Title	Investigating diffuse browning disorder (DBD) in stored Cox apples
Project number:	TF 139
Report:	Annual report, June 2003
Previous report	None
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Location of project	HRI East Malling
Project coordinator:	N/a
Date project commenced:	1 April 2002
Date completion due:	31 May 2005
Key words:	Apple, Cox, diffuse browning disorder, DBD, storage, CA storage

Grower Summary

Background and objectives

A hitherto rarely seen storage disorder of Cox apples, diffuse browning disorder (DBD), caused significant losses during the 2000/2001 storage season. The disorder is referred to colloquially as 'Boggy Bank disorder' after the first reported occurrence in a Cox orchard of that name. Others refer to the disorder as 'Gorgate syndrome'. First signs are a localised browning of the flesh predominantly towards the calyx end of the fruit. The disorder progresses around the fruit and may progress to the inner cortex.

In the 2000 Cox crop, diffuse browning disorder (DBD) was first seen in fruit removed from CA storage in early November. There were no reported cases of the DBD in air-stored Cox. The disorder often progressed significantly in fruit removed from store and in the worst cases the fruit became unmarketable in a short time.

Objective

The purpose of the project is to identify the factors that induce diffuse browning disorder (DBD) in Cox apples and to suggest measures that will prevent development of the disorder in CA-stored fruit.

Summary of results and main conclusions (2002/2003)

<u>When does DBD become apparent?</u>

Although DBD was present in a few apples removed from store in November 2002 the major increase in its development occurred in fruit removed from store in December and subjected to a further 7 days of air storage at 3, 10 or 20°C. During this 7 day period the average incidence of DBD increased from 2% to 10-15%. This emphasises the importance of ensuring that samples removed from commercial stores for monitoring purposes should be examined after a 7-day period in air in order to detect the first symptoms of DBD. The presence of DBD in any monitoring samples should initiate immediate marketing of the fruit.

<u>Does store oxygen concentration influence the development of the disorder?</u>

DBD developed earlier in the traditional CA regime of 2%O_2 (<1%CO_2) than in 'ultra-low oxygen' conditions of 1.2%O_2 (<1%CO_2). However, by February there was no effect of store oxygen level on the percentage of fruit affected by DBD but CA-stored fruit were more affected than air-stored fruit.

<u>Does store temperature influence the development of the disorder?</u>

Storage at a temperature (1.5°C) below that recommended (3.5°C) aggravated DBD. It is advisable that a minimum temperature of 4°C is adopted for fruit in commercial CA stores containing fruit from orchards with a history of DBD. The condition of the fruit should be monitored rigorously and the fruit sold early. For short-term air storage the recommended storage temperature of 1.5°C can be used regardless of DBD risk as these fruits should be marketed in October i.e. before DBD is likely to develop in the fruit. The temperature of fruit in CA stores containing fruit from orchards with no history of DBD should be maintained at the correct temperature of 3.5-4°C.

Does shelf-life temperature influence the development of the disorder?

Shelf-life temperature had little effect on the development of DBD. Clearly it is the transfer from CA to air storage that exaggerates the problem particularly in the early months of storage. At harvest growers should ensure that they make provision for sufficient numbers of samples for monitoring the quality of fruit in store including a 7-day period in air after removal from CA storage. It is advisable to keep the fruit 'shelf-life' samples at room temperature (18-20°C). Although DBD development was not generally affected by temperature during 'shelf-life', a temperature of 18-20°C is appropriate to monitor changes in other quality attributes such as firmness and the development of other disorders such as bitter pit and breakdown.

What is the extent of variation in the incidence of the disorder due to orchard site?

The 3 orchards used in the study had a history of DBD in commercial CA storage. The development of DBD in fruit from these orchards in our experimental stores confirms that the problem is site-related. Overall the 2 Kent sites in the study developed similar amounts of DBD and were affected more than fruit from the Essex site.

Action points for growers

- Where fruit from orchards with a history of diffuse browning disorder (DBD) are stored in CA they should be kept at a minimum temperature of 4°C and marketed early.
- Growers can use either 1.2 or 2%O_2 (<1%CO_2) for the storage of Cox regardless of DBD risk. It is not known whether storage in 5%CO_2 + 3%O_2 would affect the development of DBD.
- Growers should be aware of perceived risk of DBD reported by advisory groups.
- Where there is no perceived risk of DBD it is important to adhere rigidly to minimum recommended storage temperatures (3.5-4°C) for CA storage .
- Regardless of DBD risk fruit stored in air should be kept at 1.5°C and sold by mid-October.
- Monitor fruit rigorously. Examine calyx region of fruit carefully, repeat examination after a further 7 days at room temperature (18-20°C).
- Detection of DBD should prompt immediate marketing.

Further work (2003-2005)

Work in 2003-2005 will test whether light levels are directly implicated in DBD development. In addition, the effects of 'Cultar' will be investigated.

Science Section

Background

A hitherto rarely seen storage disorder of Cox apples caused significant losses during the 2000/2001 storage season. The disorder is referred to colloquially as 'Boggy Bank disorder' after the first reported occurrence in a Cox orchard of that name. Others refer to the disorder as 'Gorgate syndrome'. First signs are a localised browning of the flesh predominantly towards the calyx end of the fruit. The disorder progresses around the fruit and may progress to the inner cortex. In the 2000 Cox crop the disorder was first seen in fruit removed from CA storage in early November. There were no reported cases of the diffuse browning disorder (DBD) in air-stored Cox. The disorder often progressed significantly in fruit removed from store and in the worst cases the fruit became unmarketable in a short time.

A meeting of advisory and producer groups was held in July 2001 to review the problem and as a result some definitive advice was published (Grower, September 13 2001) on the future prediction and management of the problem. At the time it appeared that the disorder was associated with unusually dull weather conditions in 2000 and it was considered improbable that the disorder would recur to a significant level for some time. However, contrary to expectations, the disorder occurred to a significant level in some consignments of Cox from the 2001 crop. It appears that the occurrence of diffuse browning disorder (DBD) in the 2001 crop of Cox has been significantly less than in the previous year's crop and in many cases rigorous store monitoring and prompt decisions to market affected fruit has minimised commercial losses.

Objectives for year 1 of the project (2002/2003)

The work programme in the first year of the project was designed to answer a number of key questions about the development of DBD in stored Cox:

- When does DBD become apparent?
- Does store oxygen concentration influence the development of the disorder?
- Does store temperature influence the development of the disorder?
- Does shelf-life temperature influence the development of the disorder?
- What is the extent of variation in the incidence of the disorder due to orchard site?

Although it was unlikely that the work done in the first year of the project would identify the underlying cause of the problem, answers to these questions were likely to influence the way the storage of fruit from 'high-risk' orchards are managed and commercial losses prevented.

Materials & Methods

Fruit was obtained from 3 ‘high-risk’ orchards in East Kent (Reference TC), West Kent (Reference BT) and Essex (Reference FH). Samples were taken during the optimum ‘Window’ for long-term storage as advised by the Quality Fruit Group (TC 11 September 2002, BT 6 September 2002 and FH 10 September 2002). Samples were taken for storage and for assessment of fruit maturity and for mineral analysis.

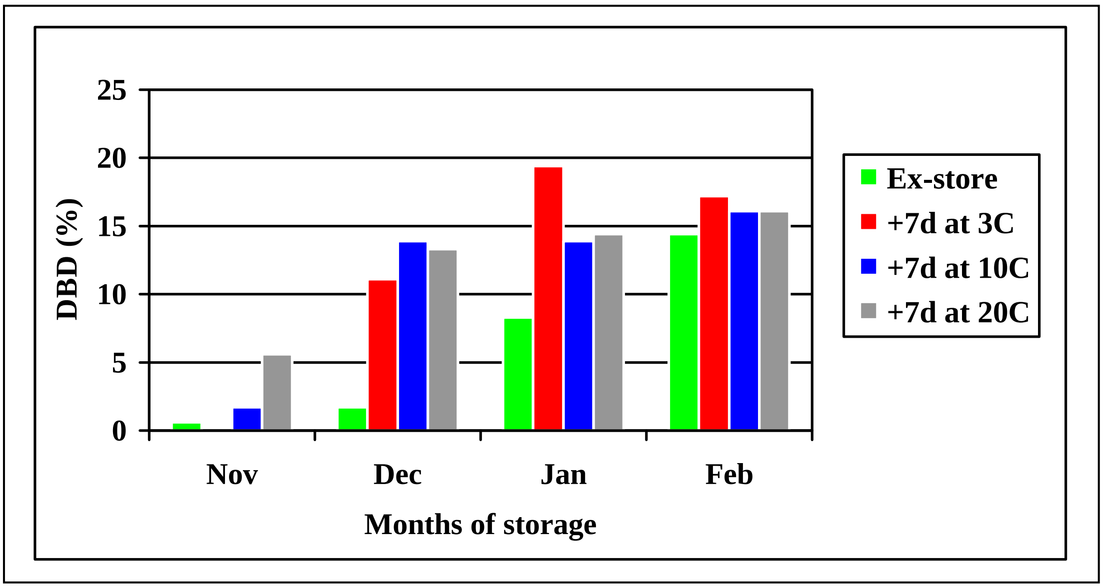
Fruit was stored in 3 concentrations of oxygen (21% (air), 2% and 1.2% O_2) at 2 temperatures (1.5-2 and 3.5-4°C). Carbon dioxide concentrations were maintained below 1% using hydrated lime scrubbers. Fruit samples were removed in the middle of November 2002, December 2002, January 2003 and February 2003 and examined immediately and after 7 days at 3, 10 and 20°C.

Results & Discussion

<u>1. Time course for DBD development</u>

There was little indication of the disorder in fruit removed from storage in mid-November 2002 and examined immediately. Figure 1 indicates the average incidence of the disorder in fruit from the 3 orchards in all 6 storage conditions. Slightly more DBD was found in fruit subjected to a 7-day simulated marketing period (SMP) particularly at higher temperatures. The first indications of DBD in experimental fruit coincided with the first detection of symptoms in samples used for monitoring purposes in commercial stores. The importance of subjecting fruit to a SMP is indicated by the results presented in Figure 1. In mid-December 2002 the incidence of DBD in fruit examined immediately ex-store was low (2%) but increased to 10-15% in just 7 days after removal from store. By February 2003, the ex-store incidence was similar to the ex-SMP incidence, which suggests that the disorder had reached a maximum level of around 15%. The temperature used for the SMP did not seem important at this stage.

Figure 1 DBD development in 2002/2003 - averages for all conditions

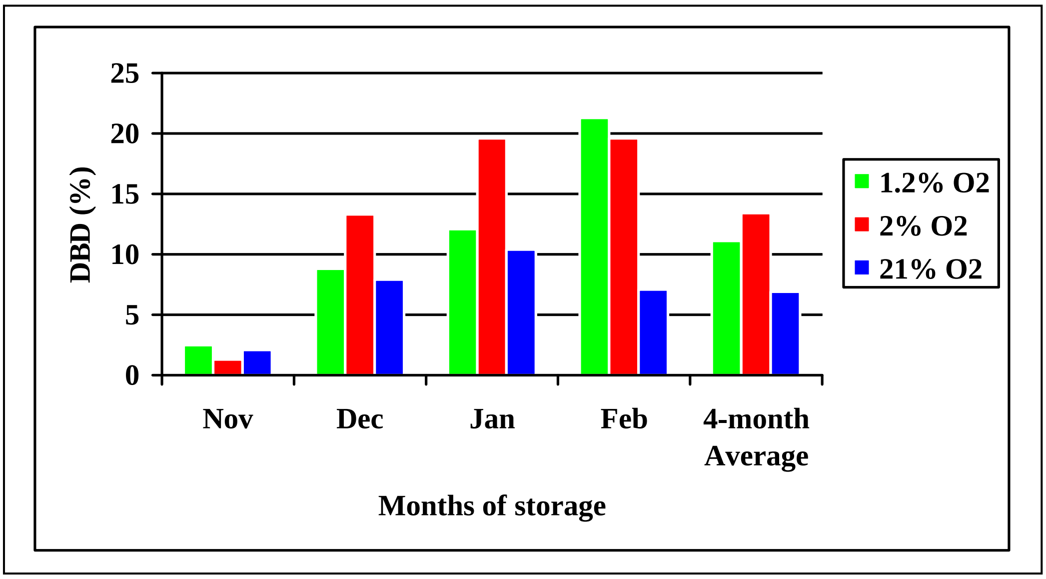


2. Influence of store oxygen concentration on the development of DBD

Contrary to popular belief, DBD did develop in air-stored fruit albeit when stored beyond the period currently recommended (mid October). Clearly there could be confusion between the early signs of senescent breakdown and those of DBD. However symptoms were sufficiently distinct early in storage prior to the development of a significant amount of senescent breakdown. The development of DBD in air storage is rather academic in that the quality of the fruit becomes unacceptable by the time DBD begins to develop. However it was interesting to note that the fruit at risk from DBD was also highly susceptible to senescent breakdown.

In the early months of CA storage there was an indication that DBD developed to a greater extent in the higher oxygen regime. In effect it appeared that DBD developed earlier in 2% O_2 than in 1.2% O_2. It is comforting to the UK industry that the most popular CA regime for Cox i.e. 1.2% O_2, does not worsen DBD development since this regime is necessary for maintaining the overall quality of the fruit during the marketing period.

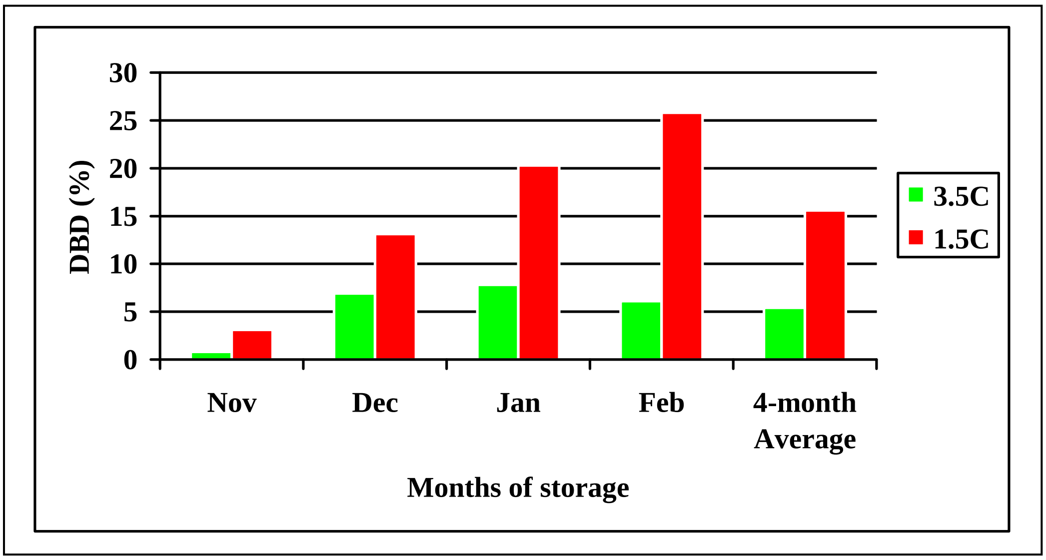
Figure 2 Overall effect of store oxygen concentration (%O_2) on DBD development in 2002/2003



3. Influence of store temperature on the development of DBD

The incidence of DBD was increased markedly by the lower storage temperature. Again this is of slightly academic interest in that growers are unlikely to store Cox apples below the recommended storage temperature of 3.5-4^{o}C. However the result will serve to strengthen advice to store Cox from orchards with a history of DBD at a minimum temperature of 4^{o}C. The data suggests that DBD may result from low temperature stress. This is particularly interesting in view of the possible association of DBD susceptibility with dull summers which are often associated with low temperature storage disorders such as core flush.

Figure 3 Overall effect of store temperature on DBD development in 2002/2003

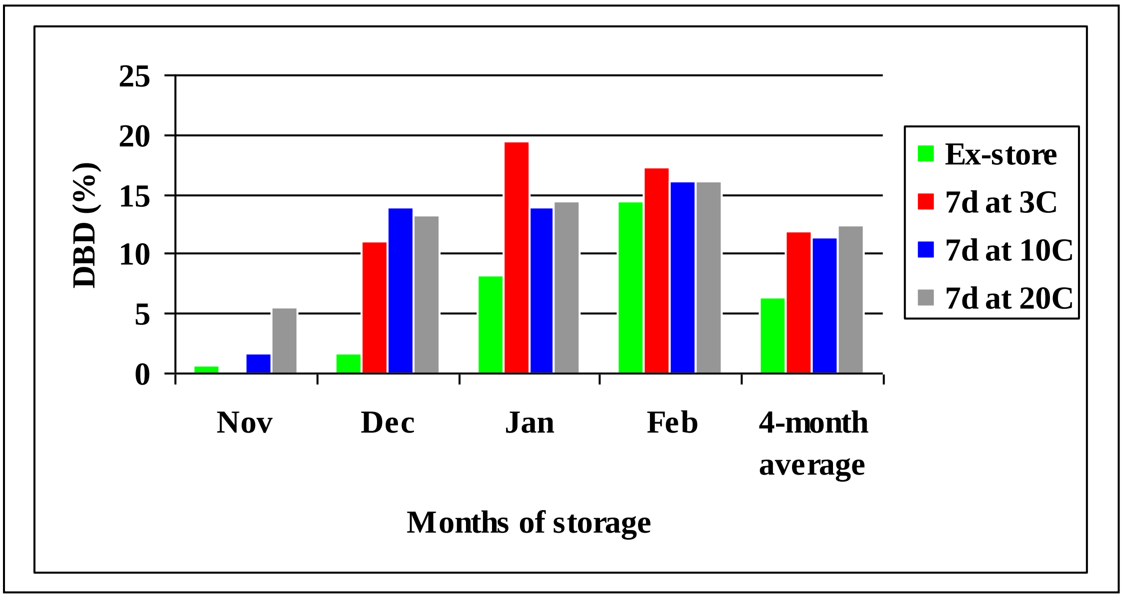


4. The influence of post-storage temperature on the development of DBD

As mentioned previously the incidence of DBD increased markedly in fruit removed from CA storage (see Figure 4). However the disorder continued to develop in fruit kept in cold or CA storage until an apparent maximum incidence was reached in mid February. This suggests that fruits are harvested with a certain potential to develop DBD much like bitter pit and other calcium-related disorders. Thus storage conditions serve to modify the expression of that potential to develop problems.

DBD did not show a response to storage conditions that would normally be expected in the case of bitter pit. Lower storage temperatures and lower levels of oxygen in the storage atmosphere would normally retard the latter. It is clearly imperative that samples used for monitoring the quality of fruit in commercial stores are subjected to a simulated marketing period of at least 7 days in order to detect the first signs of DBD. Clearly the first observation of symptoms should initiate immediate marketing of the fruit.

Figure 4 Effect of post-storage temperature on DBD in 2002/2003

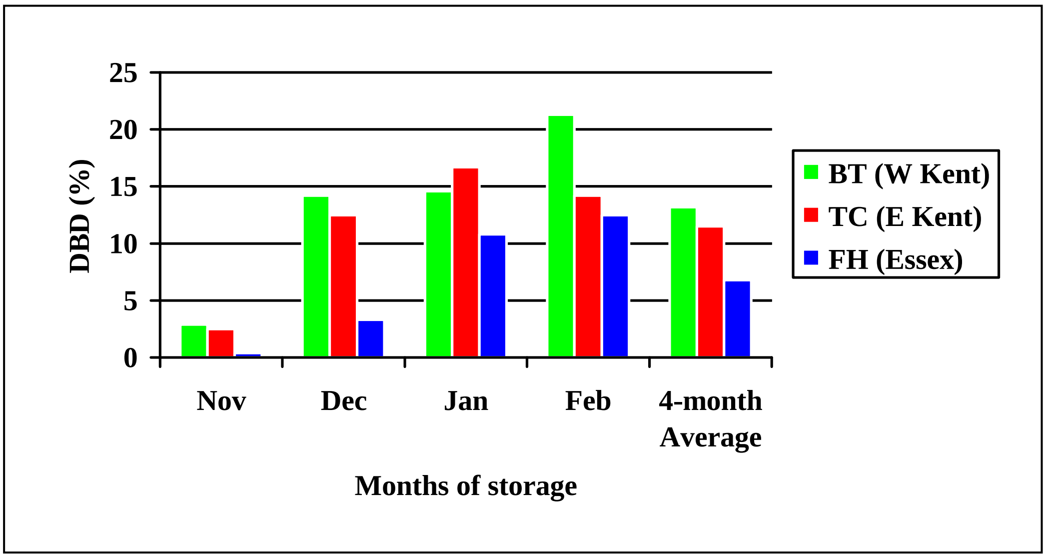


5. Variation in the incidence of the disorder due to orchard site

In order to make progress with the investigation into the cause of DBD in stored Cox apples it is necessary to identify sites that produce susceptible fruits consistently. It was fortunate that the orchards chosen for the 2002 study developed sufficiently high incidences of the disorder to allow the effects of post harvest treatment to be determined.

Overall fruit from the West Kent orchard were most affected by DBD (13.2%) but fruit from the East Kent orchard was only slightly less affected (11.5%) and those from the Essex orchard were least affected (6.8%). If February data is an indication of the full potential of the problem then average incidences for the West Kent, East Kent and Essex orchards were 21.3, 14.2 and 12.5%. DBD development was slower initially in the fruit from Essex. It is intended to continue using these orchards in years 2 and 3 of the project.

Figure 5 Effect of orchard site on DBD development in 2002/2003



6. The development of diffuse browning disorder in relation to the development of other disorders

It was to be expected that fruit stored in air for extended periods would develop senescent breakdown and those stored in CA at a temperature below that recommended would develop low temperature breakdown. It was interesting to note that the development of these disorders occurred in parallel and the results suggest that DBD may occur in apples that are predisposed to senescent or low temperature breakdown. Senescent breakdown in air-stored fruit occurred early and to a greater extent than predicted on the basis of harvest date and mineral composition. Fruit with less than 4 mg $100g^{-1}$ of calcium are more susceptible to senescent breakdown but analysis of bulk samples of fruit at harvest revealed that only site TC was marginally below this level (Table 1). With the exception of TC the analysis of fruit at harvest indicated a satisfactory potential for CA storage. There may be a link between a heightened susceptibility of fruit to senescent breakdown in air storage and the development of DBD in CA storage. There was no association between DBD susceptibility and mineral composition of individual apples (data not presented). Average values of particular mineral nutrients were similar for affected and non-affected fruit. Any possible association of DBD with calcium dependent disorders such as bitter pit can be ruled out in view of the higher average concentration of calcium in affected fruit (Table 2).

Figure 6 Development of DBD in relation to other disorders

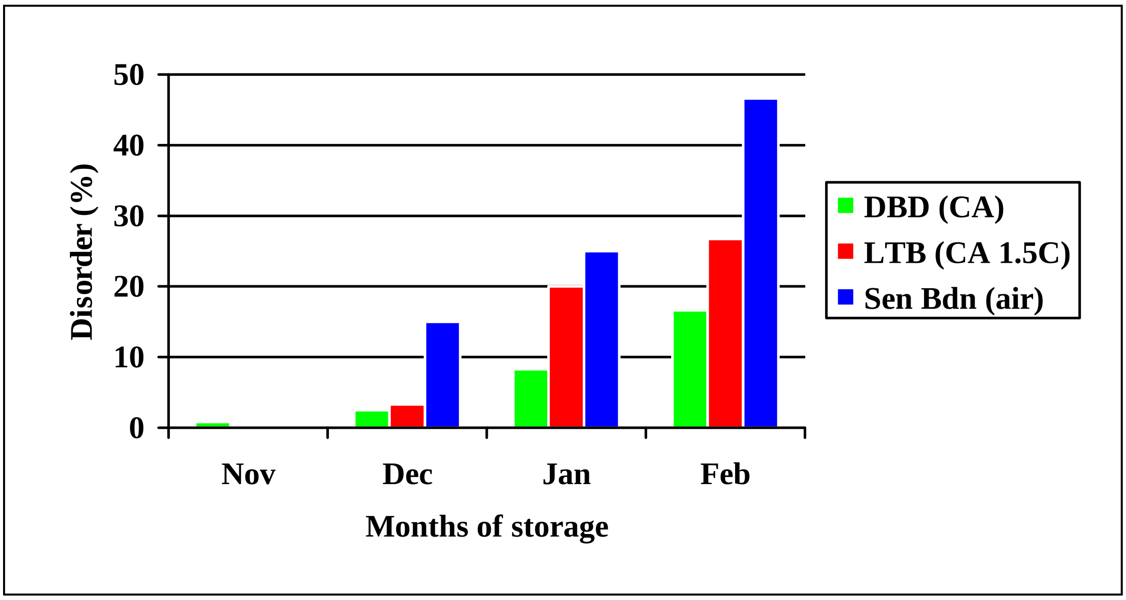


Table 1. Mineral analysis (mg $100g^{-1}$) of bulk samples of fruit at harvest and standards for Cox stored in CA conditions of 1.2% O_2, <1% CO_2 at 3.5-4ºC.

	Mean Fruit Wt (g)	N	P	K	Ca	Mg	K/Ca
FH	146.0	52.5	11.2	125	4.3	5.6	29.1
TC	160.2	71.5	11.1	128	3.9	6.1	33.1
BT	147.4	72.5	12.5	132	4.5	6.3	29.6
Standards for CA		50-70	11 min	130-150	4.5	5	35

Table 2. Mineral analysis (mg $100g^{-1}$) of individual apples affected or unaffected by DBD. Results are the average of 25 affected fruit and 22 unaffected fruits.

	Mean Fruit Wt (g)	N	P	K	Ca	Mg	B	Cu	Mn	Zn
Yes	140.6	78.6	12.5	140.2	5.4	6.1	0.46	0.06	0.04	0.03
No	152.4	77.1	12.2	137.9	4.4	5.9	0.42	0.06	0.04	0.03