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The results and conclusions in this report are based on a series of experiments conducted over a one year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

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

Dr T M O'Neill
Plant Pathologist
ADAS Arthur Rickwood

Signature .... Date ....

Report authorised by:

Dr M Heath
Team Manager
ADAS Arthur Rickwood

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CONTENTS

PRACTICAL SECTION FOR GROWERS

Commercial benefits of the project

This project has identified fungicide products and programmes for effective control of rusts with minimum risk of phytotoxicity on a range of rust-susceptible bedding plant species. Commercial exploitation of the results by growers can be made now as many of the treatments are covered by Specific Off Label Approvals (SOLAs), or permitted by extrapolation under the Revised Long Term Arrangements for Extension of Use - 2000.

Background and objectives

Several of the most popular species of bedding plants are susceptible to rust diseases. Rust-affected plants suffer from reduced quality and/or a lack of vigour, and if severely affected may even die. Because there can be a considerable period from the time a plant is first infected to the production of symptoms, there is great potential for the spread of rust diseases between nurseries on infected but symptomless plants and cuttings. The commercial objective of this project was to devise fungicide programmes which, in addition to giving effective disease control, also minimise the risk of the rust fungi developing fungicide resistance, and have no deleterious effect on crop growth.

Work completed in previous years

<u>Literature review: 1999/2000</u>

The symptoms and life-cycles of the rust diseases of the following host plants are described:

Pelargonium (*Puccinia pelargonii-zonalis*)
Fuchsia (*Pucciniastrum epilobii*)
Bellis (*Puccinia distincta*, *Puccinia obscura*, *Puccinia lagenophorae*)
Antirrhinum (*Puccinia antirrhini*)
Dianthus (*Uromyces dianthi* (carnation/pinks), *Pucinnia arenariae* (sweet william))
Chrysanthemum (*Puccinia horiana* (white rust), *Puccinia chrysanthemi* (brown rust))
Cineraria (*Puccinia lagenophorae, Coleosporium tussilaginis*)

Symptoms are variable according to the host plant, but commonly pustules are produced containing large numbers of spores which may be yellow, orange, brown or black in colour. The pustules are invariably produced on the leaves, but other parts of the plant (e.g. stems, flower parts) may be affected on some hosts. The disease not only affects the aesthetic quality of the plants but can also reduce vigour and occasionally result in death.

The spores are usually splash-dispersed and/or carried on air currents, and in this way spread the disease throughout the growing house. Research has shown that the spores of most bedding plant rusts can survive for weeks or sometimes even months on detached leaves. The spores can be carried great distances on the wind, and long-distance spread via this means is possible. However, with most of the rusts a more common cause of long-distance spread is the transport of infected plants or cuttings. These may be carrying the disease in a latent (symptomless) state. Depending on the environmental conditions, symptoms may not be produced until several weeks after infection has taken place.

Environmental conditions which are conducive to infection also vary somewhat between the different rust species, but a critical factor is the presence of free water on the leaf surfaces. If this is present, and other criteria such as a suitable temperature are satisfied, rust spores on the leaf surface can germinate and infect the plant, usually through the stomata. Germination and infection can occur in just a few hours.

The life-cycles of the rusts also vary. The majority spend their entire life on a single host (e.g. pelargonium rust, antirrhinum rust, the chrysanthemum and dianthus rusts). Others, such as fuchsia rust, have a life-cycle which includes a second, and usually totally unrelated plant (known as the alternate host).

Cultural control methods for rusts on bedding plants aim to try and prevent the conditions (leaf wetness being the most important) which lead to infection. Strict hygiene, to try and prevent the carry-over of the disease on a nursery, is also important, as is the need to maintain disease-free stock plants. Heat treatment has been used in an attempt to eradicate rusts from plant material, but although this proved successful in experiments it has not been adopted on a commercial scale. Similarly, attempts at the biological control of rusts have not led to any techniques that are used commercially.

Attempts to breed disease resistance into plants have also met with mixed fortunes, with antirrhinum rust in particular gaining the upper hand over the plant breeders. There are differences in disease susceptibility between cultivars of many of the bedding plant species, however, and these are summarised in the full review available from the HDC office.

Work on the fungicidal control of each of the rusts is summarised. Resistance to oxycarboxin (Plantvax 75) has been documented in the carnation rust *Uromyces dianthi*, and resistance to benodanil, oxycarboxin, bitertanol, triforine, propiconazole and myclobutanil in the chrysanthemum white rust *Puccinia horiana* (resistance to propiconazole and myclobutanil having just been reported in the UK). Details are given of all the fungicides available in the UK which should have some activity against rusts and which are permitted for use on protected bedding plants (Annual Report March 2001).

Recent research has shown that a rust which was previously unknown in the UK has caused serious problems on cultivated Bellis, and can also affect wild daisies. This rust, *Puccinia distincta*, has a life-cycle which lends itself to a rapid increase in disease levels under suitable conditions. However, the fungicide myclobutanil (Systhane 20 EW) was found to have extremely good activity against the disease, when applied as either a preventative or an eradicant treatment. Indeed, this fungicide has given effective control of all the bedding plant rusts against which it has been tested (with the exception of the chrysanthemum white rust resistance problem mentioned above).

<u>Crop safety trials: 2000</u>

The crop safety of ten fungicides was assessed on seven different bedding plant subjects (Antirrhimum, Bellis, Chrysanthemum, Cineraria, Dianthus, Fuchsia and

Pelargonium). Two sprays of each of the fungicides were applied, with a seven day interval between them. The first spray was applied during hot, sunny conditions, the second during cooler, cloudy conditions.

Most of the fungicides caused little or no damage to the plants, even when applied at double the recommended rate. However, scorch symptoms were produced on some of the plants from the first application of Amistar (azoxystrobin), Twist (trifloxystrobin), Nimrod-T (bupirimate + triforine) or Plantvax 75 (oxycarboxin). No damage was caused by the second applications of these products.

The second application of Alto 240EC (cyproconazole) resulted in severe damage symptoms on a range of plant types. A specific effect of fungicides from the triazole group (Alto 240 EC (cyproconazole), Tilt 250EC (propiconazole), Plover (difenoconazole) and Systhane 20EW (myclobutanil)) was noted on Fuchsia, consisting of distortion and thickening of young leaves. Application of Twist (trifloxystrobin) to Fuchsia resulted in a change in flower shape (later experiments showed that this may have been a specific effect on the variety used in the crop safety experiment).

There were few significant effects of the fungicides on either plant height or dry weight. In an observation trial to assess the effect of compost drenches of Plantvax 75 (oxycarboxin), damage symptoms were produced on most of the plant types.

<u>Fungicide efficacy trial: 2000</u>

This was assessed using the rusts of Bellis (*Puccinia distincta*), Fuchsia (*Pucciniastrum epilobii*) and Pelargonium (*Puccinia pelargonii-zonalis*). The strobilurin fungicides, Amistar (azoxystrobin) and Twist (trifloxystrobin), performed well as protectants against all three of the rusts. They were less effective at eradicant activity when applied shortly after the plants had been inoculated with the rusts.

Three fungicides from the triazole group (Plover (difenoconazole), Systhane 20EW (myclobutanil), Tilt 250EC (propiconazole)) showed excellent activity against Bellis and Fuchsia rusts, as both protectants and eradicants. Their performance against Pelargonium rust, however, was poor, particularly when they were used as protectants. Nimrod-T (bupirimate + triforine) and Plantvax 75 (oxycarboxin) also gave useful reductions in disease levels, but Dorado (pyrifenox) did not perform well.

Specific objectives for 2001

This year, the objective was to devise and evaluate fungicide programmes based on the 'modern' fungicides which performed well in trials in 2000, combined with older, broad-spectrum fungicides (e.g. mancozeb, chlorothalonil) with an inherently low risk of fungicide resistance.

Summary of results and conclusions - 2001

Fungicide programmes trial: 2001

A range of fungicide treatments and programmes were assessed for control of rusts on Bellis (*Puccinia distincta*), Fuchsia (*Pucciniastrum epilobii*) and pelargonium (*Puccinia pelargonii-zonalis*). Inoculation was successful and all three rusts established on untreated plants. Rust occurred first on the Bellis and soon affected most untreated plants; rust was slowest to develop on the Pelargonium but was severe on untreated plants by the end of the trial.

Four 2-spray treatments were tested. Amistar and Plover, which both performed well in the autumn 2000 trial, gave very good control of all three rust diseases. Treatments consisted of repeat sprays of Plover or Amistar 26 days apart with the first spray applied as a preventative treatment. These results demonstrated the effectiveness of some of the newer fungicides against rust diseases even where there is continuing disease pressure (3 inoculations in this instance). A 2-spray treatment of the older fungicide Karamate Dry Flo (mancozeb), at the same timings, gave noticeably poorer control of rust on both Bellis and Pelargonium than the Amistar and Plover. It is not advocated that such single product treatments are used as programmes on commercial crops because of the risk of selecting resistant pathotypes (see Action Points, below); they were used here for the experimental purpose of testing the performance of newer fungicides at an extended spray interval.

Six alternating 3-spray programmes were also tested, with the fungicides applied at 18 day intervals. The first spray was applied before the plants were inoculated with rust spores. Five of the programmes gave good control of all three rust diseases for the duration of the trial. The two most effective programmes (equally so) were Amistar/Karamate/Plover and Plover/Karamate/Amistar, resulting in no rust on Fuchsia and Pelargonium and less than 0.1% leaf area affected on the Bellis.

A programme consisting of 3 sprays of a biocontrol product significantly reduced the severity of Pelargonium rust. A 2-spray programme of Plover and Amistar, with the first spray applied on initial symptoms and the second spray 7 days later, significantly reduced rust on Bellis and Pelargonium.

Crop safety results: 2001

Torch resulted in brown leaf spotting on Bellis, which appeared 7 days after the first spray and increasing in severity with subsequent sprays. This same active ingredient (spiroxamine) has previously been found to cause brown leaf spotting on outdoor Solidago (see HDC report BOF 44). In this trial it also caused slight spotting on the Fuchsia. It is recommended that this active ingredient is not used on any bedding plants because of the risk of severe crop damage. Elsewhere in the fungicide programmes trial, symptoms of slight leaf distortion were observed on occasional Fuchsia plants in plots treated with Plover followed by Amistar 7 days later.

In a separate phytotoxicity trial, three programmes which performed well against rust on Bellis, Fuchsia and Pelargonium were tested for crop safety to Antirrhinum, Cineraria, Chrysanthemum and Dianthus. These were: Amistar/Karamate/Plover;

Plover/Karamate/Amistar and Bravo/Systhane 20EW/Thianosan DG. Fungicides were applied at the same rates as previously but at 7 day intervals. No phytotoxic symptoms were observed on any of the species. There was no statistically significant effect from the fungicide programmes on plant height or dry weight 14 days after the third spray.

Action points for growers

1. *Which fungicides*
   The fungicides listed in Table A1 are currently permitted on protected bedding plants, and should be considered in fungicide programmes directed at control of rust diseases. For ease of reference in devising low-resistance risk programmes, they are grouped according to the chemical type of fungicide. When devising programmes, choose products from more than one group. Make full use of multi-site fungicides such as chlorothalonil, mancozeb and thiram which are less prone to resistance, particularly in any protectant programme. See also Action Point 8.

2. *Crop safety*
   The results of the crop safety experiments showed that the majority of the fungicides were safe to the majority of plant subjects when used at recommended rates. However, care should be taken to apply the fungicides during appropriate environmental conditions (i.e. avoid hot, sunny or very bright conditions). A summary of instances where we observed crop damage is given in Table A2. Photographs of symptoms are given in the March 2001 Annual Report.

3. *Do not use drench treatments*
   Plantvax 75 should not be used as a drench treatment on bedding plants. It caused obvious crop damage to most of the plant species on which it was tested. When applying Plantvax 75 as a spray treatment, take care not to spray beyond the point of run-off.

4. *Test treat first*
   Because of the large number of different species and varieties grown, which may differ in susceptibility to crop damage, it is recommended that a small batch of plants is tested initially before a treatment is used widely on a species or variety for the first time. Note that number of applications, the weather at time of application and the 'softness' of plant growth may all influence the risk of crop damage.

5. *Protectants and eradicants*
   Amistar works extremely well as a protectant product. It also shows some eradicant activity, but should not be relied upon to control existing rust infections.

   Plover and Systhane can be used as both protectants and eradicants against Bellis and Fuchsia rust. There is some potential for crop damage from these products on Fuchsia, so they should be used with care.

   Plantvax 75 and Nimrod-T gave useful reductions in disease, and should be considered as part of a rust control programme (particularly protectant programmes). Plantvax 75 is particularly useful as it belongs to a different chemical group from both Amistar and Plover/Systhane.

If rust occurs and no protectant sprays have been applied, consider treatment with Plover followed by Amistar 7 days later. This eradicant treatment worked well on Bellis and Pelargonium in this project.

6. *Successful programmes*
   Programmes of fungicides which performed well against Bellis, Fuchsia and Pelargonium rust and were crop-safe to these species and also to Antirrhinum, Cineraria maritima, pot Chrysanthemum and Dianthus were:

   Amistar/Karamate Dry Flo/Plover
   Plover/Karamate Dry Flo/Amistar
   Amistar/Plover/Amistar
   Bravo/Systhane 20 EW/Thianosan

7. *Activity on other rust diseases*
   Differences in the performance of the fungicides against the different rusts were sometimes noted. Check carefully on the level of control achieved when using fungicides against rust diseases of bedding and pot plant species other than those described in this report.

8. *Avoiding resistance to strobilurin fungicides*
   The strobilurin fungicide (Amistar) gave excellent control with no obvious detrimental effects on the varieties used. This product and others in the strobilurin group of fungicides are single-site inhibitors and there is a risk that resistant rust strains could develop (this has already happened with chrysanthemum white rust). In order to prevent this, the following guidelines, issued by the Fungicide Resistance Action Committee (FRAC) should be followed:

   (i) Strobilurins should be used where possible as preventative treatments.
   (ii) Strobilurins should be applied at the manufacturer's recommended rates.
   (iii) Strobilurins should not constitute more than 30% to 50% of the total number of fungicide applications made to the crop in one season (strobilurin spray numbers should move to the lower limit when the total number of fungicide sprays made to the crop exceeds 8).
   (iv) Strobilurins should be used in blocks of 1 to 3 consecutive applications.
   (v) Where blocks of 2 or 3 strobilurins are applied, they should be separated by a minimum of 2 applications of fungicide from a different cross-resistance group.
   (vi) For perennial crops or where crops are grown successively, alternation of programmes should continue between seasons and between crops respectively.
   (vii) These recommendations apply to strobilurins used alone or in formulated or tank mixtures with chemicals from other fungicide groups designed to increase the level or spectrum of disease efficacy.

Table A1: Fungicides with rust activity currently permitted on protected bedding plants and used in this project[a]

Products (arranged in fungicide groups)	Active ingredient	Standard spray rate[b]	Comment [c]
Amistar	azoxystrobin	1.0 ml/l	Modern, broad-spectrum protectant. SOLA 1536/2000
Plover Systhane 20EW Tilt 250 EC Dorado	difenoconazole * myclobutanil * propiconazole * pyrifenox	1.0 ml/l 0.45 ml/l 0.40 ml/l 0.25 ml/l	SOLA 1729/97 SOLA 1881/99. Expires 25/7/03 SOLA 1388/97 Approval expires 31/7/02
Karamate Dry Flo	mancozeb	1.2 g/l	Protectant. Multi-site fungicide
Unicrop Thianosan DG	thiram	4.0 g/l	Protectant. Multi-site fungicide
Plantvax 75[d]	oxycarboxin *	0.5 g/l	Do not use as a drench treatment except where stated. A higher rate is recommended on chrysanthemum
Nimrod-T	bupirimate * + triforine *	3.2 ml/l	Moderate activity; generally less effective than triazole and strobilurin fungicides in our trials
Bravo 500	chlorothalonil	2.2 ml/l	Protectant. Multi-site fungicide. Other products based on chlorothalonil also available.

[a] Other products with rust activity are listed in Tables 2 and 3 of the first Annual Report, (March 2001), which also provides more information on the products listed above. See also HDC Factsheet 23/00.

[b] Always read and follow the label or SOLA instructions.

[c] See Table A2 for a summary of crop species/varieties where crop damage was observed in this project following fungicide treatment.

[d] This product is not being supported for Annex 1 listing in the EC review Programme. However, a document has been submitted to PSD seeking essential use justification for continued use on protected ornamentals.

* Systemic activity.

Table A2: Summary of fungicides tested indicating combinations where crop damage was observed[a]

Fungicide[b,c]	Rate used	Antirrhinum 'Chimes'	Bellis -	Chrysanthemum 'Bravo'	Cineraria 'Silver Dust'	Dianthus 'Strawberry Parfait'	Fuchsia 'Beacon Rose'	Pelargonium 'Maverick Red'
<u>Spray treatment</u>								
Alto 240 EC	0.33 ml/l	None ***	None **	None **	None *None*	None *None*	** **	None *
Amistar	1.0 ml/l	** *None*	None *None*	None *None*	None *None*	** *None*	None *None*	None *None*
Dorado	0.25 ml/l	None *None*	None *None*	None *None*	None *None*	None *None*	None *None*	None *None*
Nimrod-T	3.2 ml/l	* *None*	None *None*	None *None*	None *None*	** *None*	None *None*	None *None*
Plantvax 75	0.5 g/l	(*) *None*	None **	None ***	None ***	None *None*	None *None*	None *None*
Plover	1.0 ml/l	None *None*	None *None*	None *None*	None *None*	None *None*	* *	None *None*
Systhane 20 EW	0.45 ml/l	None *None*	None *None*	None *None*	None *None*	None *None*	** **	None *None*
Tilt 250 EC	1.0 ml/l	None (*)	None *None*	None *None*	None *None*	None *None*	** ***	None *None*
Torch	1.5 ml/l	NT NT	** ***	NT NT	NT NT	NT NT	* **	None *None*
Twist	1.0 ml/l	(*) *None*	None *None*	(*) *None*	None *None*	** *None*	None *[d]	None *None*
Kif 3535 (experimental)	0.8 g/l	None *None*	None *None*	None *None*	None *None*	None *None*	None *None*	None *None*
<u>Drench treatment</u>								
Plantvax 75	0.5 g/l	***	***	***	**	**	None	***

(*) No damage when tested at normal rate; damage seen when tested at double rate; * - slight damage (e.g. droplet scorch); ** - moderate damage (e.g. young leaves distorted); *** - severe damage (e.g. necrosis, loss of growing point); NT – not tested

[a] Assessed after the first spray (top line) or the *second spray* (bottom line).

[b] Two applications were made 7 days apart, 3 weeks after potting. The first spray was applied (deliberately) on a hot, sunny day; the second on a cool, cloudy day.

[c] The severity of damage on fuchsia caused by triazole fungicides was: Tilt >> Alto > Systhane 20EW> Plover.

[d] Elongated flower petals; no foliar symptoms.

Anticipated and practical financial benefits

The value of the UK bedding plant industry in 1998 was approximately £150 million (MAFF Basic Horticultural Statistics 1988-1998). The value of Pelargonium crops alone was £11.5 million, and that of Fuchsias £5.5 million. Losses due to rust diseases are variable, but probably average from two to five per cent overall of those crops susceptible to the disease. However, some Bellis crops have suffered severe losses due to rust, and this work has shown that total crop loss could occur where plants remain untreated. Heavy losses have also been reported in some Fuchsia crops.

These experiments have identified fungicides which give effective control of rusts, and which can be used legally by growers of protected bedding and pot plants. Effective fungicides have been identified from a number of different chemical groups, and programmes suggested which should help prevent the development of fungicide resistance in the rusts.

SCIENCE SECTION

INTRODUCTION

Fungicide products which gave effective control of rust diseases in the year 1 trial, and which produced nil or very slight phytotoxicity in that trial, were selected for use in the fungicide spray programmes trial in year 2 (2001). A wide range of chemicals from different fungicide groups were chosen, in order to be able to devise programmes with a low risk of selecting resistant strains of rust fungi. Some of the older, broad-spectrum multi-site fungicides (e.g. mancozeb, thiram, chlorothalonil) with an inherently low resistance risk were deliberately chosen for this purpose. Additionally, this trial was used to evaluate: two treatments not previously tested (the fungicide 'Torch', and a biological control agent ('BCA')); extended interval spray-programmes; and a 2-spray eradicant programme, commencing at the first sign of rust.

A second trial was conducted to test the crop-safety of some of the best programmes from the above work on a further four rust-susceptible bedding plants, namely Antirrhinum, Cineraria maritima, Chrysanthemum and Dianthus.

MATERIALS AND METHODS

Evaluation of fungicide programmes

Fungicide programmes consisting of two and three sprays were tested for control of rust on Bellis, Fuchsia and Pelargonium.

<u>Crop production</u>

Experiments were undertaken in glasshouse compartments at ADAS Wolverhampton. The varieties used were Bellis 'Mixed'; Fuchsia 'Winston Churchill' and Pelargonium 'Pink Satisfaction'. Plug plants were potted into Optipot 7M pots using Levington M2 compost and placed on capillary matting on the glasshouse bench on 12 April 2001. Each plot consisted of a separate, isolated section of matting, watered individually via a trickle-pipe leading from a central irrigation line. In this way, the risk of cross-contamination between fungicide treatments by capillary movement of chemicals in water was avoided. Plants were also watered daily from overhead to help maintain an environment conducive to rust development. The temperature of the glasshouse compartments was maintained around 18-20^0 C, as far as possible.

<u>Preparation of rust inoculum</u>

Bellis, Fuchsia and Pelargonium plants each affected by rust (*Puccinia distincta, Pucciniastrum epilobii* and *Puccinia pelargonii-zonalis* respectively) were maintained in a controlled environment cabinet. A high humidity was used to promote severe disease development. When spores were required, rust-affected leaves of each species were individually collected, placed in a Petri-dish of de-ionised water, and the spores dislodged with a paint brush. After agitation, the spore concentrations were calculated using a haemocytometer and adjusted to 5-10 x 10^3 spores/ml.

Inoculation of plants

Spore suspensions were applied using a Cooper-Pegler Minipro sprayer, spraying plants to the point of run-off. On each bench, a sheet of black polythene was laid over the plants immediately after treatment and left in position for 18 hours to prevent the applied spore suspension drying out. It was then removed and the plants were fogged daily, around 10 minutes per hour from 9 pm to 7 am. The fogging regime was maintained throughout the duration of the trial following the first application of rust spores. Plants were inoculated with rust spores on three occasions, at 9 days after each fungicide treatment date.

Fungicide treatments

The fungicides were applied to the plants *in situ*, using a sprayer with a single nozzle producing a spray pattern sufficient to treat the plants in a single plot. Boards were placed on each side of the plot being treated, to prevent spray drift to adjacent plots.

The rates of each of the fungicides used is given below. Control treatments were sprayed with water. The aim was to thoroughly wet the foliage, but to avoid excessive dripping of the fungicides onto the compost (which could lead to unwanted phytotoxicity symptoms via root uptake).

Product name	*Active ingredient*	*Rate*	*Approval status*
Amistar	azoxystrobin	1.0 ml/l	Approved*
Bravo 500	chlorothalonil	2.2 ml/l	Approved
Karamate Dry Flo	Mancozeb	1.2 g/l	Approved
Nimrod-T	bupirimate + triforine	3.2 ml/l	Approved
Plover	difenoconazole	1.0 ml/l	Approved*
Systhane 20EW	myclobutanil	0.45 ml/l	Approved*
Torch	spiroxamine	1.5 ml/l	Not approved
Unicrop Thianosan DG	Thiram	4.0 g/l	Approved
Biological control agent (BCA)	-	1% w/v	Not approved

* Off-label use under a SOLA permissible under the Revised Long Term Arrangements for Extension of Use (2000).

Plants were inoculated with rust on days 10, 28 and 46 and the programmes as follow were applied:

Treatment	Day 1	Day 19	Day 37
1.	Water	Water	Water
2.	Amistar	Water	Amistar
3.	Plover	Water	Plover
4.	Torch	Water	Torch
5.	Karamate	Water	Karamate
6.	Karamate	Bravo 500	Karamate
7.	Amistar	Karamate	Plover
8.	Plover	Karamate	Amistar
9.	Amistar	Plover	Amistar
10.	Amistar	Nimrod-T	Bravo 500
11.	Bravo 500	Systhane 20 EW	Thianosan
12.	BCA	BCA	BCA
13.	Plover at first sign of rust on any plant within the treatment, plus Amistar 7 days later.		

<u>Assessments and records</u>

A study diary was kept, detailing the dates of all treatment applications, assessments, etc. Plants were checked regularly for the first occurrence of rust on each species. Two full assessments of rust were made, at approximately half way through the trial and 2 weeks after the final spray. Assessments were:

1. Number of plants of each type affected by rust.
2. Percentage leaf area affected (the leaves to be assessed were decided when the pattern of disease development was known). Where disease has developed on only one or two leaves per plant, and the age of these leaves varied between plants, the total number of pustules per plant was counted.

Symptoms of phytotoxicity developing during the trial were also recorded.

<u>Experiment design and statistical analysis</u>

The trial consisted of a randomised block split-plot design with four replicate blocks. There were eight replicates of the untreated control. The trial was split between two glasshouse bays, with each bay holding two blocks. Each block occupied two adjacent benches. The three plant types within each replicate of the fungicide treatments were grouped together; there was randomisation of the plant types within each plot. Results were examined by Friedman's test as the data were predominantly low counts and unsuitable for ANOVA.

There were six plants per bedding plant type per replicate, giving a total of 336 plants of each type (6 plants x 14 fungicide treatments (including a double control) x 4 blocks), or 1008 plants in total.

Diary of events 2001

Day 1	(spray 1)	17 April
Day 10	(inoculate 1)	26 April
Day 19	(spray 2)	5 May
Day 24	(T13 spray)	10 May
Day 28	(inoculate 2)	14 May
Day 31	(T13 spray)	17 May
Day 37	(spray 3)	23 May
Day 44	(assessment 1)	30 May
Day 46	(inoculate 3)	1 June
Day 70	(assessment 2)	25 June

Treatment 13 (T13) sprays were applied at first symptoms and 7 days later.

Phytotoxicity of fungicide programmes

Three of the fungicide programmes which performed well in the above experiment were tested for phytotoxicity against four additional, rust-susceptible bedding plants species. These were:

Antirrhinum - 'La Bella'
Chrysanthemum - 'Charm' and 'Swingtime'
Cineraria maritima - 'Silver Dust'
Dianthus - 'Strawberry Parfait'

The plants were not inoculated with rust.

Crop production

The Cineraria and Dianthus were grown from plug plants in Optipot 7M pots in Levington M2 compost; the Antirrhinum were grown in six-packs; the Chrysanthemum were grown in 13 cm half-pots (5 cuttings/pot). Plant production was on capillary matting on benches as previously described. No insecticides or growth regulators were used.

Fungicide programmes

1. Untreated control
2. Amistar / Karamate / Plover
3. Plover/Karamate/Amistar
4. Bravo / Systhane 20EW / Thianosan DG

Fungicides were applied at the same rates and by the same method as used in the initial experiment, except that the spray interval was reduced to 7 days.

Assessments

Plants were examined for any evidence of phytotoxicity immediately before the second and third sprays and two weeks after the final spray. Maximum plant height was measured. Leaf chlorosis was assessed on a 0 to 10 decimal incremental scale. Dry weights of the above ground parts were determined after the final phytotoxicity assessment.

Experiment design and statistical analysis

The trial consisted of a split-plot randomised block with four replicates and occupied four benches of a glasshouse compartment (1 block/bench). Position of each plant species was randomised within the plot. There were 6 Cineraria, 6 Dianthus, 6 Antirrhinum and 2 pots of Chrysanthemum per plot. Results on plant height and dry weight were examined by analysis of variance; results on leaf chlorosis by Friedman's test.

Diary of events 2001

Day 1	(spray 1)	13 July
Day 8	(spray 2)	20 July
Day 15	(spray 3)	27 July
Day 28	(final assessment)	9 August

RESULTS AND DISCUSSION

Evaluation of fungicide programmes

Rust development

The inoculation procedure was successful and rust developed on all three species. It was first observed on the Bellis on 10 May, 14 days after inoculation, when it was noted in 17 of 56 plots. Sixteen of these plots were untreated with fungicide, one had been treated with Karamate. Rust was first observed on the Fuchsia on the same date (two untreated plots) and on the Pelargonium four days later. The general development of rust in the trial is summarised in Table 1. Detailed results according to fungicide treatment are given later.

Table 1. No of plots with plants affected by rust at intervals after the first inoculation (26 April)

No. plots with rust affected plants (of 56)	Days after inoculation					
	12 (8 May)	14 (10 May)	15 (11 May)	18 (14 May)	20 (16 May)	22 (18 May)
Bellis	0	17	21	24	24	24
Fuchsia	0	2	4	14	15	15
Pelargonium	0	0	0	11	15	18

Generally, rust was most severe on the Bellis, causing leaf yellowing, distortion and eventually plant collapse. On the Fuchsia, active rust sporulation was sparse with grey-brown, irregular-shaped lesions suggestive of rust attack also present. Sporing and non-sporing rust were scored separately. On the Pelargonium, typical dark-brown concentric zones of rust pustules developed.

Fungicide efficacy

An initial assessment was made on 30 May, 1 week after the final fungicide treatment and 16 days after the second inoculation of plants, with rust spores. At this stage, it would be expected that symptoms from the second inoculation would be apparent where the treatments had failed to control the disease. Results are shown in Tables 2 and 3.

The incidence and severity of rust was greatest on untreated plants of all three species. Mean disease incidence (Table 2) was greatest on Bellis (5.5) and was reduced to zero by six treatments. Disease severity was also greatest on Bellis (Table 3), where all fungicide treatments reduced the mean number of pustules from 19.2 to less than 2. The two-spray Karamate programme (treatment 5) was the least effective fungicide programme. The two-spray 'first symptoms' programme of Plover followed by Amistar 7 days later worked very well. The BCA appeared to reduce the severity of Bellis rust although it was not as effective as the fungicide treatments. Disease severity on the Fuchsia and Pelargonium was less and there were no statistically significant differences between treatments. Programmes which appeared slightly more effective were the 2-spray Plover programme, Amistar/Plover and

Bravo/Systhane 20EW/Thianosan.

A second full assessment was made on 25 June, 24 days after the final inoculation with rust and 33 days after the final fungicide treatment. By this time, approximately 50% of untreated Fuchsia plants and most untreated Pelargonium plants were affected by rust (Table 4). The incidence of affected Bellis plants appeared to have decreased from the earlier assessment. This was because of the collapse and subsequent bacterial soft rot of severely affected plants.

On Bellis, all the treatments reduced disease severity compared with the untreated, except for the 2-spray Karamate programme, the 3-spray Karamate/Bravo/Karamate programme and the BCA treatment.

On Fuchsia, the mean number of pustules was low (due largely to severely affected leaves falling off) and although there were statistically significant differences between fungicide treatments (Table 5) it was difficult to separate them.

On Pelargonium, there was a high number of pustules on untreated plants (28.2), which was reduced to less than 5.0 by all programmes, including the Plover/Amistar first symptoms programme and the BCA treatment.

Five programmes (Amistar/ - /Amistar; Amistar/Karamate/Plover; Plover/Karamate/ Amistar; Amistar/Plover/Amistar and Amistar/Nimrod/Bravo) kept the Pelargonium completely free of rust symptoms (Table 5).

Table 2. Evaluation of fungicide programmes for control of rust on bedding plants - disease incidence, 30 May 2001

Treatment (3 timings at 18d intervals)	Mean no. plants affected (of 6)		
	Bellis	Fuchsia	Pelargonium
1. Untreated	5.5	2.3	1.5
2. Ami/-/Ami	0.8	0.5	1.3
3. Plo/-/Plo	0.3	0	0.5
4. Tor/-/Tor	0	1.5	1.8
5. Kar/-/Kar	1.0	0.8	2.0
6. Kar/Bra/Kar	1.0	0.5	1.0
7. Ami/Kar/Plo	0	1.3	0.3
8. Plo/Kar/Ami	0	0.8	0.8
9. Ami/Plo/Ami	0	0.3	0.5
10. Ami/Nim/Bra	0	1.3	0.8
11. Bra/Sys/Thi	0	0	0.8
12. BCA	4.3	1.5	1.5
13. Plo/Ami[a]	0.5	1.3	2.3
Significance (Friedman's test)	***	NS	NS

NS, no significant differences between treatments; *, ** and ***, significant at the 5%, 1% and 0.1% levels of probability.

[a]Programme of Plover (10 May), followed by Amistar (17 May), commencing at the first sign of rust.

Key to treatments: Ami-Amistar, Plo - Plover, Tor - Torch, Kar - Karamate Dry Flo, Bra - Bravo 500, Nim - Nimrod T, Sys - Systhane 20EW, Thi - Thianosan DG, BCA - biological control agent.

Table 3. Evaluation of fungicide programmes for control of rust on bedding plants - disease severity, 30 May 2001

Treatment (3 timings at 18d intervals)	Mean no. pustules[a]		
	Bellis	Fuchsia	Pelargonium
1. Untreated	19.5	1.9	2.2
2. Ami/-/Ami	0.4	0.2	0.5
3. Plo/-/Plo	0.2	0	0.1
4. Tor/-/Tor	0	0.3	4.5
5. Kar/-/Kar	1.4	0.3	0.9
6. Kar/Bra/Kar	0.6	0.3	0.4
7. Ami/Kar/Plo	0	0.3	0.1
8. Plo/Kar/Ami	0	0.2	0.2
9. Ami/Plo/Ami	0	0.1	0.1
10. Ami/Nim/Bra	0	1.0	0.2
11. Bra/Sys/Thi	0	0	0.3
12. BCA	6.8	1.3	0.6
13. Plo/Ami[a]	0.1	0.3	1.5
Significance (Friedman's test)	***	NS	NS

NS, not significant; *, ** and ***, significant at the 5%, 1% and 0.1% levels of probability.

[a] Assessed on youngest leaves 2 and 3 for Bellis; on whole plant for Fuchsia and Pelargonium.

Key to treatments: Ami-Amistar, Plo - Plover, Tor - Torch, Kar - Karamate Dry Flo, Bra - Bravo 500, Nim - Nimrod T, Sys - Systhane 20EW, Thi - Thianosan DG, BCA - biological control agent.

Table 4. Evaluation of fungicide programmes for control of rust on bedding plants - disease incidence, 25 June 2001

Treatment (3 timings at 18d intervals)	Mean no. plants affected (of 6)		
	Bellis	Fuchsia	Pelargonium
1. Untreated	3.0	3.4	5.2
2. Ami/-/Ami	1.8	0	0
3. Plo/-/Plo	0.3	0	0.3
4. Tor/-/Tor	0	1.0	3.3
5. Kar/-/Kar	3.5	0	2.8
6. Kar/Bra/Kar	4.8	0	0.5
7. Ami/Kar/Plo	0.5	0	0
8. Plo/Kar/Ami	0.5	0	0
9. Ami/Plo/Ami	0.5	0	0
10. Ami/Nim/Bra	1.8	0	0
11. Bra/Sys/Thi	1.8	0	2.8
12. BCA	2.3	0.5	3.3
13. Plo/Ami[a]	0.3	3.0	0.3
Significance (Friedman's test)	**	***	***

NS, not significant; *, ** and ***, significant at the 5%, 1% and 0.1% levels of probability.

Key to treatments: Ami-Amistar, Plo - Plover, Tor - Torch, Kar - Karamate Dry Flo, Bra - Bravo 500, Nim - Nimrod T, Sys - Systhane 20EW, Thi - Thianosan DG, BCA - biological control agent.

Table 5. Evaluation of fungicide programmes for control of rust on bedding plants - disease severity - 25 June 2001

Treatment (3 timings at 18d intervals)	Mean disease severity			
	Bellis	Fuchsia		Pelargonium
	(% leaf area)	(No. pustules)	(No. lesions)	(No. pustules)
1. Untreated	1.43	1.9	6.8	28.2
2. Ami/-/Ami	0.23	0	1.5	0
3. Plo/-/Plo	0.02	0	2.1	0.1
4. Tor/-/Tor	0	0.3	3.0	4.3
5. Kar/-/Kar	2.3	0	3.5	1.5
6. Kar/Bra/Kar	1.4	0	0.6	0.1
7. Ami/Kar/Plo	0.04	0	3.9	0
8. Plo/Kar/Ami	0.04	0	1.7	0
9. Ami/Plo/Ami	0.13	0	2.1	0
10. Ami/Nim/Bra	0.50	0	0.5	0
11. Bra/Sys/Thi	0.27	0	1.3	1.3
12. BCA	1.52	0.1	8.8	2.8
13. Plo/Ami[a]	0.02	1.5	7.7	0.1
Significance Friedman's test	**	***	**	***

NS, not significant; *, ** and ***, significant at the 5%, 1% and 0.1% levels of probability.

Key to treatments: Ami-Amistar, Plo - Plover, Tor - Torch, Kar - Karamate Dry Flo, Bra - Bravo 500, Nim - Nimrod T, Sys - Systhane 20EW, Thi - Thianosan DG, BCA - biological control agent.

Phytotoxicity

Most of the Bellis plants treated with Torch showed brown leaf spots and marginal necrosis and chlorosis when examined on 23 April, 6 days after the first application of this fungicide. The symptoms increased in severity with subsequent treatments, developing extensive areas of leaf scorch and secondary bacterial rotting. These symptoms were not observed on untreated plants, or plants treated with other fungicides.

By 1 May, a pale brown leaf spotting, with a red/dark brown margin, was also observed in many Fuchsia plants which had been treated with Torch. The Pelargoniums appeared to be unaffected by this chemical. At the final assessment on 25 June, in addition to the obvious damage caused by Torch, there was also evidence of damage to Fuchsias associated with Karamate (treatment 5) where it appeared to produce a slight leaf tip scorch on a few plants. No damage was observed on the Pelargonium from any of the treatments.

Three programmes which gave good control of rust on Bellis, Fuchsia and Pelargonium with no evidence of crop damage were tested for their safety to Antirrhinum, Cineraria, Chrysanthemum and Dianthus. The programmes caused no symptoms during the course of the trial, and had no significant effect on plant height, or mean dry weight (Table 6). Slight leaf chlorosis occurred in the Antirrhinum, Cineraria and Dianthus but it was not associated with fungicide treatment (Table 7).

Table 6. Effect of three fungicide programmes on plant height and dry weight of Antirrhinum, Cineraria, Chrysanthemum and Dianthus

Fungicide programme and crop growth	Antirrhinum	Cineraria	Chrysanthemum	Dianthus
1. Untreated	325.2	127.2	259.2	176.7
2. Ami/Kar/Plo	326.9	155.2	264.9	185.8
3. Plo/Kar/Ami	276.5	152.2	276.1	173.3
4. Bra/Sys/Thi	307.7	146.7	265.9	186.8
Significance (9 df)	NS	-	-	-
Mean dry weight/plot (g)				
1. Untreated	18.12	7.10	25.45	9.43
2. Ami/Kar/Plo	19.08	7.05	26.85	9.52
3. Plo/Kar/Ami	21.77	7.52	25.62	8.80
4. Bra/Sys/Thi	19.40	7.32	27.05	10.20
Significance (9 df)	NS	-	-	-

NS - no significant differences between means.

Table 7. Effect of three fungicide programmes on leaf chlorosis

Leaf chlorosis (0-10 index)				
1. Untreated	0.49	0.18	0	0.12
2. Ami/Kar/Plo	1.13	0.56	0	0.04
3. Plo/Kar/Ami	0.17	0.06	0	0.25
4. Bra/Sys/Thi	0.58	0.06	0	0.16
Significance (Friedman's test)	NS	NS	-	NS

NS - no significant differences between means.

CONCLUSIONS

1. Amistar and Plover again demonstrated to provide very good control of Bellis, Fuchsia and Pelargonium rusts.

2. Karamate Dry Flo alone, and a programme of Karamate and Bravo 500 provided moderate control of these rusts.

3. Torch caused obvious brown leaf spotting and severely damaged Bellis; it caused similar symptoms, to a lesser extent, on Fuchsia.

4. Programmes based on one or more of the newer rust fungicides (e.g. Amistar, Plover and Systhane) alternating with one or more of the older fungicides with low resistance risk (e.g. Karamate Dry Flo, Bravo 500 or Thianosan) provided good control with no evidence of crop damage on seven bedding plant species. Numerous permutations of newer rust fungicides with older, multi-site fungicides are possible, for example:

   Plover/Karamate/Amistar (then repeat the sequence)
   Amistar/Karamate/Plover
   Systhane/Bravo 500/Amistar

   These programmes are recommended as they are at low risk of selecting resistant pathotypes.

5. A 2-spray programme of Plover followed by Amistar 7 days later, commencing at the first appearance of rust, gave good control of rust on Bellis and Pelargonium.

6. An experimental biocontrol product significantly reduced the severity of rust on Pelargonium though not on Bellis.

TECHNOLOGY TRANSFER

HDC Grower Factsheet 23/00, summarising the results of the literature review, was written and published in September 2000.

The project was presented and discussed at an HDC Seminar on Bedding Plants R&D at HRI Wellesbourne on 26 October 2000.

Results of the project were presented at a meeting of the Midlands Bedding and Pot Plant Group on 30 January 2001.

A document was prepared and submitted to PSD, via HDC, seeking essential use justification for continued use of Plantvax on protected ornamentals. This became necessary following the decision of the manufacturer not to support the active ingredient for Annex 1 listing in the EC Review Program.

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