) in stored Cox apples”, TF 166a “Investigating the link between spray programme characteristics and the occurrence of diffuse browning disorder (DBD) in Cox”, TF 166b “Investigation into the relationship between sap, leaf and fruit mineral analysis and the occurrence of diffuse browning disorder (DBD) in Cox” and TF 166c “Investigation into fruit position in relation to tree structure and the occurrence of diffuse browning disorder (DBD) in Cox” failed to identify the cause of this problem and consequently further research is necessary to determine factors influencing the onset of DBD in Cox.

Although the occurrence of DBD in HDC project TF 166c was too low to show links between DBD and fruit tree characteristics the data did show that fruit with DBD appeared to occur in clusters within the orchard and within the tree. This project aimed to build on HDC project TF 166c and determine the link between position of the fruit within the tree structure and the occurrence of DBD by recording individual fruit characteristics in relation to tree canopy and correlating with development of DBD.

This project was conducted on two sites:

- A repeated assessment of the site used for project TF 166c using the same trees to determine if the occurrence of DBD is predominantly in the same location as in 2005 or if the occurrence of DBD is not static in relation to location on a year on year basis.
- An orchard with a known history of DBD with smaller trees than those in the other assessed orchard. Ten pairs of adjacent trees were strip picked providing more information on the apparent localised occurrence of DBD within an orchard as well as within tree characteristics relative to the occurrence of DBD.

### **Materials and Methods**



The trial was conducted at two sites:

Farm A Lee Priory Farm, Littlebourne, Kent by kind permission of Stephen Twyman. The Cox (M9) orchard is well managed and was planted in 1987/88, is of moderate - high vigour and is situated on a silt loam soil type. Ten trees spaced at regular intervals within the orchard were strip picked on 13-15/09/06. The trees were the same as those picked in 2007 for HDC project TF 166c.

Farm B Monks Farm, Norton, Kent by kind permission of Simon Bray. The Cox (M9) orchard is planted as a well managed four row bed, is of moderate vigour and is situated on a silty clay loam soil type. Ten pairs of adjacent trees spaced at regular intervals within the orchard were strip picked on 20-21/09/06.

Each fruit was numbered at the time of picking and the following characteristics for each fruit were recorded:

- Apple number
- Tree number
- Number of fruit in cluster
- Aspect (N, S, E, W)
- Height (top 175cm+, middle 90-175cm or bottom 0-90cm portion of the tree)
- Canopy position (outside or inside)
- Age of wood that produced the fruit cluster
- Presence of a strong shoot arising from the cluster
- Branch length (cm)

After picking the fruit was transported to East Malling Research for storage under standard Cox conditions. Fruit was stored until 19<sup>th</sup> February 2007 when the fruit was taken from the store and left for one week for DBD symptoms to develop before conducting post storage assessments. Fruit was assessed on 26<sup>th</sup> – 28<sup>th</sup> February 2007 and the following characteristics were recorded:

- Presence/absence of DBD
- Fruit diameter

- Presence/absence of other storage disorders
- Number of viable seeds
- Fruit pressure (on one in ten fruit)

Results of fruit in relation to tree structure characteristics were then compared with incidence of DBD to indicate potential causes of DBD and to provide recommendations to for further research and initial recommendations to growers.

## **Results and Discussion**

Orchard A, Lee Priory Farm

### *Total occurrence of DBD*

54 of the 1,028 fruit picked and recorded (5.25%) developed symptoms of DBD. This incidence of DBD was greater than the previous year (0.74%) and was more typical of fruit stored in previous years which had developed high levels of DBD.

### *Occurrence of DBD in relation to recorded characteristics*

Of the fruit that exhibited symptoms of DBD:

- 26% occurred in fruit that were singular on the tree, 23% occurred in fruit that had 2 apples in the cluster and 5% occurred in fruit that had 3 apples in the cluster
- 44% were found on the East sides of the trees, 28% on the West sides, 19% on the North sides and 9% on the South sides
- 89% were found in the mid section of the tree and 11% were found in the lower section of the tree
- 54% occurred on the outside canopy of the tree and 46% occurred on the inside canopy of the tree
- 37% occurred in fruit arising from 2 year wood, 44% occurred in fruit arising from 3 year wood, 11% occurred in fruit arising from 4 year wood and 7% occurred in fruit arising from 5 year wood
- 17% occurred in fruit from clusters with a strong shoot emerging from the cluster and 83% occurred in fruit without the presence of a strong shoot arising from the cluster

- fruit density along the branch ranged from one fruit per 5.0cm of branch length to one fruit per 95.0cm of branch length
- fruit diameter ranged from 50mm to 86mm
- 20% occurred in fruit with no viable seeds, 22% occurred in fruit with one viable seed, 17% occurred in fruit with two viable seeds, 11% occurred in fruit with three viable seeds, 11% occurred in fruit with four viable seeds, 6% occurred in fruit with five viable seeds, 6% occurred in fruit with six viable seeds, 6% occurred in fruit with seven viable seeds, 2% occurred in fruit with eight viable seeds and 2% occurred in fruit with nine viable seeds
- the average pressure was 5.68

It was observed that of the 54 fruit with DBD, 21 were found on one tree and 13 fruit were found on another tree, the other 20 fruit were found as 8, 2, 2, 1, 2, 1 and 4 fruit on 6 trees. It was also observed that the occurrence of DBD appeared to be specific to particular branches and that branches with DBD fruit were commonly adjacent to each other.

Of the total fruit recorded:

- 52% were singular on the tree, 35% had 2 apples in the cluster, 11% had 3 apples in the cluster, 1% had 4 apples in a cluster and 1% had 5 apples in a cluster
- 22% were found on the North sides of the trees, 32% on the East sides, 26% on the South sides and 20% on the West sides
- 4% were found at the top of the tree, 72% were found in the mid section of the tree and 24% were found in the lower section of the tree
- 38% occurred on the outside canopy of the tree and 62% occurred on the inside canopy of the tree
- 46% occurred on fruit arising from 2 year wood, 40% occurred on fruit arising from 3 year wood, 13% occurred on fruit arising from 4 year wood and 1 % occurred on fruit arising from 5 year wood
- 22% occurred in fruit from clusters with a strong shoot emerging from the cluster and 78% occurred in fruit without the presence of a strong shoot arising from the cluster
- fruit density along the branch ranged from one fruit per 4.4cm of branch length to one fruit per 200.0cm of branch length
- fruit diameter ranged from 43mm to 89mm
- 13% occurred as fruit with no viable seeds, 13% occurred as fruit with one viable seed, 17% occurred as fruit with two viable seeds, 14% occurred as fruit with three viable seeds, 11% occurred as fruit with four viable seeds, 12% occurred as fruit with

five viable seeds, 9% occurred as fruit with six viable seeds, 6% occurred as fruit with seven viable seeds, 3% occurred as fruit with eight viable seeds and 1% occurred as fruit with nine viable seeds

- the average pressure was 5.29

Orchard B, Monks Farm

#### *Total occurrence of DBD*

Only 17 of the 2,352 fruit picked and recorded (0.72%) developed symptoms of DBD.

#### *Occurrence of DBD in relation to recorded characteristics*

Of the fruit that exhibited symptoms of DBD:

- 47% occurred in fruit that were singular on the tree and 53% occurred in fruit that had 2 apples in the cluster
- 12% were found on the South sides of the trees, 18% on the East sides, 47% on the West sides and 24% on the North sides
- 47% were found in the mid section of the tree, 18% were found in the lower section of the tree and 35% were found in the upper part of the tree
- 53% occurred on the outside canopy of the tree and 47% occurred on the inside canopy of the tree
- 24% occurred in fruit arising from 2 year wood, 47% occurred in fruit arising from 3 year wood, 24% occurred in fruit arising from 4 year wood and 6% occurred in fruit arising from 5 year wood
- 24% occurred in fruit from clusters with a strong shoot emerging from the cluster and 76% occurred in fruit without the presence of a strong shoot arising from the cluster
- fruit density along the branch ranged from one fruit per 3.8cm of branch length to one fruit per 25.0cm of branch length
- fruit diameter ranged from 56mm to 68mm
- 0% occurred in fruit with no viable seeds, 35% occurred in fruit with one viable seed, 6% occurred in fruit with two viable seeds, 6% occurred in fruit with three viable seeds, 12% occurred in fruit with four viable seeds, 12% occurred in fruit with five viable seeds, 12% occurred in fruit with six viable seeds, 12% occurred in fruit with seven viable seeds and 6% occurred in fruit with eight viable seeds
- the average pressure was 4.25

It was observed that of the 17 fruit with DBD, 6 were found on one tree and 5 fruit were found on another tree, the other 6 fruit were found as 1 fruit on each of 6 trees. It was also observed that the occurrence of DBD appeared to be specific to particular branches and that branches with DBD fruit were commonly adjacent to each other.

Of the total fruit recorded:

- 51% were singular on the tree, 38% had 2 apples in the cluster, 11% had 3 apples in the cluster and 1% had 4 apples in a cluster
- 21% were found on the North sides of the trees, 27% on the East sides, 30% on the South sides and 22% on the West sides
- 12% were found at the top of the tree, 68% were found in the mid section of the tree and 21% were found in the lower section of the tree
- 50% occurred on the outside canopy of the tree and 50% occurred on the inside canopy of the tree
- 44% occurred on fruit arising from 2 year wood, 40% occurred on fruit arising from 3 year wood, 14% occurred on fruit arising from 4 year wood and 2 % occurred on fruit arising from 5 year wood
- 18% occurred in fruit from clusters with a strong shoot emerging from the cluster and 82% occurred in fruit without the presence of a strong shoot arising from the cluster
- fruit density along the branch ranged from one fruit per 1.1cm of branch length to one fruit per 100.0cm of branch length
- fruit diameter ranged from 37mm to 80mm
- 4% occurred in fruit with no viable seeds, 10% occurred in fruit with one viable seed, 13% occurred in fruit with two viable seeds, 11% occurred in fruit with three viable seeds, 11% occurred in fruit with four viable seeds, 12% occurred in fruit with five viable seeds, 11% occurred in fruit with six viable seeds, 10% occurred in fruit with seven viable seeds, 6% occurred in fruit with eight viable seeds, 4% occurred in fruit with nine viable seeds and 2% occurred in fruit with 10 viable seeds
- the average pressure was 4.43

As a whole sample, and as in HDC project TF 166c, fruit within the selected trees was either found singly or in clusters of two to five fruit, predominantly as one, two or three fruit. In the portion showing DBD, fruit was predominantly held singly or in clusters of two. Again, across the whole sample fruit was found around all sides of the tree but within the DBD sample the greater proportion of fruit was found on the East sides whereas in HDC project TF 166c most affected fruit was found on the North and West sides of the tree. This however is only a

fraction of fruit found on these sides of the tree and no recommendations for altered tree management can be drawn from this. The occurrence of DBD at differing heights in the canopy followed a similar pattern to total yield as did the pattern for age of wood and presence of a strong shoot arising from the fruit cluster. The range of fruit per length of branch was less for the DBD sample than for the whole sample but this is to be expected as it is a sub-sample from the whole population and this is the same for fruit diameter. There also appears to be no correlation between number of viable seeds and occurrence of DBD as the proportion of number of seeds follows that of the whole sample.

In the case of all of the above results 5.25% of the sample from Priory Farm developed DBD whereas in the previous year for the same site only 0.74% of the sample showed any signs of DBD and for Monks Farm, 0.72% of the sample developed DBD, a figure lower than in previous years.

However it is worth noting that again as in HDC project TF 166c most of the fruit with DBD occurred on relatively few of the trees and it was also observed that the occurrence of DBD appeared to be specific to particular branches and that branches with DBD fruit were commonly adjacent to each other.

## **Conclusions**

The results show no definite links between the occurrence of DBD and any of the measured characteristics and hence no practical grower recommendations can be made from these results.

However as in HDC project TF 166c, the occurrence of DBD centred around specific trees although not always the same trees year on year. Also occurrence within trees was again typically localised to specific points within the canopy, often on the same or adjacent branch, but not linked to the measured parameters.

## **References**

HDC Project TF 166c: Final Report

### Appendix I: Characteristics of Fruit Showing DBD, Farm A (Lee Priory Farm)

Apple Number	Tree Number	Number of Apples in cluster	Aspect	Canopy: Top/Middle/Bottom	Canopy: Outside/Inside	Age of wood	Shoot from cluster	Branch length	Fruit per cm of branch length	Fruit diameter	DBD Y/N	viable seeds
1-1028	1-10	1/2/3/	N/E/S/W	T/M/B	O/I	1/2/3/	Y/N	cm				
5	1	3	N	M	O	3	N	154	19.25	64	Y	0
6	1	3	N	M	O	3	N	154	19.25	61	Y	0
7	1	1	N	M	O	2	N	154	19.25	65	Y	0
8	1	1	N	M	O	2	N	154	19.25	64	Y	0
9	1	1	N	M	O	2	N	154	19.25	62	Y	1
15	1	2	N	M	I	3	Y	77	38.50	68	Y	4
16	1	2	N	M	I	3	Y	77	38.50	64	Y	7
34	1	1	E	M	O	3	N	100	14.29	71	Y	4
41	1	1	E	M	I	2	N	125	31.25	72	Y	7
42	1	1	E	M	I	2	N	125	31.25	67	Y	1
53	1	1	E	M	O	4	Y	50	10.00	80	Y	6
90	1	1	S	M	O	3	N	150	5.00	68	Y	2
133	1	1	W	M	O	4	N	130	18.57	71	Y	6
150	1	1	W	M	O	4	N	110	15.71	64	Y	0
157	1	1	W	M	O	5	N	170	8.10	52	Y	1
158	1	1	W	M	O	5	N	170	8.10	55	Y	0
160	1	2	W	M	O	5	N	170	8.10	51	Y	0
161	1	2	W	M	O	5	N	170	8.10	50	Y	0
162	1	2	W	M	O	3	N	170	8.10	59	Y	1
163	1	2	W	M	O	3	N	170	8.10	62	Y	1
177	1	2	W	B	I	2	N	170	8.10	78	Y	2
201	2	2	N	M	O	3	N	130	9.29	59	Y	4
227	2	2	E	M	O	3	N	190	7.60	70	Y	2
230	2	1	E	M	O	3	N	190	7.60	75	Y	2
235	2	1	E	M	O	2	N	190	7.60	62	Y	1
238	2	1	E	M	O	4	Y	190	7.60	64	Y	2

Apple Number	Tree Number	Number of Apples in cluster	Aspect	Canopy: Top/ Middle/ Bottom	Canopy: Outside/ Inside	Age of wood	Shoot from cluster	Branch length	Fruit per cm of branch length	Fruit diameter	DBD Y/N	viable seeds
1-1028	1-10	1/2/3/	N/E/S/W	T/M/B	O/I	1/2/3/	Y/N	cm				
240	2	1	E	M	O	2	N	190	7.60	80	Y	2
242	2	1	E	M	O	2	N	190	7.60	74	Y	1
347	2	1	W	M	I	2	N	130	14.44	59	Y	0
382	3	2	E	M	I	2	N	90	10.00	68	Y	4
396	3	1	E	B	I	2	N	160	80.00	71	Y	2
577	5	2	W	M	I	3	N	140	9.33	62	Y	3
612	5	2	W	M	O	3	Y	170	42.50	86	Y	3
637	6	1	E	M	I	3	N	130	13.00	74	Y	3
722	7	2	E	M	I	2	Y	140	23.33	85	Y	5
723	7	2	E	M	I	2	Y	140	23.33	80	Y	4
745	7	2	E	M	O	3	N	180	6.92	76	Y	4
747	7	2	E	M	O	3	N	180	6.92	64	Y	1
748	7	2	E	M	O	3	N	180	6.92	72	Y	5
753	7	2	E	M	I	3	Y	180	6.92	78	Y	3
755	7	1	E	M	I	3	N	180	6.92	75	Y	1
758	7	3	E	B	I	3	N	180	6.92	65	Y	2
769	7	2	E	B	I	3	N	130	6.19	70	Y	9
774	7	2	E	B	I	3	N	130	6.19	66	Y	3
784	7	2	E	B	I	2	N	130	6.19	62	Y	5
800	7	1	S	M	I	2	N	110	36.67	68	Y	3
801	7	1	S	M	I	2	N	110	36.67	58	Y	1
831	8	1	N	M	I	2	N	120	7.50	74	Y	0
865	8	2	S	M	O	2	N	160	9.41	74	Y	6
927	9	1	S	M	O	4	N	170	13.08	68	Y	2
1002	10	3	W	M	I	3	N	140	23.33	64	Y	0
1004	10	3	W	M	I	3	N	140	23.33	62	Y	1
1007	10	1	W	M	I	4	Y	190	95.00	73	Y	1
1010	10	2	N	M	I	2	N	170	17.00	65	Y	8



## Appendix II: Characteristics of Fruit Showing DBD, Farm B (Monks Farm)

Apple Number	Tree Number	Number of apples in cluster	Aspect	Canopy: Top/Middle/Bottom	Canopy: Outside/Inside	Age of wood	Shoot from cluster	Branch length	Fruit per cm of branch length	Fruit diameter	DBD Y/N	viable seeds
1-2353	1-20	1/2/3/	N/E/S/W	T/M/B	O/I	1/2/3/	Y/N	cm				
89	1	1	N	T	O	3	Y	110	7.3	68.0	Y	1
148	2	1	N	T	I	2	N	30	7.5	67.0	Y	5
299	4	2	S	B	O	2	Y	160	4.2	64.0	Y	3
848	7	2	W	M	I	4	N	80	8.0	59.0	Y	1
1102	9	1	S	T	I	3	N	80	3.8	57.0	Y	1
1156	9	1	E	M	O	3	N	140	7.8	62.0	Y	2
1166	9	1	E	T	O	2	Y	50	25.0	61.0	Y	1
1181	9	1	N	T	I	3	N	120	12.0	65.0	Y	5
1188	9	1	N	T	O	4	N	90	8.2	66.0	Y	6
1296	10	2	E	M	I	3	Y	160	8.0	65.0	Y	6
1418	12	2	W	M	I	2	N	20	6.7	57.0	Y	8
1914	16	2	W	M	I	5	N	110	7.3	56.0	Y	1
1920	16	2	W	M	O	4	N	110	7.3	62.0	Y	7
1921	16	2	W	M	O	4	N	110	7.3	57.0	Y	7
1926	16	2	W	B	O	3	N	110	7.3	58.0	Y	1
1927	16	2	W	B	O	3	N	110	7.3	63.0	Y	4
1937	16	1	W	M	I	3	N	20	4.0	56.0	Y	4