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PROJECT REPORT
No IAS 30904 (SP71)

Storage Rots

Undertaken for APRC

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Authentication

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

A. M. Berrie .... A M Berrie
Signature

Date 18-3-97

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Effects of fungicide sprays at blossom time on *Botrytis* rot of stored pears and apples

Summary

In large plot replicated trials in an orchard of pear cv Conference, sprays of Bavistin, or Bavistin + Captan or Thianosan applied during blossom and petal fall had no significant effect on the development of *Botrytis* rot in store. In similar trials conducted on apple cv Cox, sprays of Bavistin or Bavistin + Captan or Ronilan also had no effect on the development of *Botrytis* rot in store. However these treatments did significantly reduce the incidence of *Nectria* fruit rot in store at one site.

Orchard testing of NECTEM™, a warning system for apple canker and *Nectria* fruit rot

Summary

In trials over two seasons (1994-96) at three orchard sites, the NECTEM model successfully predicted *Nectria* fruit rot and leaf scar infection on Cox, Spartan and Ida Red apples. Prediction of canker development on pruning cuts was less reliable.

Effect of fungicide sprays at blossom time on *Botrytis* rot of stored pears and apples

Introduction

In the UK *Botrytis cinerea* is the most important cause of rotting in stored Conference pears, accounting for over 70 per cent of rotting (Berrie, 1989) and causing significant losses in pears from most orchards in most seasons in the absence of fungicide treatment. Most of the rotting appears to be secondary, originating from damage to pears at harvest, although some *Botrytis* rot does occur at the stalk and calyx ends of the fruit, indicating a possible origin from orchard infections. The use of post-harvest fungicide drenches, initially of benzinidazole fungicides and subsequently of dicarboximide fungicides, has given adequate control of *Botrytis* rot in stored pears, however with increased consumer concerns over their use, the need to exploit alternative methods of control has become important.

Botrytis rot in UK Cox apples was considered of minor importance compared to rotting due to *Nectria galligena*, *Gloeosporium* spp, *Phytophthora syringae* and *Monilinia fructigena* in a survey conducted in the 1960s (Preece, 1967). However, the significance of *Botrytis* rot in Cox has steadily increased over the past few seasons until it has become one of the most important causes of rotting (Berrie, 1994). Two distinct types of *Botrytis* rot are apparent on Cox - secondary infection associated with damage, and primary infection arising at the fruit calyx possibly from previous orchard infection at blossom time. As with pears there is a need to rationalise the use of post-harvest fungicides to control rotting in stored apples. Various approaches are being explored, one of which is the development of a system of rot risk whereby the risk of rotting pre-harvest can be assessed and hence the need for treatment. The development of this system has been hampered by the lack of information on the biology and epidemiology of *Botrytis* rot on apples. This is currently being addressed in a MAFF-funded project (HH1903STF).

Botrytis cinerea is the main cause of fruit losses in most soft fruit crops. In strawberry, raspberries and blackcurrants the importance of blossom infection to the subsequent development of rotting in the mature fruit has been established (Williamson and McNicol, 1986). Infection of apple blossom and calyx-end rot have also been recognised in other apple cultivars (Tronsmo and Raa, 1977; Tronsmo *et al.*, 1977) but this was considered unimportant in the epidemiology of the post-harvest rot (Rosenberger, 1990). However, the observation of *Botrytis* rot symptoms in Cox apples and the preliminary results from the MAFF-funded study would suggest that flower infection was significant in relation to subsequent rot development in store. In pears the significance of flower infection in the subsequent development of *Botrytis* rot in store is less clear, although elsewhere the importance has been established for other pear cultivars (Combrink *et al.*, 1983). In other studies (Berrie and Luton, 1996) fungicide sprays applied to Cox apples at petal fall had no effect on the subsequent development of *Botrytis* rot in store. The timing of sprays in these trials may have been too late.

The purpose of the work described here was to look at the effect of fungicide sprays applied to Cox apples and Conference pears, during blossom and petal fall, on the subsequent development of *Botrytis* rot in store.

1 Objective

To examine the effect of fungicide sprays applied at blossom time on subsequent development and control of *Botrytis* rot in stored apples cv Cox and pears cv Conference.

2 Materials and Methods

2.1 General

Apple cv Cox and pear cv Conference orchards were chosen with a known history of *Botrytis* rot. In large plot replicated trials over two years fungicide sprays were applied during and after blossom. Fruit was harvested into bulk bins and stored. The incidence of *Botrytis* rot was assessed post storage when the fruit was marketed.

2.2 Pear

2.2.1 Site/Orchard

The same orchard site was used in both years. Site:- Orchard number 1, Paynes Farms Ltd, Swanton Farm, Bicknor. The orchard consisted of cv Conference with cv Williams planted 1 in 9 as pollinators.

2.2.2 Trial design/Plot size

The trial was designed as a fully randomised complete block design, with each treatment replicated seven times. Each plot consisted of eight rows of 19-25 pear trees. The middle four rows of each plot were treated and used for assessments. The same plots were retained in years one and two.

2.2.3 Treatments

Fungicide treatments applied in years one and two and spray timings are shown in Tables 1 and 2. Details of the fungicides used are shown in Table 4. Sprays were applied at 500 litres/ha using a tractor-trailed orchard air blast sprayer. Treatments were applied in addition to the normal pesticide sprays applied for control of scab, mildew and insect pests.

2.2.4 Harvest

At harvest fruit was picked from the centre four rows into bulk bins, at least three bins/plot depending on the size of the crop. Bins treated with a fungicide post-harvest or untreated were stored from each plot. A sample of 20 pear fruits were taken at random at harvest and checked for sugar content using a refractometer (Bellingham and Stanley Ltd). Fruit was stored in a commercial pear store in air at -1.5°C. After storage fruit was graded and the rots removed. The rots were then weighed and identified.

Table 1 **Fungicide treatment applied to pears and apples in 1994**

Treatment	Fungicide product	Product rate/ha	Number* of sprays	Timing
A	Untreated	-	-	-
B	Bavistin	1.1 kg	3 or 4	First flower + 7 days petal fall + 7 days
C	Bavistin + Captan	1.1 kg) + 3.3 kg)	3 or 4	First flower + 7 days petal fall + 7 days

* Number of sprays applied will depend on the length of the blossom period

Table 2 **Fungicide treatment applied to pears in 1995**

Treatment	Fungicide product	Product rate/ha	Number* of sprays	Timing
A	Untreated	-	0	-
B	Unicrop Thianosan	5.6 kg	3 or 4	First flower + 7 days petal fall + 7 days
C	Bavistin + Captan	1.1 kg) + 3.3 kg)	3 or 4	First flower + 7 days petal fall + 7 days

* Number of sprays applied will depend on the length of the blossom period

2.2.5 <u>Assessments</u>

a Orchard

In 1994 after petal fall 30 set fruit and 30 aborted fruit (approximately one/tree) were sampled from the centre four rows of each plot. These were surface sterilised in sodium hypochlorite for one minute and then incubated in damp chambers at ambient temperature. After five days the fruitlets were assessed for *Botrytis* sporulation and rot incidence. In 1995 after petal fall five fruitlet trusses were sampled per plot from the centre four rows. These were incubated in damp chambers at ambient temperature and assessed for the incidence of *Botrytis* sporulation.

In both 1994 and 1995 the fruit was also checked prior to harvest for visible eye rot and rot incidence.

b Post-store

The rots from each plot were weighed and identified.

2.2.6 <u>Statistical analysis</u>

The data was analysed using analysis of variance with significance at the 5% level.

2.3 **Apple**

2.3.1 <u>Site/Orchard</u>

1994 (Year 1) - Sawpits Orchard, Gallants Farm, East Farleigh. The orchard consisted of cv Cox on MM.106 with cv Ida Red planted 1 in 4 as the pollinator.

1995 (Year 2) - In 1995 two apple orchard sites were used as follows:

Site A - Perry Block D, Perry Farm, Wingham. The orchard consisted of cv Cox on MM.106 with cv Spartan and *Malus* as pollinators.

Site B - German Cox, Elverton Farm, Teynham. The orchard consisted of Cox on M.9 with cvs Ida Red, Spartan and *Malus* as pollinators.

2.3.2 <u>Trial design/Plot size</u>

1994

The trial was designed as a completely randomised design with each treatment replicated three times. Each plot consisted of three or four rows of mainly cv Cox with 24-50 trees/row. Only the centre two or three rows in each plot were treated and used for assessment.

1995

Site A - The trial was designed as a complete randomised block design with each treatment replicated six times. Each plot consisted of four rows of mainly cv Cox with 17-38 trees/row. In each plot any of the centre two rows were treated and used for assessment.

Site B - The trial was designed as a complete randomised block design with each treatment replicated four times. Each plot consisted of four rows of mainly cv Cox with approximately 55 trees/row. In each plot only the centre two rows were treated or used for assessments.

2.3.3 Treatments

Fungicide treatments applied and spray timings in years 1 and 2 are shown in Tables 1 and 3, and details of the fungicides used are given in Table 4.

Sprays were applied at 500 litres/ha using a tractor trailed orchard air blast sprayer. Treatments were applied in addition to the normal orchard spray programme for pest and disease control.

2.3.4 Harvest

At harvest fruit was picked from the centre rows into bulk bins, at least four bins/plot, two bins being treated with a fungicide post-harvest and two remaining untreated. Fruit was stored in a commercial CA store (3.5°C, 1.5% O_2 and 5% CO_2). After storage the fruit was graded and the rots removed and assessed.

2.3.5 Assessments

a Orchard

After petal fall eight fruitlet trusses were sampled from each plot at trial site B in 1995 and incubated in the laboratory at ambient temperature for *Botrytis*. Observation on the incidence of *Botrytis* on fruitlets from *Malus* pollinators were also made at sites A and B in 1995. In 1994 and 1995 the fruit was assessed prior to harvest in August for dry eye rot and calyx necrosis on 20 fruits chosen at random on each of ten trees per plot.

b Post-store

The rots from each plot were weighed and identified.

2.3.6 Statistical analysis

The data was analysed using analysis of variance with significance at the 5% level.

Table 3 **Fungicide treatment applied to apples in 1995**

Treatment	Fungicide product	Product rate/ha	Number* of sprays	Timing
A	Untreated	-	0	-
B	Ronilan	1.5 l	2	First flower + 7 days later
	Bavistin	1.1 kg	2	Petal fall + 7 days later
C	Bavistin + Captan	1.1 kg + 3.3 kg	3 or 4	First flower + 7 days petal fall + 7 days later

* The number of sprays applied will depend on the length of the blossom period

Table 4 **Fungicide products used in the trials on apple and pear in 1994 and 1995**

Fungicide product	Active ingredient	Chemical manufacturer	Diseases controlled or part-controlled
Bavistin	50% carbendazim	BASF	Various including *Botrytis* (sensitive strain), scab, canker, storage rots
PP Captan 83	83% captan	Zeneca	Scab, canker, *Botrytis*, storage rots
Ronilan FL	500 g/l vinclozolin	BASF	*Botrytis*, blossom wilt
Unicrop Thianosan	80% thiram	Unicrop	*Botrytis*, scab, storage rots

3.0 Results

3.1 **Pear 1994**

3.1.1 General

Two sprays of Bavistin or Bavistin + Captan were applied during blossom (12.4 and 19.4) and two during petal fall (28.4 and 3.5). The trial was harvested on 19-20 September. Mean sugar content of pear fruits at harvest was 13.8%. In 1994 the crop was very light, therefore only two bins were picked per plot, and only one bin for some plots. Where two bins were picked, one was drenched in Rovral prior to storage and the other left untreated. Where only one bin was picked, this was left untreated. The trial was stored until 2.2.95.

3.1.2 Orchard assessment

The aborted and set fruitlets sampled in June developed rots after incubation. The incidence of rotting was significantly less (Table 5) on those fruitlets from plots treated with Bavistin + Captan. No *Botrytis* was detected on the fruitlets. Isolation of the rots onto Potato Dextrose Agar (PDA) indicated that most were caused by *Alternaria* spp or *Cladosporium* spp. No *Botrytis* rot was observed in the orchard prior to harvest.

3.1.3 Post-storage

The use of a Rovral post-harvest drench reduced total rotting by 50% (Table 6). Sprays of Bavistin + Captan reduced overall rotting, but use of Bavistin alone had no effect. *Botrytis cinerea* was the principal rot recorded in undrenched fruit (Table 7). Use of Rovral as a post-harvest drench reduced the incidence of *Botrytis* rot by above 90%. Sprays of Bavistin + Captan reduced both total *Botrytis* and primary *Botrytis* rots (calyx, stalk and complete *Botrytis* rots) compared to the untreated but this difference was not significant. The use of Bavistin alone did not reduce *Botrytis* rotting.

The other main cause of rotting was *Mucor* which accounted for above 10-20% of rotting in the undrenched and around 50% in the drenched fruit. Fungicide treatment does not control *Mucor* rot, but the use of a post-harvest fungicide serves as an effective means of spreading the rot. Hence the incidence of *Mucor* rot is usually higher in drenched fruit.

Other rots present included brown rot, *Potebniamyces* sp, *Penicillum*, *Gloeosporium* sp, *Fusarium* and *Alternaria*.

3.2 **Pear 1995**

3.2.1 General

Since Bavistin alone appeared to be ineffective, in 1995 this treatment was substituted by Thianosan at the same timings. In 1995 two sprays of Thianosan or Bavistin + Captan were applied during blossom and two during petal fall. The trial was harvested on 20-21

September. The mean sugar content of pear fruits at harvest was 14.5%. Three bins of fruit were picked per plot. One was left untreated and the other two drenched with Rovral prior to storage. The trial was stored until 24.4.96.

3.2.2 Orchard assessments

The incidence of *Botrytis* sporulation on incubated fruitlets sampled from the orchard were very low and detected only on three fruitlets from treatment C (Bavistin + Captan).

No *Botrytis* rot was observed in the orchard prior to harvest.

3.2.3 Post-harvest

The use of a post-harvest drench of Rovral reduced overall rotting by about 50-75% (Table 8). Sprays of either Thianosan or Bavistin + Captan did not reduce overall rotting compared to the untreated and appeared to actually increase the weight of rots (Table 8). The orchard spray treatments also failed to reduce either total *Botrytis* rot or primary *Botrytis* (Calyx rot, stalk rot and complete *Botrytis*), again tending to increase *Botrytis* incidence compared to the untreated.

The treatments applied had little effect on the incidence of the other causes of rotting. The principal rot species present were: brown rot, *Potebniamyces*, *Penicillum*, *Gloeosporium*, *Fusarium*, *Alternaria*, *Nectria* and a Basidiomycete.

3.3 Apple 1994

3.3.1 General

Two sprays of Bavistin or Bavistin + Captan were applied during blossom and two during petal fall. Unfortunately, the trial was harvested without our knowledge, so no data on post-harvest rotting was obtained.

3.3.2 Orchard assessment

The incidence of dry eye rot in the orchard in August was negligible. However necrosis of the calyx was common. the highest incidence of calyx necrosis (Table 10) was present in the untreated plot. Both Bavistin and Bavistin + Captan significantly reduced the incidence of calyx necrosis.

3.4 Apple 1995

3.4 Site A - Perry Farm

3.4.1 General

Two sprays of Ronilan or Bavistin + Captan were applied during blossom and two sprays of Bavistin or Bavistin + Captan applied during petal fall. Fruit was harvested on 11.9.95. Four bins were picked per plot. Two were drenched in Ridomilmbc prior to storage and two remained untreated. The fruit was graded from store on 18.1.96.

3.4.2 Orchard assessment

The incidence of dry eye rot in the orchard in August was negligible. The incidence of calyx necrosis was also low and showed no clear differences between treatments (Table 11).

The incidence of *Botrytis* sporulation in July on young fruitlets from the *Malus* pollinators was very low; *Botrytis* was observed sporulating on 12% of fruitlets from untreated plots, compared to 9.7% of fruitlets from Bavistin + Captan treated plots and 6% Ronilan treated plots.

3.4.3 Post-storage

The use of a post-harvest drench did not significantly reduce overall rotting (Table 12). However overall rotting was less in the fruit from plots treated during blossom.

Botrytis was the principal rot present, but neither orchard spray treatment reduced the level of overall *Botrytis* rot or primary *Botrytis* (calyx, stalk and complete rot). Actual levels of *Botrytis* may have been increased by the spray treatments.

The other principle rots present were *Nectria*, brown rot and *Penicillium*. The incidence of *Nectria* rot was significantly reduced by orchard sprays.

3.5 Apple 1995

3.5 Site B - Elverton Farm

3.5.1 General

Two sprays of Ronilan or Bavistin + Captan were applied during blossom and two sprays of Bavistin or Bavistin + Captan applied during petal fall. Fruit was harvested in September 1995. Up to four bins were picked per plot, two of which were drenched post-harvest with Ridomilmbc and the remaining two left untreated. Unfortunately, the fruit was graded in February without out knowledge. No data on rot incidence was therefore obtained.

3.5.2 Orchard assessment

The incidence of *Botrytis* sporulating on incubated fruitlets was very low. *Botrytis* was observed sporulating on the flower petal of one fruitlet from treatment B and C. None was observed on fruitlets from untreated plots. A low incidence of *Botrytis* was also observed on *Malus* fruitlets from untreated plots (6% of fruitlets) and plots treated with Bavistin + Captan (12% of fruitlets).

No dry eye rot was observed in the orchard during assessments in August. The incidence of calyx necrosis was highest in the plots which were unsprayed at blossom/petal fall time (Table 14).

4 Discussion

The sprays applied during blossom and petal fall were not effective in reducing the development of *Botrytis* rot in store in either apple or pear. In strawberries and raspberries, where the importance of blossom infection to the subsequent development of rotting in the mature fruit has been established (Williamson and McNicol, 1986), the application of fungicide protection during blossom is essential to the control of rotting. The failure to control subsequent rotting in these top fruit trials by similar timed sprays suggests that either the fungicides used were ineffective or that blossom infection is not important.

On pear the results from the MAFF-funded project indicate that while some rots occur at the calyx end of the fruit, most of the rotting is associated with damage which occurs near harvest. In both years of this trial 30-50% of the *Botrytis* rots were attributed to primary infection associated with the calyx or stalk, although it is not always easy to distinguish these from rots resulting from contact spread. The fungicides used in the trial - Captan and Thiram - give control of *Botrytis* but are not completely effective and though Bavistin is very effective in control of *Botrytis*, up to 70% of isolates from pear are resistant (Berrie, 1989; Berrie and Koomen, 1994). Thus the fungicides used may not have been very effective, but were the best available that could have been used in large scale trials. More effective products such as Ronilan or Elvaron are not cleared for use on pears and would have required crop destruction.

On apple most *Botrytis* rots originate at the fruit calyx indicating a clear association with flowering. In all three trials, orchard assessments in August showed an effect of treatment on the incidence of calyx necrosis, which may be associated with *Botrytis* infection, but could also be caused by other fungi such as *Alternaria* and *Cladosporium* which are equally prevalent during flowering. In the trial where rot data were obtained, however, this orchard effect was not carried through to rotting in store. The incidence of primary *Botrytis* rot (calyx, stalk and complete rot) was either the same in treated and untreated or increased in the treated (Ronilan sprayed). Reasons for the latter are not clear but may have been due to control of *Alternaria*, for which Ronilan is also effective, and reduced competition on the flower petal for *Botrytis*. Ronilan is very effective in control of *Botrytis* and though resistant isolates are known to occur in other crops, their incidence in apples and pears are very low (Berrie and Koomen, 1994). The failure to reduce storage *Botrytis* by the use of blossom sprays is therefore difficult to understand unless the timing of sprays is incorrect. Further studies on this aspect are required.

Although in the apple trials, blossom/petal fall sprays failed to reduce subsequent *Botrytis* rot in store, at site A in 1995, which also had significant *Nectria* canker infection in the orchard, the incidence of *Nectria* fruit rot was significantly reduced by these sprays. Since Ronilan is completely ineffective against *Nectria*, the sprays responsible for the reduction of *Nectria* fruit rot must have been the Bavistin + Captan applied at petal fall and seven days later. From the currently accepted view on the biology and epidemiology of *Nectria* on apple it is difficult to explain why sprays applied at this time should be effective. Further studies are needed since if the control achieved was consistent in subsequent years, treatment at this time would have obvious advantages over treatments applied nearer harvest.

5 Conclusions and Future work

1 The sprays applied during blossom and petal fall did not significantly reduce subsequent *Botrytis* rotting in store in apple and pear.

2 In pear this is most likely explained by the fact that most *Botrytis* originates from damage to fruit at or near harvest. In apple where blossom infection has been shown to be significant, the failure of blossom sprays to reduce subsequent rotting is difficult to explain. Further work is required to understand the epidemiology of this rot in apple and to examine the effect of sprays at other timings.

3 Sprays applied at petal fall in apple were effective in reducing the incidence of *Nectria* fruit rot in store. This trial should be repeated to see whether this is a seasonal effect.

Table 5 **Effect of fungicide sprays applied during blossom on rotting in aborted and set pear fruitlets in June (1994)**

Orchard treatment	Set fruitlets		Aborted fruitlets
	% fruits with no rot	% fruits totally rotted	% rotted
Untreated	4.7	29.6	81.2
Bavistin	1.9	44.8	87.2
Bavistin + Captan	13.3	12.6	48.2

Table 6 **Effect of fungicide sprays applied during blossom on subsequent rotting in stored Conference pears, treated and untreated post harvest with Rovral (1994/95) and assessed 2.2.95**

Orchard treatment	Post harvest drench Rovral	No post harvest drench
Untreated	17.2	34.6
Bavistin	13.4	30.7
Bavistin + Captan	9.0	24.6
S E D		

Table 7 **Effects of fungicide sprays applied during blossom on subsequent rotting in stored Conference pears, treated or untreated post-harvest with Rovral 1994/95, and assessed on 2.2.95. Mean number of rots/bin**

Orchard treatment	Total rots	Total *Botrytis*	Primary *Botrytis*	Brown rot	Poteb	Pen	Mucor	Gloeo	Fus	Alt	Total* other rots
Drenched											
Untreated	97.4	16.8	9.3	1.8	2.8	1.3	65.0	2.0	0.3	6.8	80.6
Bavistin	77.5	18.7	8.3	2.5	2.2	1.7	40.2	1.5	0	9.3	58.8
Bavistin + Captan	49.3	10.6	4.6	1.4	2.7	1.6	26.6	1.3	0.1	4.3	38.7
S E D											
Undrenched											
Untreated	192.6	121.6	45.9	1.1	6.0	1.7	24.1	15.7	1.3	20.3	70.9
Bavistin	175.7	137.0	50.7	0.9	6.3	2.1	17.6	8.4	0.6	2.4	38.7
Bavistin + Captan	137.0	85.4	30.9	1.0	4.1	3.0	30.0	6.6	1.4	3.9	51.6
S E D											

* includes other minor rots

Key Primary *Botrytis* = Calyx rot, stalk rot, completely rotted fruits; Poteb = *Potebniamyces*; Pen = *Penicillium*; Gloeo = *Gloeosporium*; Fus = *Fusarium*; Alt = *Alternaria*

Table 8 **Effects of fungicide sprays applied during blossom on subsequent rotting in stored Conference pears treated and untreated post-harvest with Rovral 1995/96, assessed 24.4.96**

	mean wt rots/bin kg	
Orchard treatment	Post-harvest drench	No post-harvest drench
Untreated	11.4	46.0
Thianosan	24.3	61.4
Bavistin + Captan	20.2	50.3

Table 9 **Effect of fungicide sprays applied during blossom on subsequent rotting in stored Conference pears, treated or untreated post-harvest with Rovral 1995/96, and assessed on 24.4.96**

Mean number of rots/bin

Orchard treatment	Total rots	Total *Botrytis*	Primary *Botrytis*	Brown rot	Poteb	Pen	Mucor	Gloeo	Fus	Alt	Nect	Basid	Total other rots
Drenched													
Untreated	65.7	26.4	16.5	4.5	2.2	2.6	13.6	5.1	0.3	4.4	4.1	0	39.3
Thianosan	130.3	57.2	32.0	1.8	2.3	5.1	33.4	12.8	1.6	6.3	5.0	0.3	73.2
Bavistin + Captan	104.9	66.2	36.2	0.8	1.5	3.3	16.7	2.3	0.8	5.9	1.4	3.1	38.7
S E D													
Undrenched													
Untreated	257.4	187.3	98.9	0.3	20.3	4.3	11.4	11.3	0.6	15.9	3.6	0.4	70.1
Thianosan	314.3	243.7	113.3	0.3	20.4	2.6	8.6	11.7	1.0	11.6	3.3	6.6	70.6
Bavistin + Captan	260.1	200.7	105.3	1.1	14.3	4.7	8.1	4.3	0.7	12.1	4.7	7.7	59.4
S E D													

Key Primary *Botrytis* = Calyx rot, stalk rot, completely rotted fruits; Poteb = *Potebniamyces*; Pen = *Penicillium*; Gloeo = *Gloeosporium*; Fus = *Fusarium*; Alt = *Alternaria*; Nect = *Nectria*; Basid = Basidiomycete

Table 10 **Effect of fungicide sprays applied during blossom on incidence of calyx necrosis/dry eye rot in Cox apples 1994 - Sawpits Cox, Gallants Farm**

Orchard treatment	% Calyx necrosis 18.8.94
Untreated	66.0
Bavistin	28.7
Bavistin + Captan	43.7

Table 11 **Incidence of calyx necrosis in Cox apples from plots treated or untreated with fungicide during blossom and petal fall - 24.8.95, Perry Farm (Site A)**

Orchard treatment	% Fruit with necrosis calyx
Untreated	14.5
Ronilan/Bavistin	12.0
Bavistin + Captan	8.0

Table 12 **Effect of fungicide sprays applied during blossom on subsequent rotting in stored Cox apples drenched and undrenched post-harvest with fungicide 1995/96. Perry Farm (Site A), Wingham, assessed 16.1.96**

	Mean wt rots/2 bins kg	
Orchard treatment	Post-harvest drench	No post-harvest drench
Untreated	12.8	13.6
Ronilan/Bavistin	7.3	10.1
Bavistin + Captan	7.5	6.0
S E D		

Table 13 **Effect of fungicide sprays applied during blossom on subsequent rotting in stored Cox apples, treated or untreated post-harvest 1995/96. Perry Farm, Wingham (Site A), assessed on 16.1.96**

Mean number of rots/2 bins

Orchard treatment	Total rots	Total *Botrytis*	Primary *Botrytis*	Brown rot	Phytop	Nect	Pen	*Mucor*	Botryo	Gloeo	X rot	Total other rots
					Drenched							
Untreated	99.3	38.5	33.2	10.5	1.5	33.2	14.2	0.2	0	0.2	1.2	60.8
Ronilan/ Bavistin	67.5	40.7	36.0	10.5	1.3	4.0	9.8	0.7	0	0	0.5	26.8
Bavistin + Captan	66.2	38.7	33.8	10.3	0.3	4.8	10.5	1.3	0	0	0.2	27.5
S E D												
					Undrenched							
Untreated	123.3	34.2	29.7	11.0	3.7	48.7	23.0	0.5	0.5	0.2	1.7	89.2
Ronilan/ Bavistin	97.0	48.7	40.0	16.3	3.3	16.7	11.2	0.3	0.2	0	0.3	48.3
Bavistin + Captan	55.2	25.7	21.8	10.0	0.3	7.0	11.5	0.3	0	0	0.3	29.5
S E D												

Key Primary *Botrytis* = Calyx rot, stalk rot, completely rotted fruits; Phytop = *Phytophthora*; Nect = *Nectria*; Pen = *Penicillium*; Botryo = *Botryosphaeria*; Gloeo = *Gloeosporium*; x rot = Unknown rot

Table 14 **Effect of fungicide sprays applied during blossom on incidence of calyx necrosis/dry eye rot in Cox apples 1995. German Cox, Elverton Farm, Teynham (Site B)**

Orchard treatment	% calyx necrosis 21.8.95
Untreated	26.1
Ronilan/Bavistin	16.5
Bavistin + Captan	19.4

Orchard testing of NECTEM™, a warning system for apple canker and *Nectria* fruit rot

6 Introduction

Nectria galligena is a serious disease of apple and pear trees causing canker and fruit rot. Recent research funded by MAFF has generated information on the effect of temperature, rainfall, humidity and surface wetness on *Nectria* infection of wood and fruit. This has enabled the development of a model, implemented as an operational system (NECTEM™) giving warnings of infection periods leading to *Nectria* fruit rot and apple canker (Xu *et al.*, 1994). The purpose of this project was therefore to test the model and consider ways of how the information could be made use of in practice.

7 Objective

To test NECTEM™ in the identification of *Nectria* infection periods leading to the development of fruit rot and canker.

8 Method

The study was conducted over two seasons 1994/95 and 1995/96. Metos (Pessl, Weiz, Austria) weather stations were established in three orchards cv Cox in Kent. The orchards selected were at Rocks Farm, East Malling (Cox, MM.106, Spartan and Discovery), Molland Orchard, Lower Goldstone, Ash (Cox, M.9 and Spartan), and Resevoir Orchard, Cryals Farm, Matfield (Cox, M.9 and Ida Red). All three orchards had a history of *Nectria* canker and fruit rot and were in areas of Kent which normally experienced different weather patterns. Weather data was collected from July to November at Ash and Matfield and from March to January at East Malling in 1994. In 1995 weather data was collected from March to December at all three sites. The weather data collected was used to run the NECTEM™ model and generate risks of *Nectria* fruit infection and canker.

At harvest 200 fruits were collected from each orchard from cvs Cox, Spartan and Ida Red. The fruits were collected from around *Nectria* cankers to ensure exposure of fruit to *Nectria* spores and the maximum chance of becoming infected if conditions were favourable. Cox samples were stored in CA stores (3.5°C, 1.5% O_2, 5% CO_2) until March. The samples of Spartan and Ida Red were stored in air at 3.5°C until March. After storage the number of fruit infected with *Nectria* fruit rot were recorded. The incidence of rotting was then compared with that expected from the numbers of NECTEM™ infection periods recorded.

The accuracy of NECTEM™ in identifying *Nectria* canker infection of leaf scars at autumn leaf fall was measured by assessing the incidence of canker infection on one-year-old wood in late May/early June the following season.

The accuracy of NECTEM™ in predicting *Nectria* infection of pruning wounds was also investigated at one site - Rocks Farm, East Malling, in 1994/95. Pruning cuts were made to two-year-old wood at roughly weekly intervals on trees of cvs Cox, Spartan and Discovery. Five cuts were made on two-year-old wood on each of ten trees per cultivar. The incidence of canker development was assessed in March 1996.

9 Results

9.1 Fruit rot

The numbers of NECTEM periods and incidence of fruit rot are shown in Table 15. In 1994/95 the highest incidence of fruit rot was recorded at Rocks Farm on both Cox and Spartan. This was associated with up to 39 NECTEM periods. A similar number of NECTEM periods were recorded at Ash and Matfield particularly associated with the Ida Red, which was the latest harvested variety. The incidence of fruit rot on this cultivar was the lowest. Numbers of NECTEM periods recorded in 1995/96 were fewer than in 1994/95. On Cox the incidence of fruit rot was also lower compared to 1994/95. However, on the pollinator cultivars, the incidence of fruit rot in 1996 was similar or higher than in 1994/95 despite fewer NECTEM periods being recorded.

9.2 Incidence of canker on one-year shoots

The per cent cankered one-year shoots recorded in the orchard at the Ash site and the Matfield site are shown in Table 16. The NECTEM periods are shown for the period October to December. The incidence of canker was higher in spring/summer 1995 than in 1996 despite the fact the numbers of NECTEM periods recorded were similar in autumn 1994 and 1995.

9.3 Pruning cuts

The percentage of pruning wounds that became cankered are shown in Table 17 together with the weather conditions at the time of pruning and the number of NECTEM periods recorded in the ten days after pruning. There appeared to be little relationship between the number of cankers that developed and the *Nectria* infection periods recorded.

10 Discussion

It is difficult to validate the NECTEM model in the same way that the scab model (VENTEM) was validated because of the difficulty of relating the development of canker or fruit rots to particular infection events. However a high frequency of NECTEM infection periods appears to result in a high incidence of *Nectria* fruit rot and likewise cankered shoots. IN 1994/95 the incidence of *Nectria* fruit rot was much higher on the fruit from Rocks Farm despite being exposed to a similar number of infection periods as the other sites. This was most likely because fruit from Rocks Farm was badly scabbed thus providing more sites for canker spores to lodge in and cause infection. In 1995/96 the incidence of fruit rot on the Cox at Rocks Farm was lower than expected because the orchard had received late sprays of the protectant fungicide Captan.

The development of cankers following pruning cuts was difficult to relate to the occurrence of NECTEM periods. This is most likely because if *Nectria* spores are present on a freshly cut surface they are sucked into the wound. The subsequent environmental conditions then become less important.

The data reported here indicate that NECTEM can predict likely fruit infection and leaf scar infection. At present the ability to predict the leaf scar infection is of doubtful practical use because of the absence of fungicides with curative action against *Nectria galligena* which could be used after an infection event has been identified. The fruit infection model can be used to predict likely fruit rot in store. This information can be used to assist in decisions on treatment of fruit at harvest with fungicide or the potential storage period. However further work needs to be done on the period of risk to be considered pre-harvest, ie only from July to harvest or from blossom to harvest. The latter may be of greater significance in view of the result obtained in the *Botrytis* control project reported here. It is also important to consider which infection periods are significant and which can be ignored.

11 Conclusions and future work

1. The NECTEM model was successful in predicting fruit infection and leaf scar infection in apple.

2. Prediction of *Nectria* infection of pruning cuts was less successful.

3. The model can be used to make practical decisions on management of apples to minimise losses due to fruit rot. However further work is needed to decide how best to make use of the information.

4. At present it is difficult to see how practical use can be made of the predicted risk of leaf scar infection without the availability of fungicides with curative action.

5. Further work on the practical use of NECTEM will be carried out in the MAFF-funded project HH2107STF.

Table 15 **Incidence of *Nectria* fruit rot in relation to NECTEM periods for three sites in Kent in 1994/95 and 1995/96**

		1994/95			1995/96		
Orchard site	Cultivar	Harvest date	No NECTEM periods 1/7-harvest	% *Nectria* rot	Harvest date	No NECTEM period 1/7-harvest	% *Nectria* rot
East Malling Rocks TL109	Cox	16/9	36	35.7	8/9	18	8.7*
	Spartan	27/9	39	44.1	26/9	27	40.6
Molland Ash	Cox	7/9	30	20.0	4/9	12	11.4
	Spartan	27/9	39	23.8	25/9	25	33.5
Cryals Matfield	Cox	9/9	31	20.0	6/9	10	11.0
	Ida Red	3/10	42	11.3	27/9	18	15.2

* Late Captan sprays

Table 16 **Incidence of *Nectria* leaf scar infections on one-year-old shoots of apple in spring/summer in relation to NECTEM periods recorded the previous autumn**

		1994/95		1995/96	
Orchard site	Cultivar	No of NECTEM periods Oct-Dec	% cankered one-year shoots summer 95	No of NECTEM periods Oct-Dec	% cankered one-year shoots summer 96
Molland, Ash	Cox	36	45	35	10
	Spartan	36	68	35	25
Cryals, Matfield	Cox	-	-	32	10

Table 17 **Incidence of cankers that developed on pruning cuts made on various dates in 1994 in relation to risk of *Nectria* infection determined by NECTEM. TL109 Rocks, East Malling**

Cultivar	Prune date 1994	Weather at pruning	No of NECTEM* periods	Accum NECTEM* risk	% cuts developed cankers 29.2.96
Cox	10 Nov	drizzle	4	74-88	46.0
	21 Nov	dry	1	21-87	10.0
	29 Nov	dry	4	58-82	12.0
	5 Dec	dry	3	34-13	20.0
	19 Dec	frosty	4	70-22	34.0
	4 Jan	dry	1	76-07	18.0
Spartan	10 Nov	drizzle	4	74-88	46.0
	21 Nov	dry	1	21-87	44.0
	29 Nov	dry	4	58-82	26.0
	5 Dec	dry	3	34-13	20.0
	19 Dec	frosty	4	70-22	38.0
	4 Jan	dry	1	76-07	26.0
Discovery	10 Nov	drizzle	4	74-88	14.0
	21 Nov	dry	1	21-87	32.0
	29 Nov	dry	4	58-82	16.0
	5 Dec	dry	3	34-13	14.0
	19 Dec	frosty	4	70-22	34.0
	4 Jan	dry	1	76-07	24.0

* Accumulated NECTEM risk and number of periods in ten days after pruning

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13 Bibliography

Berrie, A M (1989). Storage rots of apple and pear in south-east England. 1980-1988 incidence and fungicide resistance. *Integrated control of pome fruit diseases, II, IOBC Bulletin* **XII/6**, 229-239.

Berrie, A M (1994). The importance of *Botrytis cinerea* as a storage rot of apple cv Cox and pear cv Conference. *Norwegian Journal of Agricultural Science, Supplement No 17*, 383-389.

Berrie, A M and Koomen I (1994). Benzimidazole and dicarboximide resistance in pathogens of stored apples and pears. **In**: *Fungicide Resistance* (Eds S Heaney, D Slawson, D Holloman, M Smith, P Russell and D Parry), BCPC Monograph, **60**, 207-217.

Berrie, A M and Luton M T (1996). Alternatives to post-harvest fungicide treatments for pome fruits 1992-95. *LINK Project P46 Final Report*, 70 pp.

Combrink, J C, Eksteen, G J , and Van Zyl, H J (1983). Identification of calyx-end disorders in pears. *Deciduous Fruit Grower*, **33**, 283-285.

Preece, T F (1967). Losses of Cox's Orange Pippin apples during refrigerated storage in England 1961-65. *Plant Pathology*, **16**, 176-180.

Rosenberger, D A (1990). Grey mould. **In**: *Compendium of apple and pear diseases*, edited A L Jones and H S Aldwinckle. The American Phytopathological Society, 1990.

Tronsmo, A and Raa, J (1977). Life cycle of the dry eye rot pathogen, *Botrytis cinerea* Perl, on apple. *Phytopath Z*, **89**, 203-207.

Tronsmo, A and Raa, J (1977). Cytology and biochemistry of pathogenic growth of *Botrytis cinerea* Perl in apple fruit. *Phytopath Z*, **89**, 208-215.

Williamson, B and McNicol, R J (1986). Pathways of infection of flowers and fruits of red raspberry by *Botrytis cinerea*. *Acta Horticulturae*, **183**, 137-141.

Xu, X-M and Butt, D J (1994). The biology and epidemiology of *Nectria galligena* and an infection warning system. *Norwegian Journal of Agricultural Sciences, Supplement No 17*, 317-324.