FINAL REPORT

Project Number:	FV59a
Project Title:	Evaluation of pre and post-harvest fungicide treatments for the control of storage diseases of red beet.
Project Leader:	Dr G M McPherson
Location of Project:	Horticulture Research International Stockbridge House Cawood Selby North Yorkshire YO8 0TZ Tel: 01757 268275 Fax: 01757 268996
Project Co-ordinator:	Mr M J Holmes
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The results and conclusions in this report are based on a series of three experiments. The conditions under which the experiments were carried out and the results obtained have been reported with detail and 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. Please note that the fungicides referred to and used in these studies are not currently approved as either pre-harvest or post-harvest use.

Authentication

I declare that 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.

Signature .....

Dr G M McPherson
Project Leader
Horticulture Research International
Stockbridge House

Date ..... 3/5/96 .....

Report authorised by .....
(signature)

M R Bradley
Head of Station
Horticulture Research International
Stockbridge House
Cawood
Selby
North Yorkshire
YO8 0TZ

Tel. 01757 268275
Fax. 01757 268996

Date ..... 3.5.96 .....

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Relevance to Growers and Practical Application

Since the early work on red beet storage at Luddington EHS in the 1970s there has been changes in production techniques. Production has become more polarised with ca. 70% of the crop produced on relatively few farms where crop rotation may be limited. This intensive system of culture has almost certainly led to a build-up of soil-borne diseases and subsequent carry-over into storage. Also, perhaps significantly, has been the change in production system to grade out baby beet prior to storage. Whilst this proportion of the crop provides a high return the pre-storage grading may lead to an increase in root damage thereby providing sites of entry for soil-borne pathogens.

An earlier study (FV59) demonstrated that two soil-borne pathogens were primarily responsible for much of the storage losses, notably *Phoma betae*, cause of canker and *Botrytis cinerea*, cause of grey mould rot.

This project (FV59a) was subsequently commissioned to undertake experiments over three seasons to evaluate the performance of pre and post-harvest fungicide applications in order to reduce losses in store. Both barn stores and cold stores were used in the study.

A single post-harvest fungicide treatment prior to storage was found to be much more effective than routine foliar sprays during the growing season. Iprodione (Rovral WP) was very effective in controlling both *P. betae* and *B. cinerea*.

The project was subsequently extended in order to generate residues data in support of an application for Specific Off-Label Approval (SOLA) and separate reports were prepared and submitted to the regulators, the Pesticide Safety Directorate (PSD), in this respect (ref. FV59a: HRI/SH/FV59/93/003). To date it has not been possible to secure a SOLA use because an EU MRL for iprodione on beetroot has been set at the limit of determination and this effectively precludes the use of the

fungicide on the crop. Currently, the only course of action is for the UK regulators to petition the Commission in Brussels in order to modify the MRL using the complete residues data package generated during this work. Pressure is now being made to rationalise this petitioning process in order that new uses can be approved more rapidly in the EU. The HDC data package from this study has been submitted and we await the outcome of the petitioning process.

Introduction

Background

During the 1970s trials were carried out by MAFF at Luddington EHS to investigate techniques for long-term storage of red beet and the effect this prolonged storage had on the quality of the crop at marketing.

These early investigations provided the basic guidelines for the successful long-term storage of the red beet crop. Since then many growers have switched from imprecise field or 'clamp' stores to the more accurately controlled cold or barn stores.

Since this work was carried out however, beetroot production has changed. Firstly, production has been polarised with 70% of beet produced on relatively few farms where crop rotation may be limited. This intensification has almost certainly increased the incidence of soil-borne pathogens thereby increasing the risk to the stored crop. Secondly, baby beet are now graded out at harvest prior to storage. This practice is likely to increase the incidence and severity of mechanical damage which in turn could lead to increased disease in store.

Whatever the primary cause it has become increasingly apparent in recent years that losses in beetroot stores have increased significantly. Losses of up to 40% have been reported in some instances.

Red beet is required for the fresh market and processing all year round and successful storage of the crop enables growers to provide continuity of supply throughout the season. Over 30,000 tonnes are stored annually with a potential value of £1.5 m. Prices during the period March-June tend to be considerably higher than at other times of the year therefore to ensure the economic viability of the crop it is essential that storage losses before this time are minimised.

Tackling the Problem

Investigations have been carried out in an attempt to identify the primary causes of these losses in store. Investigations in an earlier HDC project (FV59a) pointed towards canker (*Phoma betae*) and grey mould (*Botrytis cinerea*) as the two primary causes of storage rots, though a wide spectrum of other fungi including *Fusarium* spp., *Penicillium* spp., *Rhizopus* spp., *Cylindrocarpon* spp., and *Geotrichum* spp. were frequently isolated. Many of these fungi may be opportunists developing as surface moulds and colonising previously invaded tissues in many crops. Their true importance with respect to storage rots remains unclear.

The primary objectives of this project were to:

- Secure a clearer understanding of the primary cause(s) of losses in store in support of the results in FV59.

- Determine the relative incidence and progression of disease in barn and cold stores.

- Identify fungicides which can effectively reduce storage losses.

- Determine whether pre or post-harvest fungicide applications are more effective.

- Secure an Approved use of an effective fungicide on behalf of the UK red beet industry.

Materials and Methods

Location

Horticulture Research International
Stockbridge House
Cawood
Selby
North Yorkshire
YO8 0TZ

Tel. 01757 268275
Fax. 01757 268996

Trial 1 April 1991 to April 1992
Trial 2 April 1992 to April 1993
Trial 3 April 1993 to April 1994

Cultivar

Crimson Globe (Elsoms) was used in each year.

Site

The trial was located in Field L in each year.

Design

The trial in each year comprised of a randomised block with six treatments* replicated four times. Each plot comprised three beds each 1.83 m wide and 8-12 m long with 1.5 m between plots. The crop in each year was drilled to attain a plant population of 150 plants/m^2. At harvest individual rows in each plot were lifted separately and graded, the baby beet size grade (<40 mm) being removed. Three post-harvest, pre-storage treatments were superimposed on batches of 50 root placed in netted bags. Treated roots were subsequently placed

in bulk bins, either in a cold store operating at a temperature of 2°C +/- 1° or a barn store at ambient temperature with forced fan ventilation to maintain air circulation and to optimise storage temperature where possible.

* Except in Year 1 (1991/92) when an additional MeBr sterilised plot was included.

Field Treatments

Field Treatments	1991/92	1992/93	1993/94
1. Methyl bromide soil sterilisation.	+	-	-
2. Untreated control (machine harvested)	+	+	+
3. Untreated control (hand harvested)	+	+	+
4. Benomyl (Benlate) applied at monthly intervals from emergence at a rate of 1.1 kg product/1000 litres water/ha	+	+	+
5. Prochloraz-manganese (Octave) applied at monthly intervals from emergence at a rate of 1.0 kg product/1000 litres water/ha	+	+	+
6. Iprodione (Rovral WP) applied at monthly intervals from emergence at a rate of 1 kg/product/1000 litres water/ha	+	+	+
7. Chlorothalonil (Bravo 500) applied at monthly intervals from emergence at a rate of 3 litres product/1000 litres water/ha	-	+	+

NB. Treatments 1, 2, 4 to 7 were all machine harvested.

Post-Harvest Treatments

Post-Harvest Treatments	1991/92	1992/93	1993/94
1. Untreated	+	+	+
2. Benomyl (Benlate) applied as a dip treatment prior to storage at a rate of 1.1 kg product/1000 litres water	+	+	+
3. Iprodione (Rovral WP) applied as a dip treatment prior to storage at a rate of 1.0 kg product/1000 litres water	+	+	+

Fungicide Application

The fungicide applications to the field crops were made at monthly intervals by qualified staff using an Oxford Precision boom spray (E-Bar Engineering). Post-harvest fungicide treatments were made by dipping 50 root samples contained in nets in the freshly prepared fungicide solution for a minimum period of 10 seconds with continual agitation.

Crop Husbandry

The crop in each year was grown to a good commercial standard to ensure it was representative for the intended purpose. Irrigation was applied as necessary in each year ensuring it did not interfere with the experimental fungicide applications. Pesticide treatments were kept to a minimum though occasional herbicide treatments (Goltix) for weed control and insecticide treatment (Ambush) for cutworm control were necessary. No fungicides, other than those applied experimentally, were applied to the trials either pre or post-harvest.

Crop Diary and Cultural Details

Trial 1 (1991/92)

MeBr sterilisation was carried out on 20 May and the covers removed on 24 May. Fertiliser (15:6:25 @ 650 kg/ha) was applied to the trial site on 3 June using a spreader together with Potassium sulphate at 75 kg/ha and followed by Solubor applied as a spray at 10 kg/ha in 560 litres water.

The trial was drilled on 4 June using a Stanhay drill ensuring the sterilised beds were drilled first, aiming to achieve a plant stand of 150 plants/m^2. Goltix was applied at 5 kg/1120 l/ha for weed control immediately after drilling. Ambush was applied for cutworm control on 17 July in response to a high risk warning according to label recommendations and a top dressing of nitrogen (150 kg/ha) applied on 18 July.

Experimental fungicide treatments were applied on 22 July, 19 August, 16 September and 14 October.

The crop was harvested on 21 October and assessed for the presence of root disease. Post-harvest pre-storage fungicide applications were made and the crop placed in barn and cold store on 23 October. Samples were removed from store for disease assessment on 14 January 1992 and 28 April 1992 when the trial was terminated.

Trial 2 (1992/93)

The trial was drilled on 22 May using a Stanhay drill aiming for a plant stand of 150 plants/m^2. Goltix was applied at 5 kg/500 litres water/ha for weed control on 24 May followed by Ambush at 250 ml/600 litres water/ha on 7 June following a high risk warning for cutworm.

Base dressing was applied prior to drilling and a top dressing of nitrogen (522 kg/ha Nitram) was added on 7 June.

Experimental fungicide treatments were applied on 12 June, 15 July, 18 August and 14 September and the crop ultimately harvested on 27 September when a preliminary assessment of root disease was made. Pre-storage fungicide dip treatments were applied on 1 October and the roots transferred to both cold and barn stores. Samples were removed from store for detailed assessment on 20 January and 23 April 1993 when the trial was terminated.

Trial 3 (1993/94)

The trial was drilled on 7 June using a Stanhay drill aiming for a plant stand of 150 plants/m^2. Base dressing of fertiliser (0:11:54 450 kg/ha + 400 kg/ha Nitram) was applied pre-drilling and Goltix applied (5 kg product/600 litres water/ha) on 8 June after drilling. Ambush (250 ml product/1000 litres water/ha) was applied on 9 July following a high risk cutworm warning.

Experimental fungicide treatments were applied on 9 July, 6 August, 31 August and 22 September.

The crop was harvested on 6 October when a preliminary assessment of root disease was undertaken.

Pre-storage fungicide treatments were applied on 8 October and the roots subsequently transferred to both cold and barn stores.

Samples were removed from store for detailed assessment on 2 February and 11 May 1994 when the trial was finally terminated.

Disease Assessments

At harvest 50-100 roots from each plot were taken and assessed for the presence of various root diseases. Where present the diseases were assessed on the basis of percentage root area affected. All the roots were cut longitudinally in order to determine the presence of internal rots or penetrating *Phoma* lesions.

After storage 50 root samples in the nets were examined in detail from each treatment and the incidence of both *Phoma* and *Botrytis* determined on each root in order that the percentage root infection by each pathogen could be determined.

Resistance Testing

Where *Phoma* and *Botrytis* occurred specific isolates were secured by culturing onto a potato dextrose agar (PDA) medium in the laboratory.

Following sub-culture isolates were transferred to agar amended with 2 and 20 ppm of benomyl and iprodione to determine the sensitivity of the isolates to these fungicides. After incubation the diameter of the fungal colonies was determined as a measure of the growth rate of the fungus in the presence/absence of the fungicides.

Statistical Analysis

The data in each year was subjected to an analysis of variance. Where appropriate, the data was transformed using an angular transformation to stabilise the variance of the data. Significant differences between treatments can be determined using the Least Significant Difference (LSD).

Storage of Data

The raw data from this trials series and a copy of the final report will be stored for a period of not less than 5 years in the HRI archive at Stockbridge House. Access to the data can only be made via the designated archivist.

Results

Trial 1 (1991/92)

There was no evidence of foliage or root disease in this crop during routine monitoring over the season. Phytotoxicity symptoms did not become apparent following application of any of the experimental fungicides during the course of the trial.

At harvest 100 roots/plot were examined in detail and with the exception of a low-trace level of common scab (*Streptomyces scabies*) the crop appeared disease-free. The assessments made at harvest are not presented, as there was no apparent difference between the applied treatments. No evidence of canker (*Phoma betae*) or other root pathogens was found at this time.

At the first assessment out of store on 14 January trace-low levels of *Phoma* were recorded, particularly in the MeBr treated plots held subsequently in the cold store (Table 1). Whilst trace-low levels of disease occurred in most plots the marketability of the crop was largely unaffected as the disease had not seriously affected the roots to cause a penetrating decay.

By the second assessment out of store on 28 April the disease had progressed significantly (Table 2). Infection levels in the MeBr treated plots appeared the highest, particularly where the crop had been cold-stored.

There was a slight difference in infection levels between harvest techniques ie hand v. machine, the latter having a marginally higher incidence of *Phoma* infection.

The pre-harvest foliar sprays appeared to be partially effective and a lower incidence of *Phoma* was recorded following treatment with both prochloraz and iprodione. Field treatment with benomyl appeared ineffective.

The single post-harvest dip treatment with iprodione reduced the incidence of disease considerably in this trial and provided the most effective treatment. A similar post-harvest treatment with benomyl was less effective.

Surprisingly perhaps, the incidence of disease was slightly higher in the cold store than the barn store in this experiment. Overall, however, disease levels were not particularly high during this season (1991/92) and it is not possible to draw firm conclusions from the results.

No fungicide resistance testing was carried out during the 1991/92 trial due to the low disease incidence.

Trial 2 (1992/93)

Following seedling emergence there was no evidence of pathogen infection in the trial area and routine monitoring did not detect any significant disease problems during the growing season. Fungicide sprays, commencing in June, caused no apparent phytotoxicity symptoms and the crop matured to produce a good commercial yield in late September.

A disease assessment conducted on 100 roots per plot at harvest found many roots infected with common scab (*S. scabies*) with some 15-20% roots affected. The severity of the disease was low with <1% surface area infected on individual roots. There were no significant differences between the field treatments applied and therefore the data has not bee tabulated. Canker (*P. betae*) was also detected on occasionally roots at harvest though the incidence was very low with no apparent differences between the treatments.

At the first assessment out of store on 20 January both *P. betae* and *B. cinerea* were detected (Table 3). Infection levels were low and there was little difference between the storage regimes or the applied fungicide treatments.

By the second assessment on 23 April (Table 4) disease levels had increased significantly, particularly in the barn store where 45% roots were decayed following machine harvesting. Of these 41.5% were affected by *Phoma* canker, with a relatively small number of roots (4.0%) infected with botrytis. Interestingly, the incidence of disease was much lower in the hand-harvested plots (13.5% Phoma, 1.5% botrytis) suggesting that the rots may be exacerbated by physical/mechanical damage on the roots at harvest. In the cold store the incidence of rotting was much reduced with only 8% roots affected with Phoma and Botrytis in total and this appears to contrast with the results obtained in 1991/92.

Fungicide application during the growing phase appeared largely ineffective in preventing rot development in store, though evidently some slight suppression was afforded. All the fungicides applied as field sprays appeared to suppress the incidence of *Phoma* infection, with prochloraz-Mn providing the greatest suppression. However, even this treatment failed to reduce the incidence of storage rots to the level recorded in the untreated but hand-harvested plots.

In contrast, a single post-harvest pre-storage dip with iprodione (Rovral) provided an excellent level of disease control reducing the incidence of *Phoma* in the barn store from 41.5% to 2.5%. This result with the post-harvest Rovral dip treatment was reflected across all the field applied fungicide treatments. In contrast, Benlate applied as a post-harvest dip treatment was ineffective. A fungicide resistance test using 10 random isolates of *P. betae* recovered from the stored beet demonstrated a high level of resistance to carbendazim (Table 5) and this is considered to be the most likely explanation for the poor control achieved with this fungicide.

Trial 3 (1993/94)

No evidence of disease was found in the crop during routine monitoring throughout the growing season. The foliar spray applications caused no visible phytotoxicity symptoms in the crop and maturity was not delayed following application of any of the experimental fungicide treatments.

A disease assessment conducted at harvest on 6 October revealed only trace levels of Phoma and the severity on individual roots was low. No other pathogens were detected on roots at this stage. There was no evidence of differences between treatments and therefore the results from this assessment have not been tabulated.

Following mid-term (3 month) storage an assessment, on 2 February, revealed that infection levels had not progressed and Phoma levels in the untreated control plots remained extremely low in both cold and barn stored roots (Table 6). Occasional roots were also found to be infected with *Botrytis* at this first assessment out of store though again infection levels were very low.

By the second (long-term) assessment out of store on 11 May infection levels of Phoma had risen but not to the levels recorded in the previous year (Table 7). *Botrytis* remained at low-trace levels (0.5-1.0%). Disease levels tended to be slightly higher in the barn store though there appeared to be no effect from any of the field applied fungicides. Treatment with Benlate post-harvest appeared to be ineffective in reducing infection levels with Phoma. However, *Phoma* levels following a Rovral dip were reduced significantly and this supports the results obtained in 1992/93 under conditions of high disease pressure. Isolates of both *P. betae* and *B. cinerea* were collected from the stored beet and resistance tests conducted using fungicide amended agar. This clearly demonstrated that all the isolates of *P. betae* collected were

insensitive to benomyl but sensitive to iprodione at 2 and 20 ppm (Table 8). Of the 8 isolates of *B. cinerea* collected 7 were found to be insensitive to benomyl at 2 and 20 ppm though all were sensitive to iprodione at 2 and 20 ppm (Table 9). These results help explain the results of the post-storage disease assessments.

Table 1: Percentage of roots with Canker (*Phoma betae*) and marketability following medium-term (3 month) storage (14 January 1992) of red beet in the trial conducted during 1991/92.

Treatment		% Roots with *P. betae**		% Roots Marketable	
Field	Store	Cold	Barn	Cold	Barn
1. Sterilised (MeBr)	No dip	4.0	0.5	100.0	100.0
	Benlate	3.5	0.0	100.0	99.5
	Rovral	0.0	0.0	100.0	100.0
2. Untreated control (machine harvest)	No dip	0.5	1.5	99.0	99.5
	Benlate	0.5	0.0	99.5	100.0
	Rovral	0.0	2.0	99.5	100.0
3. Untreated control (hand harvest)	No dip	0.5	0.0	100.0	99.5
	Benlate	0.0	0.0	100.0	100.0
	Rovral	0.0	0.0	100.0	100.0
4. Benlate (FSx4)	No dip	1.0	0.5	98.5	100.0
	Benlate	0.0	0.0	100.0	100.0
	Rovral	0.0	0.5	99.5	99.5
5. Octave (FSx4)	No dip	0.0	0.5	98.0	99.0
	Benlate	0.0	0.5	99.5	100.0
	Rovral	0.0	0.5	99.5	99.5
6. Rovral (FSx4)	No dip	0.0	0.0	98.0	100.0
	Benlate	0.0	1.0	99.5	100.0
	Rovral	0.0	0.0	98.0	99.5

* The level of *P. betae* was too low for an analysis of variance to be valid and therefore was not conducted following this assessment.

Table 2: Percentage of roots with Canker (*Phoma betae*) and marketability following long-term (6 month) storage (28 April 1992) of red beet in the trial conducted during 1991/92.

Treatment		% Roots with *P. betae*				% Roots Marketable			
Field	Store	Cold		Barn		Cold		Barn	
1. Sterilised (MeBr)	No dip	13.5	(21.2)	3.5	(10.5)	76.0	(61.0)	94.5	(78.8)
	Benlate	13.0	(18.2)	10.0	(20.7)	80.5	(64.6)	96.0	(78.9)
	Rovral	0.5	(2.0)	1.0	(4.1)	100.0	(90.0)	98.5	(85.1)
2. Untreated control (machine harvest)	No dip	7.0	(12.9)	5.5	(11.5)	93.5	(75.4)	98.0	(83.1)
	Benlate	4.0	(9.5)	1.5	(4.9)	92.5	(77.1)	96.5	(79.8)
	Rovral	0.0	(0.0)	3.0	(8.5)	99.5	(88.0)	95.0	(77.1)
3. Untreated control (hand harvest)	No dip	4.5	(10.0)	3.5	(9.2)	95.0	(79.4)	97.5	(82.4)
	Benlate	2.0	(8.1)	2.5	(7.0)	98.5	(83.9)	98.0	(83.1)
	Rovral	0.0	(0.0)	1.5	(3.5)	99.0	(85.9)	98.0	(84.2)
4. Benlate (FSx4)	No dip	9.0	(17.3)	8.5	(14.3)	88.0	(69.9)	95.5	(79.5)
	Benlate	2.5	(7.8)	5.0	(12.8)	95.5	(78.4)	96.5	(79.3)
	Rovral	0.0	(0.0)	2.0	(5.6)	100.0	(90.0)	99.5	(88.0)
5. Octave (FSx4)	No dip	1.0	(4.1)	1.5	(4.9)	97.0	(81.5)	97.0	(83.0)
	Benlate	0.0	(0.0)	1.0	(4.1)	100.0	(90.0)	99.0	(87.1)
	Rovral	0.0	(0.0)	2.0	(5.6)	100.0	(90.0)	98.5	(86.5)
6. Rovral (FSx4)	No dip	2.5	(7.6)	5.0	(10.6)	96.0	(80.5)	96.5	(79.5)
	Benlate	1.0	(4.1)	1.5	(4.9)	99.0	(85.9)	100.0	(90.0)
	Rovral	0.0	(0.0)	3.5	(9.0)	100.0	(90.0)	96.0	(79.3)
LSD (P = < 0.05) to compare the different field treatments			(8.1)		(8.1)		(7.8)		(7.8)
LSD (P = < 0.05) to compare the dip treatments within each field treatment			(7.5)		(7.5)		(7.4)		(7.4)

Figures in parentheses refer to angular transformation of raw data.

FS = Foliar sprays

Table 3: Percentage roots with Canker (*P. betae*) and grey mould (*B. cinerea*) following medium-term (3 month) storage (20 January 1993) of red beet in the trial conducted during 1992/93.

Treatment		% Roots with *P. betae**		% Roots with *B. cinerea**	
Field	Pre-Storage	Cold	Barn	Cold	Barn
1. Untreated control (machine harvest)	No dip	0.5	2.0	1.0	0.0
	Benlate	0.0	0.5	0.0	1.0
	Rovral	0.0	0.0	0.0	0.0
2. Untreated control (hand harvest)	No dip	0.5	2.5	0.5	0.0
	Benlate	1.5	1.0	1.5	0.0
	Rovral	1.0	0.0	0.0	0.0
3. Benlate (FSx4)	No dip	0.5	1.5	0.5	1.5
	Benlate	0.8	1.5	1.0	0.0
	Rovral	0.5	0.0	0.0	0.0
4. Octave (FSx4)	No dip	0.5	0.0	1.0	0.5
	Benlate	1.0	0.5	1.0	0.0
	Rovral	0.0	0.5	0.0	0.0
5. Rovral (FSx4)	No dip	1.0	0.0	1.0	0.0
	Benlate	0.5	1.0	0.0	0.0
	Rovral	1.0	0.0	0.0	1.0
6. Bravo 500 (FSx4)	No dip	0.5	2.0	1.0	0.0
	Benlate	0.0	1.0	1.5	0.0
	Rovral	0.0	0.5	0.0	0.0

* The level of *P. betae* and *B. cinerea* was too low for an analysis of variance to be valid and therefore this was not conducted following this assessment.

FS = Foliar sprays

Table 4: Percentage roots with canker (*P. betae*) and grey mould (*B. cinerea*) following long-term (6 month) storage (20 January 1993) of red beet in the trial conducted during 1992/93.

Treatment		% Roots with *P. betae*				% Roots with *B. cinerea*			
Field	Store	Cold		Barn		Cold		Barn	
1. Untreated control (machine harvest)	No dip	6.5	(12.1)	41.5	(40.0)	1.5	(3.5)	4.0	(7.0)
	Benlate	3.5	(9.0)	40.5	(39.4)	4.0	(7.5)	0.5	(2.0)
	Rovral	1.0	(4.1)	2.5	(7.6)	0.5	(2.0)	5.0	(10.4)
2. Untreated control (hand harvest)	No dip	10.5	(18.3)	13.5	(21.2)	1.5	(4.9)	1.5	(4.9)
	Benlate	5.5	(9.4)	15.0	(22.5)	0.5	(2.0)	3.0	(7.0)
	Rovral	0.0	(0.0)	1.0	(4.1)	0.0	(0.0)	0.5	(2.0)
3. Benlate (FSx4)	No dip	6.0	(13.7)	30.5	(33.4)	2.5	(6.4)	2.0	(5.8)
	Benlate	8.0	(15.3)	19.0	(24.5)	5.5	(11.5)	1.0	(4.1)
	Rovral	0.5	(2.0)	2.0	(4.1)	1.0	(4.1)	1.0	(2.9)
4. Octave (FSx4)	No dip	2.0	(5.6)	17.0	(2.0)	0.5	(2.0)	2.5	(7.8)
	Benlate	2.0	(5.6)	13.0	(5.6)	2.0	(5.6)	2.5	(6.4)
	Rovral	0.5	(2.0)	2.0	(2.0)	0.5	(2.0)	0.5	(2.0)
5. Rovral (FSx4)	No dip	2.5	(6.4)	26.5	(5.8)	2.0	(5.8)	1.0	(4.1)
	Benlate	1.0	(4.1)	30.0	(2.0)	0.5	(2.0)	2.0	(7.0)
	Rovral	0.0	(0.0)	5.5	(0.0)	0.0	(0.0)	1.5	(4.4)
6. Bravo 500 (FSx4)	No dip	2.5	(6.1)	26.5	(7.7)	3.5	(7.7)	2.0	(5.6)
	Benlate	2.0	(7.8)	36.5	(6.1)	2.5	(6.1)	2.0	(5.6)
	Rovral	0.0	(0.0)	2.5	(7.0)	2.0	(7.0)	3.0	(9.6)
LSD (P = < 0.05) to compare the different field treatments			(8.9)		(9.7)		(7.7)		(8.7)
LSD (P = < 0.05) to compare the dip treatments within each field treatment			(8.3)		(8.1)		(8.5)		(8.3)

Figures in parentheses refer to angular transformation of raw data.

FS = Foliar sprays

Table 5: Fungicide resistance test using ten isolates of *Phoma betae* collected at random from the stored beet in the trial conducted during 1992/93.

Isolate No.	Colony Diameter (mm)*				
	Unamended Agar	2 ppm benomyl	20 ppm benomyl	2 ppm iprodione	20 ppm iprodione
1	26.5	28.0	25.0	0.0	0.0
2	27.0	33.0	29.0	0.0	0.0
3	26.5	29.0	22.5	0.0	0.0
4	27.6	28.0	21.0	0.0	0.0
5	29.0	29.0	22.5	0.0	0.0
6	29.0	31.5	22.0	0.0	0.0
7	30.0	28.5	19.5	0.0	0.0
8	27.5	24.5	21.5	0.0	0.0
9	26.0	23.5	16.5	0.0	0.0
10	24.0	22.0	15.0	0.0	0.0
Mean	27.0	27.0	21.0	0.0	0.0

* Mean of 2 replicate plates.

Table 6: Percentage roots with canker (*P. betae*) and grey mould (*B. cinerea*) following medium-term (3 months) storage (2 February 1994) of red beet in the trial conducted during 1993/94.

Treatment		% Roots with *P. betae**		% Roots with *B. cinerea**	
Field	Pre-Storage	Cold	Barn	Cold	Barn
1. Untreated control (machine harvest)	No dip	0.0	0.0	0.0	0.5
	Benlate	0.0	0.0	0.0	0.0
	Rovral	0.0	0.5	0.0	0.0
2. Untreated control (hand harvest)	No dip	0.5	0.0	0.0	0.0
	Benlate	0.0	0.0	0.0	0.0
	Rovral	0.0	0.5	0.0	0.0
3. Benlate (FSx4)	No dip	0.0	0.0	0.0	0.0
	Benlate	0.0	0.0	0.0	0.0
	Rovral	0.0	0.5	0.0	0.0
4. Octave (FSx4)	No dip	0.0	0.0	0.5	0.0
	Benlate	0.5	0.0	0.5	0.0
	Rovral	0.0	0.0	0.0	0.0
5. Rovral (FSx4)	No dip	0.5	0.0	0.5	0.0
	Benlate	0.0	0.0	0.5	0.0
	Rovral	0.0	0.0	0.0	0.0
6. Bravo 500 (FSx4)	No dip	0.0	0.5	0.0	0.0
	Benlate	0.0	0.5	0.0	1.0
	Rovral	0.0	0.0	0.0	0.0

FS = Foliar spray

* The level of *P. betae* and *B. cinerea* was too low for an analysis of variance to be valid and therefore this was not conducted following this assessment.

Table 7: Percentage roots with canker (*P. betae*) and grey mould (*B. cinerea*) following long-term (6 months) storage (11 May 1994) of red beet in the trial conducted during 1993/94.

Treatment		% Roots with *P. betae*				% Roots with *B. cinerea**	
Field	Pre-Storage	Cold		Barn		Cold	Barn
1. Untreated control (machine harvest)	No dip	0.0	(0.0)	3.0	(9.8)	0.0	0.0
	Benlate	1.0	(4.1)	4.5	(11.6)	0.0	0.5
	Rovral	0.0	(0.0)	0.5	(2.0)	0.0	0.0
2. Untreated control (hand harvest)	No dip	1.5	(4.9)	2.0	(7.0)	0.0	0.0
	Benlate	2.0	(4.1)	5.5	(11.3)	0.0	0.5
	Rovral	0.5	(2.0)	0.5	(2.0)	0.0	0.0
3. Benlate (FSx4)	No dip	2.5	(6.1)	5.5	(13.1)	1.0	0.0
	Benlate	1.0	(4.1)	2.0	(7.0)	1.0	1.5
	Rovral	1.5	(4.9)	0.0	(0.0)	1.0	0.0
4. Octave (FSx4)	No dip	0.5	(2.0)	1.5	(6.1)	0.5	0.0
	Benlate	0.5	(2.0)	2.5	(6.1)	0.5	0.0
	Rovral	0.5	(2.0)	0.0	(0.0)	0.0	0.0
5. Rovral (FSx4)	No dip	1.5	(4.9)	1.0	(4.1)	0.0	0.0
	Benlate	0.5	(2.0)	4.0	(9.5)	0.5	0.0
	Rovral	1.0	(2.9)	0.7	(2.8)	0.0	0.5
6. Bravo 500 (FSx4)	No dip	1.5	(4.7)	1.0	(4.9)	1.0	0.0
	Benlate	1.5	(6.1)	3.0	(9.6)	0.0	0.0
	Rovral	0.5	(2.0)	0.0	(0.0)	0.0	0.0
LSD (P = < 0.05) to compare the different field treatments			(2.9)		(2.9)		
LSD (P = < 0.05) to compare the dip treatments within each field treatment			(7.1)		(7.1)		

FS = Foliar spray

* The level of *B. cinerea* was too low for an analysis of variance to be valid and therefore this was not conducted following this assessment.

Table 8: Fungicide resistance test for ten isolates of *Phoma betae* collected at random from the stored beet in the trial conducted during 1993/94.

Isolate No.	Colony Diameter (mm)*				
	Unamended Agar	2 ppm benomyl	20 ppm benomyl	2 ppm iprodione	20 ppm iprodione
1	36.0	35.0	30.0	0.0	0.0
2	26.0	26.0	24.0	0.0	0.0
3	35.0	35.0	30.0	0.0	0.0
4	36.0	28.0	35.0	0.0	0.0
5	39.0	37.0	34.0	0.0	0.0
6	35.0	35.0	32.0	0.0	0.0
7	41.0	33.0	35.0	0.0	0.0
8	29.0	27.0	29.0	0.0	0.0
9	35.0	34.0	31.0	0.0	0.0
10	40.0	38.0	34.0	0.0	0.0
Mean	35.2	32.8	31.4	0.0	0.0

* Mean of 2 replicate plates.

Table 9: Fungicide resistance test for eight isolates of *Botrytis cinerea* collected at random from the stored beet in the trial conducted during 1993/94.

Isolate No.	Colony Diameter (mm)*				
	Unamended Agar	2 ppm benomyl	20 ppm benomyl	2 ppm iprodione	20 ppm iprodione
1	48.0	47.0	40.0	0.0	0.0
2	51.0	43.0	38.0	0.0	0.0
3	46.0	0.0	0.0	0.0	0.0
4	57.0	51.0	45.0	0.0	0.0
5	46.0	0.0	0.0	0.0	0.0
6	54.0	47.0	37.0	0.0	0.0
7	53.0	47.0	36.0	0.0	0.0
8	49.0	47.0	35.0	0.0	0.0
Mean	50.5	47.0⁺	38.5⁺	0.0	0.0

* Mean of 2 replicate plates.

⁺ Mean of 6 benomyl insensitive isolates.

Discussion

In two of this three-year investigation into the control of storage diseases of red beet, disease levels occurred at either low or trace levels and it is difficult therefore to draw firm conclusions from the data. However, in 1992/93 storage rots, particularly *Phoma* canker in the barn store, occurred at moderate-high levels and this provided an excellent opportunity to compare a range of field applied fungicides in conjunction with post-harvest dip treatments.

Whilst the foliar sprays of the various fungicides applied during the growing season appeared to provide a moderate suppression of storage rots they were significantly less effective than a single post-harvest dip treatment with iprodione (Rovral) prior to storage.

Whilst *Phoma* may occur during the growing phase of the crop via seed or soil-borne infection, the greatest risk of widespread infection is likely to occur during the grading out of baby beet when spores, potentially from a few infected roots may be readily transferred to other previously healthy roots. The mechanical damage occurring through passage over the grading line is likely to exacerbate infection by providing additional routes of entry for both Phoma and Botrytis. Therefore, whilst foliar sprays in the growing crop may suppress primary infector plants, treatment of the beet after harvest and passage over the grading line, but pre-storage, is more likely to be effective in preventing rots subsequently in store. A single pre-storage dip treatment also provides an efficient cost-effective and environmentally friendly means of targeting fungicide application, minimising exposure of the pesticide to the environment and non-target organisms.

Interestingly, Benlate proved to be ineffective in preventing the development of both *Phoma* and *Botrytis* rots in store and resistance tests have demonstrated a high incidence of insensitivity in the pathogen populations. Resistance to

carbendazim in populations of *B. cinerea* is well documented on other crops though to the best of the author's knowledge resistance to carbendazim in populations of *P. betae* has not previously been reported in red beet. Fortunately, the dicarboximide fungicide iprodione (Rovral) provided superior control against both *Phoma* and *Botrytis* and therefore is an ideal candidate fungicide for further development.

Disease levels in the cold stored crop were generally much lower than in the barn stored crop, even in the absence of fungicide treatment. This is almost certainly a reflection of the better temperature control achieved delaying the onset of infection and subsequent symptom expression.

This project was subsequently extended and encompassed within the HDC/HRI SOLA programme to generate residues data for iprodione as a pre-storage dip treatment on red beet; the aim being to secure an Approved Specific Off-Label use. Unfortunately, due to changes brought about as part of the EU harmonisation process an EU MRL has been set at the limit of determination on red beet and this effectively precludes its use on the crop. It is now been made necessary to petition the Commission in Brussels to amend (raise) the EU MRL before an authorised use can be granted. In order to achieve this it is necessary to submit a full data package of eight residue trials conducted over two years.

This data package has now been generated as part of the SOLA programme and it has been submitted to the UK regulatory authority (PSD) who are progressing this issue further on behalf of the UK red beet industry. Unfortunately, however, it means that there has been an unavoidable delay in securing an Approved use for Rovral and currently it cannot be used legally as a dip treatment on red beet prior to storage. Growers will be notified directly, via HDC, as soon as progress has been made in securing an Approved use.

The inclusion of both machine-harvested and hand-harvested plots has been interesting as that it has highlighted the potential of increased root damage causing an increased incidence of disease. Where roots are lifted carefully to avoid damage disease incidence may be reduced significantly. Clearly, machine-harvesting is essential but consideration should be given to ways of reducing mechanical damage, eg scuffing, bruising, prior to storage following similar guidelines to those adopted for the potato crop.

P. betae may be seed-borne and the use of high quality disease-free seed should be used at all times. In the first years trial *P. betae* appeared at a higher incidence on MeBr sterilised plots and subsequent checks on the seed batch revealed a low (<1%) but significant incidence of *P. betae* on the seed-lot. Clearly, such infected seedlings are likely to provide primary infector plants for dissemination to other plants in the crop, ultimately leading to increased losses in store. Once introduced into the crop via a seed-borne infection it is possible that *P. betae* will carry-over from crop to crop in intensive red beet production areas.

Conclusions

1. A pre-storage dip treatment with fungicide is effective in preventing the development of *Phoma* canker and *Botrytis* rot in red beet.

2. Rovral WP (iprodione) is more effective than Benlate (benomyl) against *Phoma* canker and *Botrytis* rot in stored red beet. This is considered to be largely due to the high incidence of benomyl resistant isolates of both *P. betae* and *B. cinerea* identified in this study.

3. Routine HV fungicide applications to the growing crop whilst giving some suppression were much less effective in preventing storage losses due to *Phoma* canker and *Botrytis* rot of red beet than a single pre-storage dip treatment.

4. The incidence of infection of both *Phoma* and *Botrytis* was generally higher in barn stores than cold stores and this is likely to be a reflection of the higher, but fluctuating, temperatures in these stores.

5. In 1992/93 infection levels of *P. betae* in machine-harvested but untreated plots were much higher than equivalent hand-harvested plots and this suggests that spores may have been disseminated via the lifting machinery infection occurring through wounds following mechanical harvesting.

6. Prior to completing these studies an EU Maximum Residue Limit (MRL) was set at the limit of determination for iprodione on red beet. Therefore, an application for a Specific Off-Label Approval has not been possible to date.

7. A full two year residues data package has now been submitted to the UK regulators (PSD). This data will be used by PSD to petition the Commission in Brussels with the intention of raising the EU MRL to allow use of iprodione on red beet. Assuming an appropriate EU MRL can be established a SOLA application will be made by HDC/HRI on behalf of UK red beet growers.

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Table 4: Percentage roots with canker (*P. betae*) and grey mould (*B. cinerea*) following long-term (6 month) storage (20 January 1993) of red beet in the trial conducted during 1992/93.

Treatment		% Roots with *P. betae*				% Roots with *B. cinerea*			
Field	Store	Cold		Barn		Cold		Barn	
1. Untreated control (machine harvest)	No dip	6.5	(12.1)	41.5	(40.0)	1.5	(3.5)	4.0	(7.0)
	Benlate	3.5	(9.0)	40.5	(39.4)	4.0	(7.5)	0.5	(2.0)
	Rovral	1.0	(4.1)	2.5	(7.6)	0.5	(2.0)	5.0	(10.4)
2. Untreated control (hand harvest)	No dip	10.5	(18.3)	13.5	(21.2)	1.5	(4.9)	1.5	(4.9)
	Benlate	5.5	(9.4)	15.0	(22.5)	0.5	(2.0)	3.0	(7.0)
	Rovral	0.0	(0.0)	1.0	(4.1)	0.0	(0.0)	0.5	(2.0)
3. Benlate (FSx4)	No dip	6.0	(13.7)	30.5	(33.4)	2.5	(6.4)	2.0	(5.8)
	Benlate	8.0	(15.3)	19.0	(24.5)	5.5	(11.5)	1.0	(4.1)
	Rovral	0.5	(2.0)	2.0	(4.1)	1.0	(4.1)	1.0	(2.9)
4. Octave (FSx4)	No dip	2.0	(5.6)	17.0	(2.0)	0.5	(2.0)	2.5	(7.8)
	Benlate	2.0	(5.6)	13.0	(5.6)	2.0	(5.6)	2.5	(6.4)
	Rovral	0.5	(2.0)	2.0	(2.0)	0.5	(2.0)	0.5	(2.0)
5. Rovral (FSx4)	No dip	2.5	(6.4)	26.5	(5.8)	2.0	(5.8)	1.0	(4.1)
	Benlate	1.0	(4.1)	30.0	(2.0)	0.5	(2.0)	2.0	(7.0)
	Rovral	0.0	(0.0)	5.5	(0.0)	0.0	(0.0)	1.5	(4.4)
6. Bravo 500 (FSx4)	No dip	2.5	(6.1)	26.5	(7.7)	3.5	(7.7)	2.0	(5.6)
	Benlate	2.0	(7.8)	36.5	(6.1)	2.5	(6.1)	2.0	(5.6)
	Rovral	0.0	(0.0)	2.5	(7.0)	2.0	(7.0)	3.0	(9.6)
LSD (P = < 0.05) to compare the different field treatments			(8.9)		(9.7)		(7.7)		(8.7)
LSD (P = < 0.05) to compare the dip treatments within each field treatment			(8.3)		(8.1)		(8.5)		(8.3)

Figures in parentheses refer to angular transformation of raw data.

FS = Foliar sprays