Project title:	Roses: Fungicides for the control of powdery mildew, black spot and rust
Project number:	HNS 106
Project leader:	C M Burgess, HRI Efford
Report:	Annual Report
Previous reports:	None
Key workers:	Mr C M Burgess, Project Leader (author of report) Mr R Goode, Scientific Support Mr T Clench, Scientific Support Mr T Hiscock, Nursery Staff Mr D Joblin, Nursery Staff Mr C New, Nursery Staff
Location:	Horticulture Research International Efford Lymington Hampshire SO41 0LZ Tel: 01590 673341 Fax: 01590 671553
Project co-ordinators:	Mr Clive Faulder, Burston Nurseries Ltd Dr Paul Sopp, Fargro Ltd Mr Paul Masters, Notcutts Nurseries Ltd
Date project commenced:	March 2000
Completion due:	February 2003 (following extension to project HNS 106)
Key words:	Rose, *Rosa*, disease, powdery mildew, *Sphaerotheca pannosa* var. *rosae*, *S. macularis*, black spot, *Diplocarpon rosae*, rose rust *Phragmidium mucronatum*, *P. tuberculosum*, fungicide, Folicur, tebuconazole, Lyric, flusilazole, Unix, cyprodinil, Amistar, azoxystrobin, Twist, trifloxystrobin, Torch, spiroxamine, Tern, fenpropidin, Indar 5EW, fenbuconazole, Tilt, propiconazole, Plover, difenoconazole, Flamenco, fluquinconazole, Stroby WG, kresoxim-methyl, Dorado, pyrifenox, Corbel, fenpropimorph, Systhane 20EW, myclobutanil, Nimrod T, bupirimate, triforine, F238, dodemorph, Bavistin DF, carbendazim, efficacy, phytotoxicity.

Whilst reports issued under the auspices of the HDC are prepared from the best available information, neither the authors or the HDC can accept any responsibility for inaccuracy or liability for loss, damage or injury from the application of any concept or procedure discussed.

© 2001 Horticultural Development Council
The contents of this publication are strictly private to HDC members. No part of this publication may be copied or reproduced in any form or by any means without prior written permission from the Horticultural Development Council.

The results and conclusions in this report are based on an investigation conducted over one year. The conditions under which the experiment was 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 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.

Contents

Practical Section for Growers

Commercial benefits of the project

At the end of the first year of this project, three new fungicides have been identified as giving significantly improved control of rose black spot and rose rust compared to some standard products used by growers. Folicur (tebuconazole), Lyric (flusilazole) and Twist (trifloxystrobin), when used as part of a rotational spray programme with other products, should extend and improve the armoury of fungicides available for outdoor crops of container and field grown roses against the most common foliar diseases.

Background and objectives

Three foliar diseases of garden roses of major importance in the UK, and which require regular fungicide spray programmes, are powdery mildew (*Sphaerotheca pannosa* var. *rosae* or *S. macularis*), black spot (*Diplocarpon rosae*), and rose rust (typically *Phragmidium mucronatum* on rose rootstocks and *P. tuberculosum* on flowering cultivars). Downy mildew (*Peronospora sparsa*), while becoming an increasingly important foliar disease of roses, is beyond the scope of this project. However, downy mildew on roses and other ornamentals has been investigated in other recent HDC projects (HNS 24, HNS 53), and its epidemiology is currently being examined in a MAFF project (HH1749SHN).

There are several fungicides with label approval for these three diseases, however growers often rely on good control from relatively few, such as Systhane 20EW (myclobutanil) and Nimrod T (bupirimate + triforine). Despite regular spraying, it is often difficult to maintain a high level of disease control, especially over a long growing season, and there is a risk of developing disease tolerance to the use of a limited range of fungicides. Serious disease infection in the field can cause winter deaths and 'spring dieback' after plants are containerised. In addition, market requirements demand that container crops are kept clean throughout production to the point of sale.

The two main objectives of the project are therefore:

1. To identify new effective and safe alternative fungicides that will improve disease control for roses.
2. Extend the range of fungicides available to growers for incorporation into spray programmes, which will help reduce the risk of fungicide resistance developing.

Summary of results and conclusions

Fungicides were selected from those approved for control of powdery mildew, rust and scab on cereals, other ornamentals and top fruit. Single active ingredient products were chosen from several different chemical groups including those from the DeMethylation Inhibitors (DMI) group (including triazoles), morpholine and related fungicides, and the new strobilurin type fungicides.

© 2001 Horticultural Development Council

Thirteen products were first screened for phytotoxicity using five rose cultivars: Dearest (floribunda), Warm Wishes (hybrid tea), Kind Regards (short floribunda), Sweet Dream and Gentle Touch (patio types). Products were applied as high volume sprays to run-off on containerised plants. Standard and double rate concentrations were compared, with standard rates extrapolated from field crop recommendations where no high volume recommendation existed. E.g. a standard rate of 1.0 ml/litre HV spray to run-off assuming a volume of 1000 litres/ha was based on a field crop recommendation of 1 litre/ha in a minimum of 200 litres / ha.

The phytotoxicity test was repeated in early and late summer, and no phytotoxicity symptoms were observed on any of the test chemicals at either rate, except with Tern (fenpropidin), a morpholine analogue fungicide. This caused some leaf scorch on all test cultivars in early summer, but particularly on cv. Kind Regards and cv. Warm Wishes. No damage was observed on the late summer test. The positive control treatment, using Corbel (fenpropimorph), caused scorch on all five cultivars at both rates and following both spray occasions.

Containerised plants of the disease susceptible cultivar Silver Wedding was used to test efficacy of six of the products, Folicur (tebuconazole), Lyric (flusilazole), Unix (cyprodinil), Amistar (azoxystrobin), Twist (trifloxystrobin), and Torch (spiroxamine) against a control treatment spray rotation of Systhane 20EW (myclobutanil), Nimrod T (bupirimate + triforine) and F238 + Bavistin DF (dodemorph + carbendazim). Standard and half rates at high volume were compared. Unsprayed plots were maintained in an area away from the main trial to monitor the natural build up of disease. Artificial inoculations of plots to ensure uniform and adequate disease pressure were carried out. This was very successful from spraying suspensions of black spot spores obtained from infected leaf material. Rose rust developed readily in the plots naturally, but powdery mildew did not establish, possibly because weather conditions were not favourable during 2000.

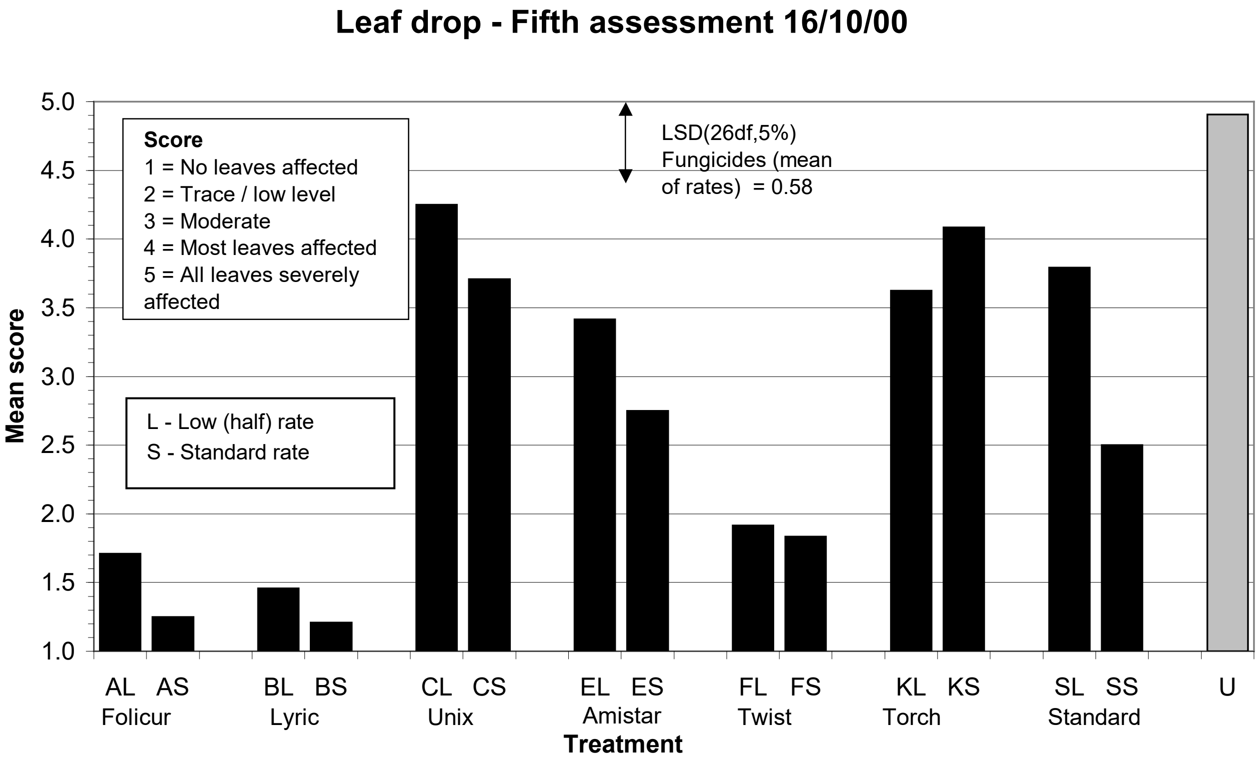
The efficacy experiment started with sprays at the first signs of disease in early June, and following a hard prune, was repeated on fresh growth in late summer/autumn with a second set of sprays starting in early August.

Two new conazole fungicides, Folicur and Lyric stood out as giving excellent control of both black spot and rust when used at the standard rates of 1.0 ml/litre and 0.625 ml/litre as HV sprays. They showed both curative and protective action, and were significantly better than the control treatment. Of the strobilurin products, Twist (standard rate 2.0 ml/litre) performed better than Amistar (standard rate 1.0 ml/litre). While these strobilurins did not show as good control as the conazoles when used once disease was present, they should offer better control when used as protectants within a spray programme with other chemicals. Additionally, they should also have activity against downy mildew, which will make them particularly useful as part of a spray programme to include this disease as well. Torch and Unix failed to give any useful control of black spot or rust.

© 2001 Horticultural Development Council

The combined effect of these two diseases on plants was clearly visible in the extent of leaf drop by the end of the growing season. The chart below summarises the efficacy of the different treatments.

Further work in this project will examine spray programmes, considering spray intervals, choice of product, and tank mixtures incorporating fungicides suitable for downy mildew control. The aim will be to maintain clean plants over the whole growing season, using an effective but economically acceptable spray programme. Efficacy of some of these promising products against powdery mildew will be examined in an experiment under protection, and others successfully screened for phytotoxicity, but not efficacy, in 2000 will be trialled further.



Action points for growers

Some caution is required in applying results after only a single year's results, but the following points can be made:

- Consider trialling Lyric, Folicur, Twist and Amistar in your spray programme using the standard rates referred to above.

- Lyric, Folicur and Twist can be used off-label on outdoor roses only, but Amistar could be used on roses under protection under the same conditions as its off-label approval for use on protected chrysanthemums. All sprays of these fungicides on roses are used at grower's risk, under the Revised Long-Term Arrangements for Extension of Use (2000).

- Although no phytotoxicity was observed in 2000 with these products on the five cultivars tested, there has been little or no commercial experience on roses and with other cultivars. Growers are therefore advised to undertake their own small-scale tests on a few plants of a range of their cultivars, before committing these products to large-scale use.

- Programme different fungicides in rotation to maximise their long-term efficacy, and to minimise the risk of disease tolerance developing. Do not use consecutive applications of the strobilurins but alternate them with fungicides from different chemical groups. Use a maximum of one strobilurin out of three fungicide applications. Do not use more than two conazole fungicide sprays (e.g. Systhane 20EW then Lyric) in succession.

Anticipated practical and financial benefits

- Development of alternative fungicide spray programmes.

- Extend the armoury of products available to the rose grower enabling a better choice of fungicides from different chemical groups to be used in programmes. This, in turn, will help prevent the development of fungicide tolerance by pathogens and extend the period over which they remain effective.

Improved control of rose black spot and rust, through the addition of these fungicides to grower's spray programmes will:

- Help maintain high quality containerised plants to the point of sale by reducing wastage and improving grade-out.

- Improve the quality of field grown roses. This in turn should help reduce establishment losses when plants are either planted out by the end user, or grown on as containerised stock by nurserymen.

- Treatment cost-benefits will be considered following work in 2001, when spray programmes are investigated in detail.

© 2001 Horticultural Development Council

Science Section

Introduction

Background

Three foliar diseases of cultivated rose are of major importance in the production of garden roses in the UK, and currently require regular fungicide spray programmes during production. These are powdery mildew (*Sphaerotheca pannosa* var. *rosae* or *S. macularis*), black spot (*Diplocarpon rosae*), and rose rust (typically *Phragmidium mucronatum* on rose rootstocks and *P. tuberculosum* on flowering cultivars). Fungicides for the control of downy mildew (*Peronospora sparsa*), while remaining an important foliar disease of roses, received attention through HDC projects HNS 24 and 53, and its epidemiology is currently being examined in MAFF project HH1749SHN. Evaluation of fungicide efficacy for downy mildew was beyond the scope of this project, although incorporation of downy mildew fungicides in spray programmes are being examined in follow-on work from that reported here.

Breeding and selection for durable disease resistance in roses is a long-term objective. However, many new cultivars, particularly within the popular HT, floribunda, shrub, climber and patio lines, are still susceptible to one or more of these diseases, as well as many of the older cultivars that are still grown because of popular demand. The main UK rootstock *Rosa* Laxa is also susceptible to both rust and powdery mildew. The use of an effective fungicide programme will therefore remain essential for rose production in the short to medium term.

Experience at Efford and elsewhere has shown that some cultivars can still develop foliar diseases late in the season, despite a regular spray programme. Although there are a number of fungicides approved for these diseases on roses, many growers are relying heavily on a few products such as Systhane 20EW (myclobutanil) and Nimrod T (bupirimate + triforine) for the most effective control. There is a risk that diseases will develop resistance to these products if overused, and so it is important to expand the armoury of effective fungicides.

There are many other fungicides, including some from other chemical groups, which have recommendations for the control of rusts and powdery mildew in cereals, or for powdery mildew and scab control in top fruit, which may have potential for use on ornamentals, including roses. Fortunately, provided the 'situation of use' conditions (ie outdoor or under protection, and method of application) are adhered to, it is not necessary to obtain a specific off-label approval (SOLA) for extending the use of these pesticides to ornamentals. However, it is important to realise that these off-label uses are at growers' own risk under the Revised Long Term Arrangements for Extension of Use (2000).

The most recent previous work in the UK on fungicides against these diseases was in the 1980's at Luddington EHS. This led to the label approval for Systhane. This report deals with results from the first year of a three year project.

© 2001 Horticultural Development Council

Objectives

The project's main commercial objectives were:

1 To identify new effective and safe alternative fungicides that will improve disease control for roses.

2 Extend the range of fungicides available to growers for incorporation into spray programmes, which will help reduce the risk of fungicide resistance developing.

Materials and Methods

Containerised roses were used for the project for practical and experimental reasons. This enabled workable sized plots and a sound replicated experimental design and layout to be used, and allowed a larger number of products to be tested. In addition, the tolerance criteria for diseases or phytotoxicity in containerised roses are stricter than for field roses, and it should be possible to readily extrapolate results to the field, even if application methods are different.

The project was divided into two main investigations – a phytotoxicity screening, to determine safety of products to the crop, and an efficacy trial to determine activity of each individual product against the three diseases.

Most new candidate fungicides were selected from the same chemical groups as the majority of effective existing products used on roses. These included the DeMethylation Inhibitors (DMI's which include the triazole, conazole, pyrimidine, pyridine and piperazine sub-groups), and morpholine groups. However, it is known that there are major differences in the activity of different DMI fungicides against specific pathogens, so it was necessary to investigate other DMI's for rose diseases. Strobilurin type compounds are a relatively new group of fungicides, which have shown excellent activity against a range of crop diseases, and are included in this project. Broadening the base of fungicide groups used for rose disease control is an important strategy in slowing the development of pathogen resistance, but use of the strobilurin group themselves require particular care to avoid resistance. Single active ingredient products were selected for testing at this stage. Even though double or multi a.i. fungicides or tank mixes could be valuable, it was important to test the activity of individual new fungicides first.

Only a few of the fungicide products used had recommended application rates for nursery stock or ornamentals that could be applied to the rose trial. The product rates normally had to be determined by extrapolation from other recommendations, e.g. cereals, where they were expressed as a product rate per ha. A typical application volume for cereals was 200 litres / ha. Application volumes for many nursery stock crops, including roses, vary according to the stage of growth and growing system used. For fungicides, higher volume sprays to run-off to give good coverage are often recommended for good control. A standard high volume application rate of

© 2001 Horticultural Development Council

1000 litres / ha was chosen as a basis to calculate standard rates for the trial, expressed as a concentration of product to be applied to run-off. Thus a product with a rate for cereals at 1.0 litres / ha in a typical volume of 200 litres/ha was extrapolated to a rate for rose of 1.0 ml/litre applied to run-off.

For the phytotoxicity trial, each product was used at a standard and double rate, and for the efficacy trial, each was used at the standard and half rate.

A selection of five cultivars, which were believed to be sensitive according to growers' and Efford's previous observations, were chosen for the phytotoxicity screening. A single cultivar, Silver Wedding, known to be susceptible to leaf diseases, was used for the efficacy trial.

Treatments

Key dates of fungicide sprays, pruning, inoculations and assessments are given in Results

, p. 16.

Fungicides

Table 1. Fungicides used in the project and their chemical activity groups

Trial fungicides				
Code	**Product**	**Active ingredient**	**Supplier**	**Chemical activity group**
A	Folicur	tebuconazole 250 g/l	Bayer	conazole
B	Lyric	flusilazole 250 g/l	Du Pont	conazole
C	Unix	cyprodinil 75% w/w	Novartis	anilinopyridine
E	Amistar	azoxystrobin 250 g/l	Zeneca	strobilurin analogue
F	Twist [F279]	trifloxystrobin	Novartis	strobilurin analogue
K	Torch	spiroxamine 750 g/l	Bayer	spiroketal amine (morpholine related)
D	Tern	fenpropidin 750 g/l	Novartis	piperidine (morpholine related)
G	Indar 5EW	fenbuconazole 50 g/l	Rohm & Haas	conazole
H	Tilt	propiconazole 250 g/l	Novartis	conazole
I	Plover	difenoconazole 250 g/l	Novartis	conazole
J	Flamenco	fluquinconazole 100 g/l	AgrEvo	conazole
L	Stroby WG	kresoxim-methyl 50% w/w	BASF	strobilurin analogue
M	Dorado	pyrifenox 200 g/l	Zeneca	pyridine
U	Untreated	water		
X	Corbel	fenpropimorph 750 g/l	BASF	morpholine
Standard fungicide rotation				
S1	Systhane 20EW	myclobutanil 200 g/l	Landseer	conazole
S2	Nimrod T	bupirimate + triforine 62.5:62.5 g/l	Scotts	pyrimidinol + piperazine
S3	F238 + Bavistin DF	dodemorph 385 g/l + carbendazim 50% w/w	BASF	morpholine + MBC

© 2001 Horticultural Development Council

All the products listed in Table 1 above, except the Standards (code S), were included in the phytotoxicity screening. Corbel (code X), known to have caused some scorch on roses from previous experience at Efford and by growers, was used as a positive control for the phytotoxicity screen. Product codes in the top part of Table 1, i.e. A, B, C, E, F, K and the standard programme S, were subsequently used in the efficacy trial.

Phytotoxicity screening

Table 2. Product rates for the phytotoxicity screening (Standard, S and High, H)

Code	Plots	Product / Active ingredient	Concentration
AS	25 38 67 100	Folicur (tebuconazole)	1.0 ml/litre
AH	10 32 72 105		2.0 ml/litre
BS	28 51 80 88	Lyric (flusilazole)	0.625 ml/litre
BH	4 33 74 86		1.25 ml/litre
CS	11 48 79 94	Unix (cyprodinil)	1.0 g/litre
CH	26 37 57 108		2.0 g/litre
DS	1 41 71 96	Tern (fenpropidin)	1.0 ml/litre
DH	17 50 85 81		2.0 ml/litre
ES	20 46 70 98	Amistar (azoxystrobin)	1.0 ml/litre
EH	9 54 64 87		2.0 ml/litre
FS	8 44 63 89	Twist [F279] (trifluoxystrobin)	2.0 ml/litre
FH	16 43 59 97		4.0 ml/litre
GS	14 56 77 109	Indar 5EW (fenbuconazole)	1.4 ml/litre
GH	5 40 78 95		2.8 ml/litre
HS	21 36 83 102	Tilt (propiconazole)	1.0 ml/litre
HH	18 30 73 91		2.0 ml/litre
IS	27 29 84 103	Plover (difenoconazole)	0.3 ml/litre
IH	6 47 65 107		0.6 ml/litre
JS	7 39 62 90	Flamenco (fluquinconazole)	1.25 ml/litre
JH	2 31 60 93		2.50 ml/litre
KS	15 55 68 112	Torch (spiroxamine)	1.5 ml/litre
KH	19 53 82 106		3.0 ml/litre
LS	24 42 69 104	Stroby WG (kresoxim-methyl)	0.3 g/litre
LH	22 34 66 101		0.6 g/litre
MS	13 35 58 99	Dorado (pyrifenox)	0.25 ml/litre
MH	12 49 76 110		0.5 ml/litre
U1	23 45 75 111	Untreated (water)	-
U2	3 52 61 92		-
X1	extra	Corbel (fenpropimorph)	1.0 ml/litre
X2	extra		2.0 ml/litre

© 2001 Horticultural Development Council

Table 3. Cultivars used for phytotoxicity screening

Code	Cultivar	Colour	Type
De	Dearest	rosy salmon	floribunda
WW	Warm Wishes	peach / orange	hybrid tea
KR	Kind Regards	scarlet	short floribunda
SD	Sweet Dream	apricot	patio
GT	Gentle Touch	pale pink	patio

Design and layout

See layout plan, Appendix 1, p33, and Appendix 3 **Error! Reference source not found.**, p.**Error! Bookmark not defined.**.

A split plot design was used with fungicides x rates as main plots and cultivars as sub plots:
14 fungicides x 2 rates = 28 treatments with 4 replicates = 112 main plots in total
This included double replicated untreated controls.

In addition, 4 replicate main plots of the positive control treatment Dorado, at two rates, were sited adjacent to the main trial.

Cultivar sub-plots contained single plants spaced at 300 mm across the bed and main plots were spaced at 850 mm down the bed.

Efficacy experiment

Table 4. Product rates for the efficacy trial (Standard, S and Low, L)

Code	Plots	Product / Active ingredient	Concentration
AS	6 21 37	Folicur (tebuconazole)	1.0 ml/litre
AL	12 16 41		0.5 ml/litre
BS	2 15 39	Lyric (flusilazole)	0.63 ml/litre
BL	14 24 42		0.31 ml/litre
CS	13 25 40	Unix (cyprodinil)	1.0 g/litre
CL	7 22 35		0.5 g/litre
ES	5 26 31	Amistar (azoxystrobin)	1.0 ml/litre
EL	11 28 38		0.5 ml/litre
FS	3 17 30	Twist [F279] (trifloxystrobin)	2.0 ml/litre
FL	8 27 29		1.0 ml/litre
KS	10 23 36	Torch (spiroxamine)	1.5 ml/litre
KL	1 18 32		0.75 ml/litre
SS	9 19 34	Standard programme* (next page)	
SL	4 20 33		
U	43 44 45 46	Untreated (water)	-

© 2001 Horticultural Development Council

***S - Standard programme**

Rotation of:

Code	Plots	Product / Active ingredient	Concentration
SS	9 19 34	Systhane 20EW (myclobutanil)	0.3 ml/litre
SL	4 20 33		0.15 ml/litre
SS	9 19 34	Nimrod T (bupirimate + triforine)	3.2 ml/litre
SL	4 20 33		1.6 ml/litre
SS	9 19 34	F238 + Bavistin DF	2.5 ml/litre + 0.5 g/l
SL	4 20 33	(dodemorph + carbendazim)	1.25 ml/litre + 0.25 g/l

This experiment was carried out using a single cultivar, Silver Wedding, known to be generally disease susceptible.

Design and layout

See layout plan, Appendix 1, p.30.

A randomised block design for rate x fungicide treatments:

7 fungicides x 2 rates = 14 treatments with 3 replicates = 42 plots

In addition, 4 replicate untreated (i.e. sprayed with water) control plots were sited approximately 15 m to one side of the main trial area. These plots were used to monitor disease incidence on untreated plants, but were not included within the main trial layout to avoid an imbalanced disease pressure developing amongst fungicide treated plots. They were assessed on the same basis as the remaining treatments, but results were not included in the formal statistical analysis.

Plot size was 25 plants in total, arranged in a 5 x 5 array. A central inoculator plant was surrounded by 8 recorded plants, enclosed in turn with an outer ring of 16 guard plants. Sprays were applied to run-off over the whole plot except for the inoculator plant, which was temporarily removed on each spray occasion. Plants were spaced at 300 mm x 300 mm. A 1.0 m gap was left between plots down the bed to allow a portable barrier to be manipulated during spraying to minimize spray drift to adjacent plots.

Disease inoculation

To encourage a sufficient supply and uniform distribution of disease inoculum, several tactics were employed for the efficacy experiment to artificially inoculate with diseases. Firstly, containerised plants from the previous year's crop, which had been left unsprayed and had developed black spot and rust the previous autumn, was placed between each efficacy plot. Old leaves from field plants of Silver Wedding that had been badly affected by black spot and rust the previous autumn, were collected in early February, and held in a cold store at about 0 °C. These were then pulverised and sprinkled on potted Margaret Merril plants later used as central inoculator plant in each plot. However, despite a rainy spring, black spot disease was slow to develop on these plants.

© 2001 Horticultural Development Council

However, black spot developed on an area of unsprayed roses elsewhere on the station during May and early June, and infected leaves were collected and held in polythene sacks for a few days in an unheated building. Leaves were then washed into 40 litres of tap water. A 250 ml sample was collected for examination. After confirmation of the presence of black spot spores (conidia), the sample was suction filtered through a 3 µm micro filter and re-suspended in 5 ml of water to concentrate the spores. Spore counts of the 2-celled black spot conidia were made under a microscope using a haemocytometer. A 40 litre sample of leaf washings collected in early June was calculated to contain 2.88×10^9 or approximately 3 billion spores in total. If all 40 litres were sprayed over the 1150 plots in the efficacy trial, this would equate to 2.5 million spores per plant!

Black spot spore suspensions were sprayed over all plots in the efficacy experiment on 12 June and repeated on 21 June 2000 using 20 – 30 litres on each occasion to achieve full wetting. This would therefore have applied around 1 - 2 million spores per plant. The same technique was used to inoculate the plots again in late summer on 25 and 30 September. It was clear from the development of discrete black spot lesions on young, as well as older leaves, that this technique was successful.

Previous years plants of cv. Renaissance, a cultivar previously shown to be powdery mildew susceptible, were left unsprayed and held under a polythene tunnel to be used as inoculator plants in the efficacy trial. However, mildew did not develop readily in these plants even by late summer. It did not develop naturally in the outdoor Silver Wedding plants either, but mid August some *Rosa* Laxa rootstock shoots from the recently budded field crop had some mildew infections present. Bunches of Laxa shoots were therefore collected and shaken over plants to distribute spores. This method has been successfully used to establish powdery mildew infections in other species, but, possibly due to unfavourable environmental conditions, it did not work with either the Renaissance kept under polythene tunnels, nor the Silver Wedding outdoors following several inoculation attempts during August and September.

General culture

Table 5. Key dates of fungicide applications, pruning, disease inoculations and assessments

Date	Fungicide sprays	Pruned back	Inoculations	Assessments
		Phytoxicity experiment		
15 May				✓
31 May – 2 June	✓			
5, 12, 19 June				✓ ✓ ✓
18 July		✓		
22 August				✓
23 – 25 August	✓			
29 Aug, 4, 11 Sept				✓ ✓ ✓

Date	Fungicide sprays	Pruned back	Inoculations	Assessments
		Efficacy experiment*		
8 June	□			
12 June			Black spot	□
19 June	□			
21 June			Black spot	
23 June				□
6 July	□**			
17 July		□		□
2 August	□			
16 August	□		P/ mildew	
23 Aug, 5 Sept			P/mildew	
6 September		□(light)	P/ mildew	
14 September	□			
15 September				□
18 September			P/mildew	
22 September	□			
25, 30 September			Black spot	
4 October	□			
4, 6, 11, 13 Oct			Black spot	
16 October				□
20 October	□			

* Standard treatment sprays:

Systhane 20 EW	8 June	2 Aug	22 Sept
Nimrod T	19 June	16 Aug	4 Oct
F238 + Bavistin DF	6 July	14 Sept	20 Oct

** F238 + Bavistin DF applied on 6 July to <u>all</u> efficacy fungicide treatment plots at standard and low rates as a 'break' treatment.

Potting

Plant roots were trimmed to a length of 200 mm from the bud union, and shoots were pruned to 130 mm prior to potting. All plants for the phytotoxicity and efficacy experiments were containerised during late February / early March and potted into deep 4 litre containers into the following medium:

100% Premium Shamrock medium / coarse grade peat
3.0 kg/m^3 Ficote 140 TE Controlled Release Fertiliser
2.4 kg/m^3 Magnesian limestone

© 2001 Horticultural Development Council

Plants were not held under protection after potting, but transferred directly to free draining outdoor growing on beds covered with a permeable woven ground cover.

Irrigation

After watering in by hand following potting, most watering was done with drip irrigation for the remainder of the trial using one dripper per pot. Overhead wetting of foliage was carried out in the early evening on several occasions during June and early July, following inoculations with black spot spore suspensions, to help encourage disease development.

Other pesticides

Occasional sprays for aphids and caterpillars were applied as HV sprays as required:

17 March	heptenophos as Hostaquick at 0.75 ml/litre
4 May	heptenophos as Hostaquick at 0.75 ml/litre
19 May	pirimicarb as Aphox at 0.5 g/litre
26 June	cypermethrin as Toppel 10 at 0.25 ml/litre

No herbicides were used on the crop. Hand weeding was carried out as necessary.

Pruning of plants for late summer experiments

Following the early summer phytotoxicity and efficacy experiments, and after the main flush of flowers had been completed, plants were pruned back hard on 17-19 July 2000 to just above the height of the original shoot framework. This was to generate a second flush of new growth, for a repetition of the experiments in late summer. Very little of the original leaf remained on the efficacy experiment plants after pruning, but fallen leaves were left as a source of disease inoculum.

A further light pruning of flowering shoots was carried out on the efficacy experiment on 6 September to encourage some new vegetative growth at this time.

Application of treatments

Sprays were applied using a hand-held sprayer with a single hollow cone nozzle HC/0.75/3. Application rates necessary to achieve full wetting of the plant foliage varied according to the stage of growth, but ranged from an equivalent of about 1000 - 3000 l/ha on the small plots used. However, if spraying was carried out over a larger commercial area of containers, it is expected that lower volumes would achieve a similar level of coverage because there would be less over-spray to plot edges, and spray drift would be more effectively intercepted by the rest of the crop.

© 2001 Horticultural Development Council

Phytotoxicity and disease assessments

For the phytotoxicity experiments in early and late summer, plants were recorded for any leaf discoloration or scorch symptoms apparent prior to applying the fungicide sprays. Close observations were then made within the first week following spraying, and on two further occasions at weekly intervals to assess the severity and nature of any damage, and the proportion of the plants affected. Also, the presence of any spray deposit was recorded. The following scoring system was used.

Scorch

0 = Nil	3 = 20%+
0.5 = trace	4 = 40%+
1 = 5%+ leaves affected	5 = 80%+
2 = 10%+ affected	

Worst affected leaf - % leaf area affected

1%+	25%+
5%+	50%+
10%+	

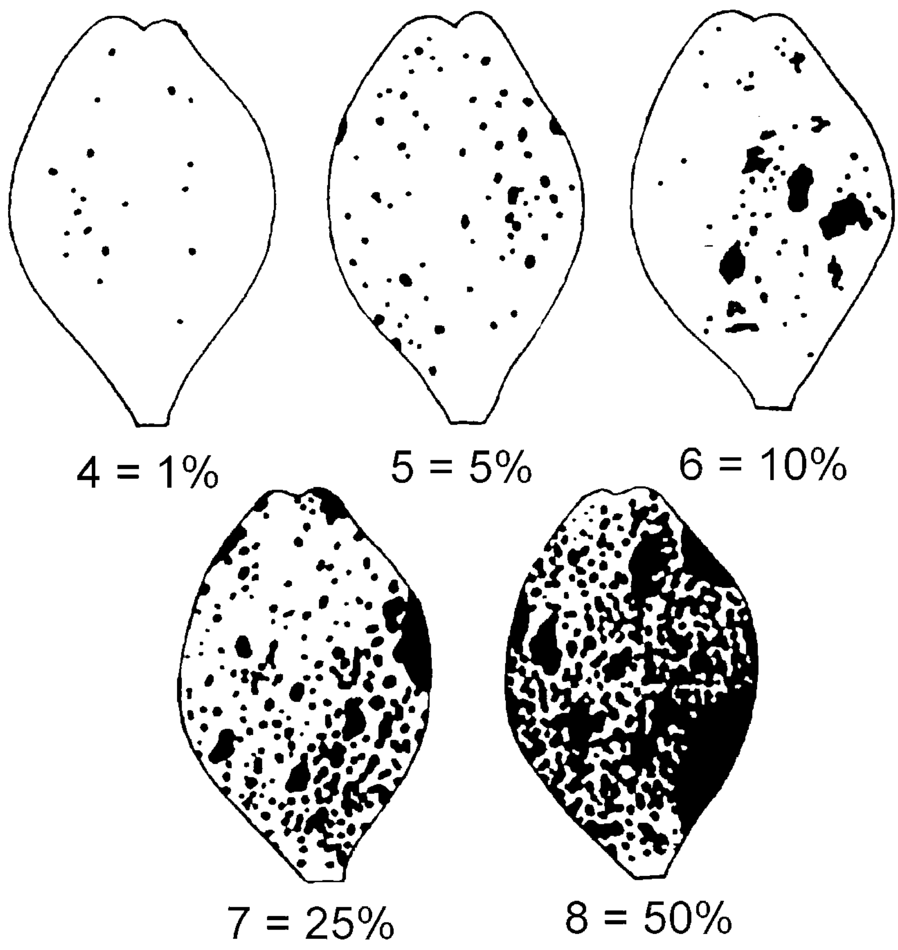
Spray deposit

0 = Nil visible or insignificant
1 = Light - ie mainly just light white deposits with few, if any, bright white concentrated deposits (eg on leaf tips)
2 = Moderate - Significant concentrated bright white deposits visible on leaves
3 = Heavy - over 50% of leaves affected with bright white deposits.

The method of disease assessment and scoring system used for the efficacy experiments was adapted during the year according to the overall level of disease present. Thus, scores are not directly comparable between assessment dates, but need to be interpreted according to the key appropriate to each assessment. For the first two assessment dates in June, while overall disease levels were low, detailed assessments for rust and black spot were carried out on five randomly selected upper and five lower leaves per assessed plant. Eight plants per plot were assessed. Leaves were scored on a 0 to 8 scale for each disease, with 0 representing no rust pustules or black spot present, 1 (trace) one to three spots or pustules, 2 and 3 ('slight' and 'moderate') meaning several pustules or spots present, but less than 1% leaf cover. A key, developed for *Botrytis fabae* on beans, was used to estimate higher infection levels (Figure 1, p.15). Scores 4 – 8 represent proportions of leaf surface covered with pustules & spots, in increments from >1% to >50%.

© 2001 Horticultural Development Council

Figure 1 Percentage leaf cover scale used for rust and black spot for scores 4 – 8 in assessments 1 and 2.



For subsequent assessments, the range of disease levels between treatments was greater, and it was adequate to assess whole plants. Also, as older / diseased leaves began to fall, it was less appropriate to try and score individual leaves at random. For the third assessment in mid July, a simple 0 – 3 scale was adopted. A score of 2 ('moderate') was equivalent to about 25% – 50% of leaves on the plant showing 1% – 5% infection levels.

Following the pruning back of plants in mid July, two further disease assessments were carried out on re-growth, in mid September and mid October on an overall plant basis (8 assessed plants per plot). For these assessments, scores based on the proportion of leaves on the plant affected by disease were the most appropriate. A leaf drop score was also carried out at the final assessment. See charts in Results section for details of score definitions.

Statistical analyses

Disease assessment data were subject to ANOVA. Square root transformations were appropriate for data for the Assessments 1 and 2, but were not required for the remaining analyses.

© 2001 Horticultural Development Council

Results

Phytotoxicity screening

Prior to the spring fungicide application, the assessment on 15 May showed that cv. Kind Regards had some slight leaf scorch present on many plants, and there was a some leaf yellowing on cv. Gentle Touch. These symptoms were probably due to some late frosts and cold winds.

Spraying days were dry and sunny for both the spring and late summer applications.

The 'positive control' treatment, Corbel, caused foliage scorch at both the Standard and High rates. Symptoms were visible within 2 - 3 days of spraying which first developed as a fine purple spotting and leaf curling, and then browning and desiccation of the leaf (**Error! Reference source not found.** & **Error! Reference source not found.**, p.**Error! Bookmark not defined.**). Symptoms appeared most severe on Warm Wishes and Kind Regards initially, but all cultivars suffered sufficient damage to render them unsaleable. At the 5 June assessment, the proportion of plants affected was 80%+ for the High rate and 40%+ to 80%+ for the Low rate treatments. The proportion of leaf damage on the worst leaves ranged from 25%+ to 50%+, with Sweet Dream and Gentle Touch tending to be less affected than the three larger leaved cultivars.
Warm Wishes also showed damage on the stems as well as the leaves. Subsequent new leaf growth in all cultivars developed normally.

Overall, apart from the Corbel positive control, there was little damage from the range of fungicides treatments tested, either in spring or late summer. In the spring, however, treatment D, Tern, did show phytotoxicity, causing average scores on the High rate treatment for proportion of leaves scorched of 4.75 (40% - 80%+) for the three larger leaved cultivars, and 3.25 - 4.25 (20% - 40%+) for the patio cultivars. Damaged areas on the worst affected leaves were about 25% - 40%+ (large leaved cvs), and 15% - 20%+ for the two patio cultivars. The Standard rate treatments caused slightly less damage, but this was still unacceptable. All four replicates were affected. Originally, treatment D, Tern, was planned to be used for the efficacy experiment, but following the phytotoxicity observed, this morpholine analogue chemical was swapped with the other morpholine related treatment K, Torch before the efficacy treatments started.

There was no damage observed from any of the other treatments, apart from on one replicate of Amistar and one replicate of Twist (both at Standard rate). However, this was minimal, and because it was inconsistent, and none of the High rate treatments were damaged, was probably not a real effect.

Unix caused some white spray deposit on the leaves (**Error! Reference source not found.**, p.**Error! Bookmark not defined.**). Again, this was most noticeable on the larger leaved cultivars. The High rate gave a score 2 (moderate) on the large leaved cultivars and score 1 (light) on the patio cultivars. The Standard rate scored 0 - 1 (nil to light). The spray deposit was sufficiently noticeable to make the foliage less attractive if plants were intended for marketing within a week or two of spraying, however the deposits did eventually disappear particularly after heavy rainfall.

Following the second spray and assessments in late summer, there was virtually no phytotoxicity observed from any of the experimental treatments, including Tern. The positive control, Corbel, however, caused similar scorch damage to that observed in spring.

Efficacy experiments

Early summer growth - First and second assessments

In this experiment, the first sprays were only applied when the first signs of rust and black spot were observed on the leaves (8 June). The first assessment followed four days after this spray. There were few or no rust pustules on the upper leaves at this stage, but a 'slight' to 'moderate' infection (but less than 1% leaf cover) observed on the lower leaves. Even at this early stage, there appeared to be some treatment effects showing, with some of the test fungicides giving lower mean scores for rust on the lower leaves than the standard programme, particularly at the standard rate (Figure 2, p.18). However, mean differences were not statistically significant (Table A 1, p.34).

With black spot, upper leaves were virtually clean. On the lower leaves, for the Unix treatment and the Untreated control treatments, early levels of infection were apparent at mean scores of about 2 ('slight') (Figure 3, p.18; Table A 2, p.34). While there was no significant effect of rates, there were significant differences between fungicides (mean of rates), compared to the standard programme ($P<0.01$). Unix showed a higher level of black spot than the standard programme (Systhane 20EW etc).

By the second assessment on 23 June, both rust and black spot levels had increased (Figure 4 & 5, p.19). On the lower leaves of the Untreated plants, this averaged Score 5 (5% cover) for rust, and Score 2.5 ('slight' to 'moderate') for black spot. While there were also rust pustules present on upper leaves at this stage, for black spot, the levels of infection were similar for both lower and upper leaves. This was probably a reflection of the successful artificial inoculations with the sprays of black spot spore suspensions on 12 and 21 June, which had established infections on the younger leaves.

For rust on the more heavily infected lower leaves, the standard rate treatments of both Folicur and Lyric had less infection than the lower rate of these products and all the other fungicides ($P<0.01$). Folicur and Lyric at both rates, had kept the newer upper leaves at trace infection levels or less, and lower than the other treatments ($P<0.001$) with scores of almost 3.0. Torch and Unix had a higher level of rust than the Standard programme, whereas the strobilurins, Amistar and Twist, were not significantly different from the Standard (Table A 3, p.35).

Treatment differences were not significant at this stage for black spot infection (Table A 4, p.34).

© 2001 Horticultural Development Council

Figure 2

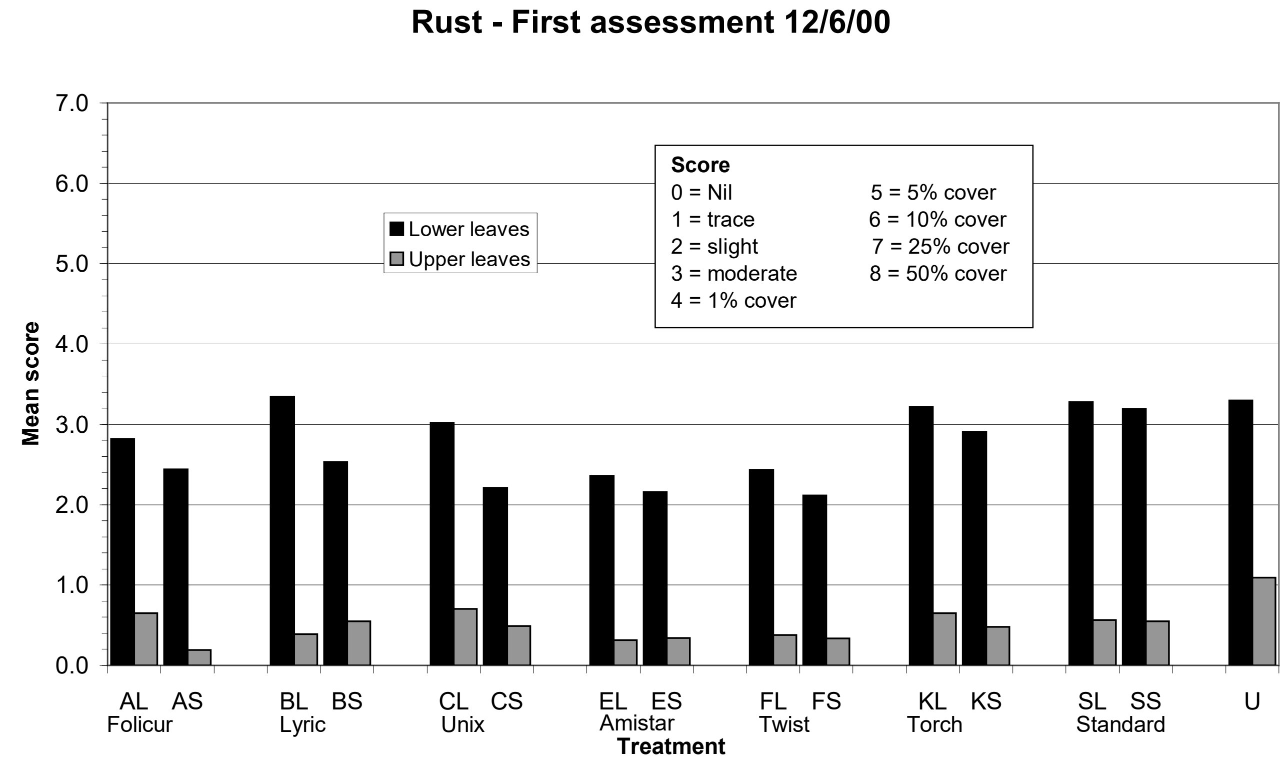
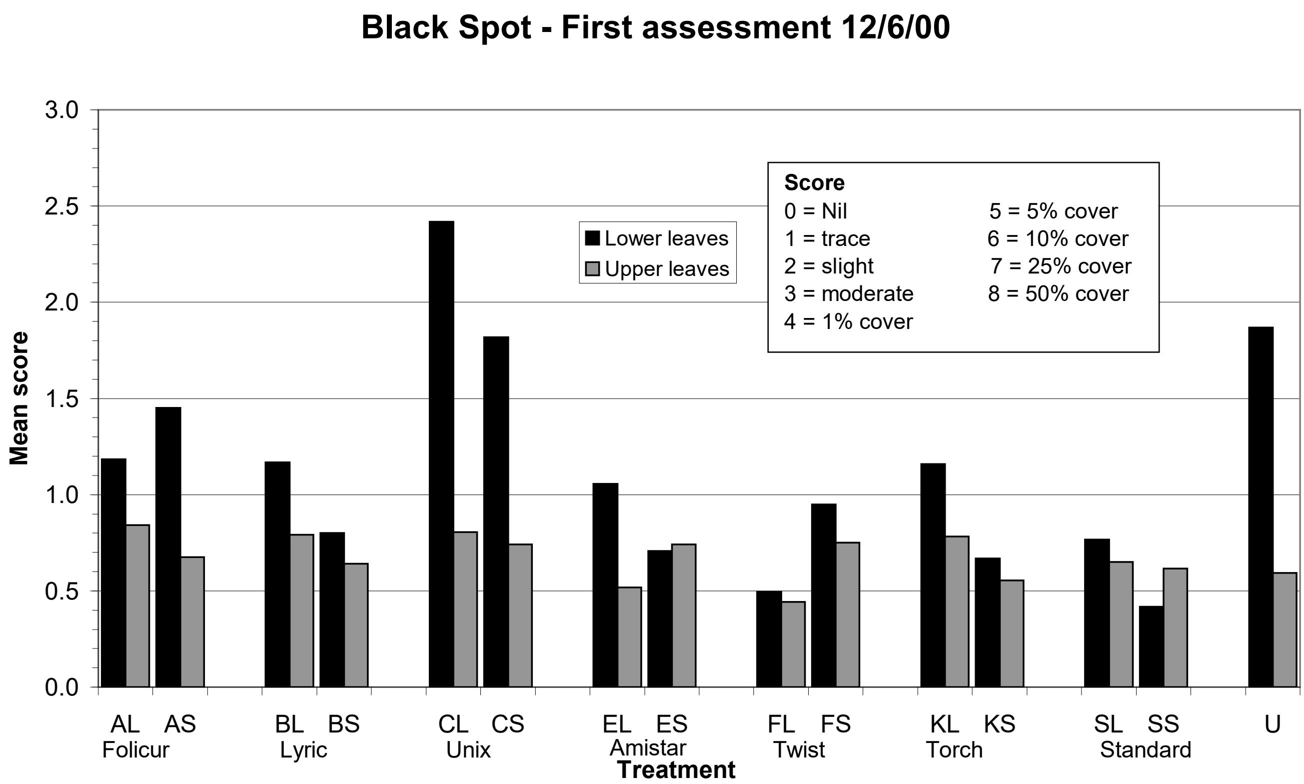


Figure 3



© 2001 Horticultural Development Council

Figure 4

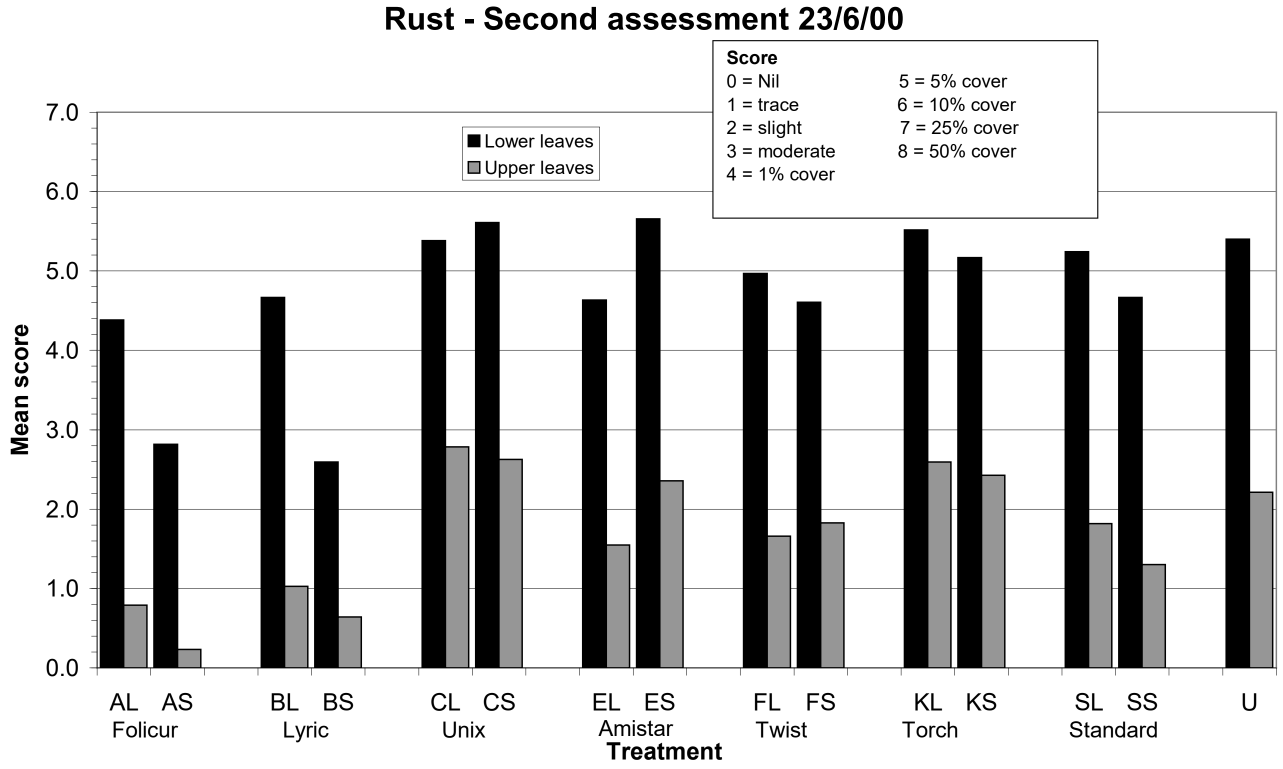
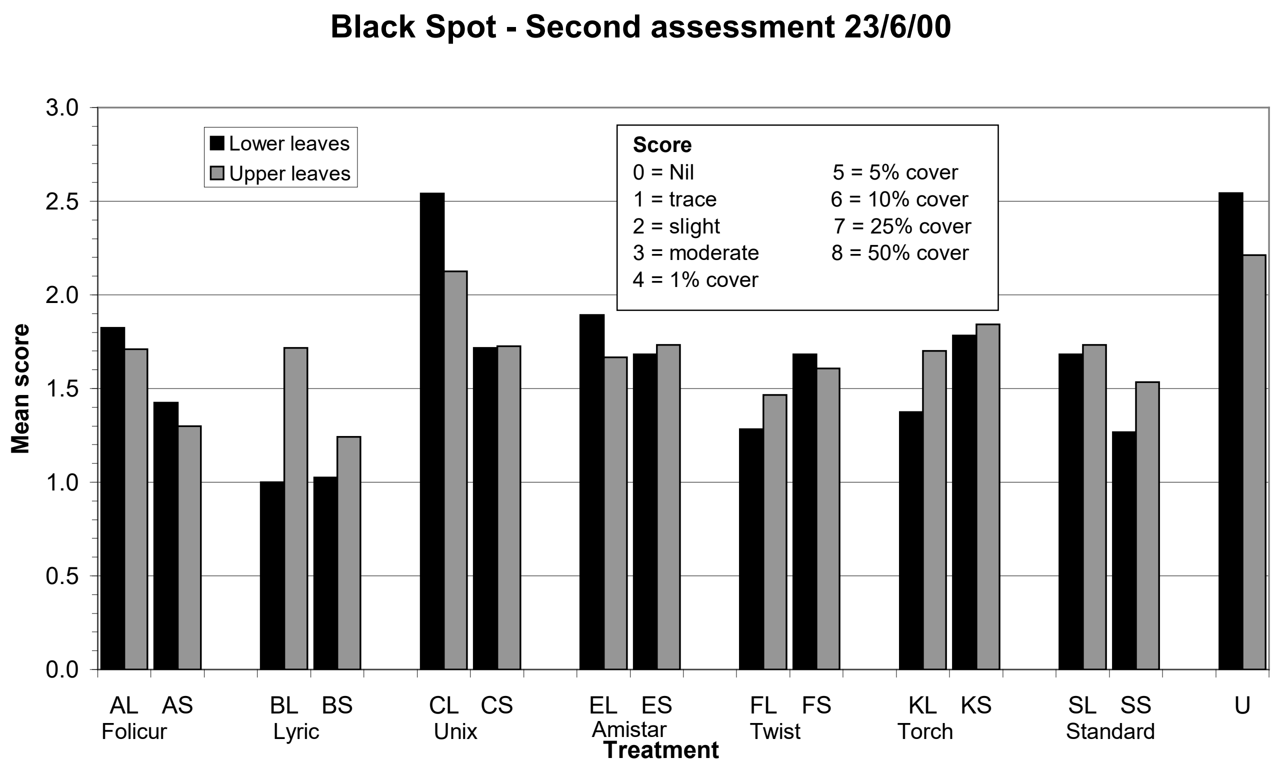


Figure 5



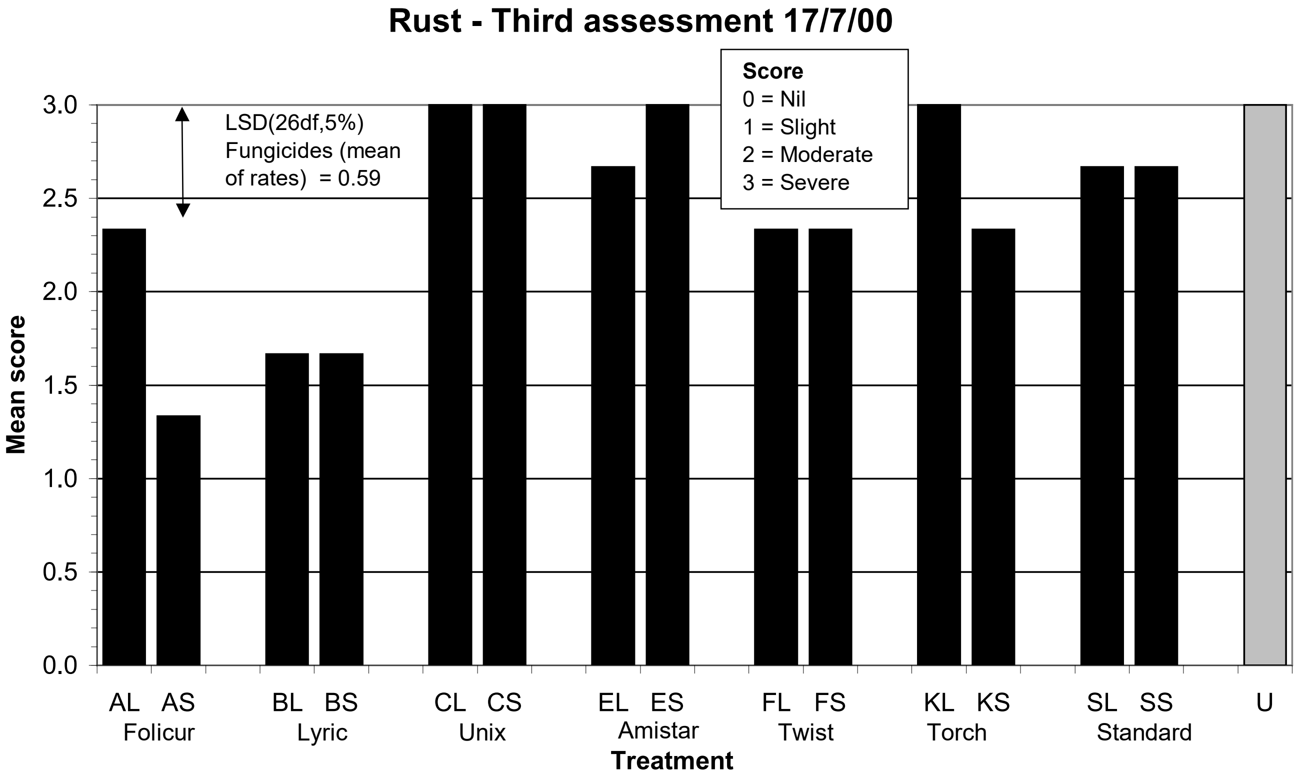
© 2001 Horticultural Development Council

Third assessment

Disease levels had generally increased still further by mid July. Although they could not be formally compared statistically with the main trial treatment scores, the Untreated plots provided a useful baseline of disease development, and by this stage they had severe levels of both rust and black spot, and were shedding the worst infected lower leaves. Scores 2 and 3 ('slight' and 'moderate'), based on whole plants, represented higher disease levels than for the first two assessments.

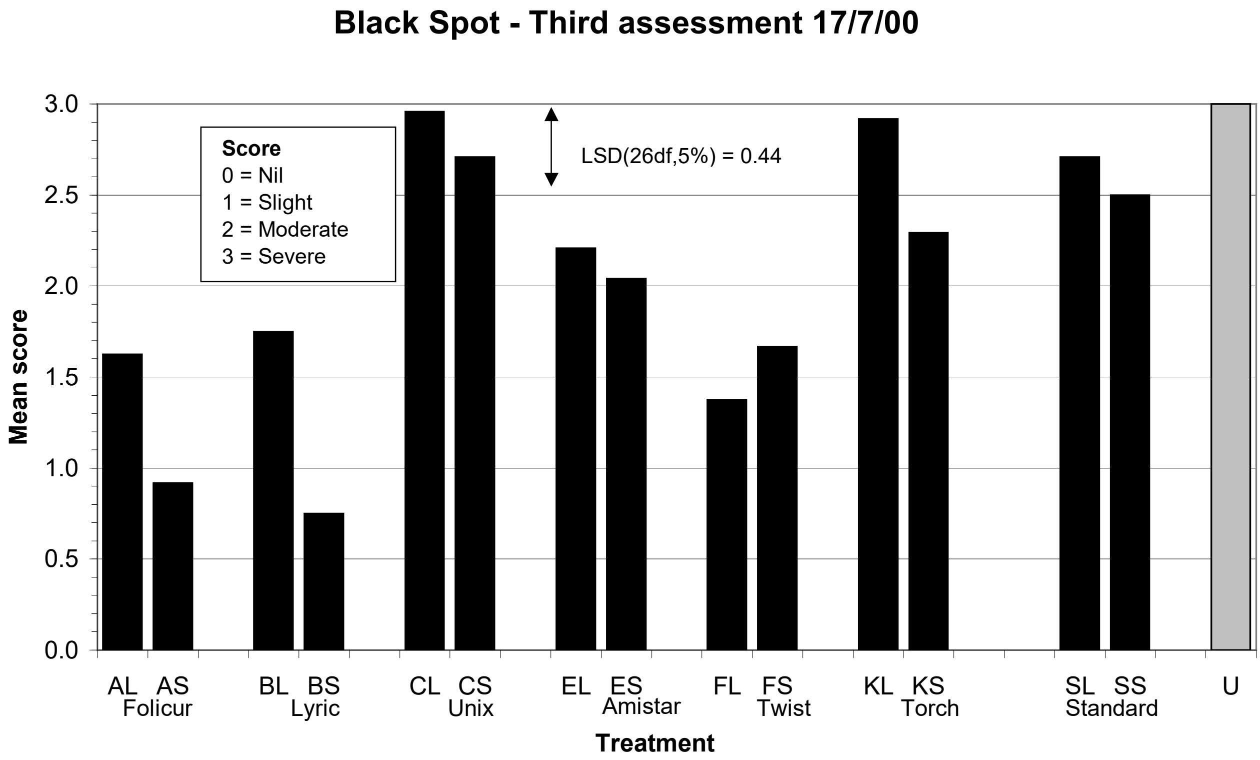
For rust, the effect of fungicide treatments (mean of rates) was significant at $P<0.001$, but rate x fungicide effects were not significant (Figure 6 below; Table A 5, p.37). Lyric and Folicur showed significantly less rust than the Standard programme. Unix had the highest mean score for rust, but only significantly greater than Twist, Lyric and Folicur ($P<0.05$).

Figure 6



For black spot, large treatment differences were becoming apparent by the third assessment (Figure 7, p.21; Table A 1, p.37). The standard rate of Folicur and Lyric was performing better than the low rate, and maintaining disease levels below a score of 1, but even the low rates were out performing the standard fungicide programme which averaged a score of 2.5 ('moderate' to 'severe' infection). The strobilurin, Twist, but not Amistar, was also giving better control than the Standard programme. Both Unix and Torch were failing to control the disease by this stage.

Figure 7



Late summer growth - Fourth assessment

Following the mid July hard pruning, spraying recommenced earlier than in the spring, i.e. as soon as the first flush of new leaf began to develop at the beginning of August. The intention was to try to test fungicidal activity against powdery mildew on this flush of growth, and inoculations using mildew infested rootstock shoots were attempted shortly after spraying started. Much of the new growth had become floral by early September, but despite reasonably warm and dry weather, powdery mildew failed to establish. A light pruning of flowering shoots followed to generate some more new leaf growth, but powdery mildew still did not develop even on untreated plants. Conditions were obviously more favourable for rust, which was probably further helped by the disease inoculum on fallen leaves from the spring flush of growth.

An assessment of rust and black spot on 15 September showed similar trends to the third assessment in mid July, but in this case both rates of Lyric had maintained virtually clean leaves. Also, there was little disease on the standard rate of Folicur compared to the low dose rate and to the other treatments (Figure 8, p.22; Table A 6, p.38). Twist performed better than the Standard programme and Amistar, even though rust was at an unacceptable high level on these plants. Finally, it was clear that Unix and Torch had failed to give any useful control of rust.

Figure 8

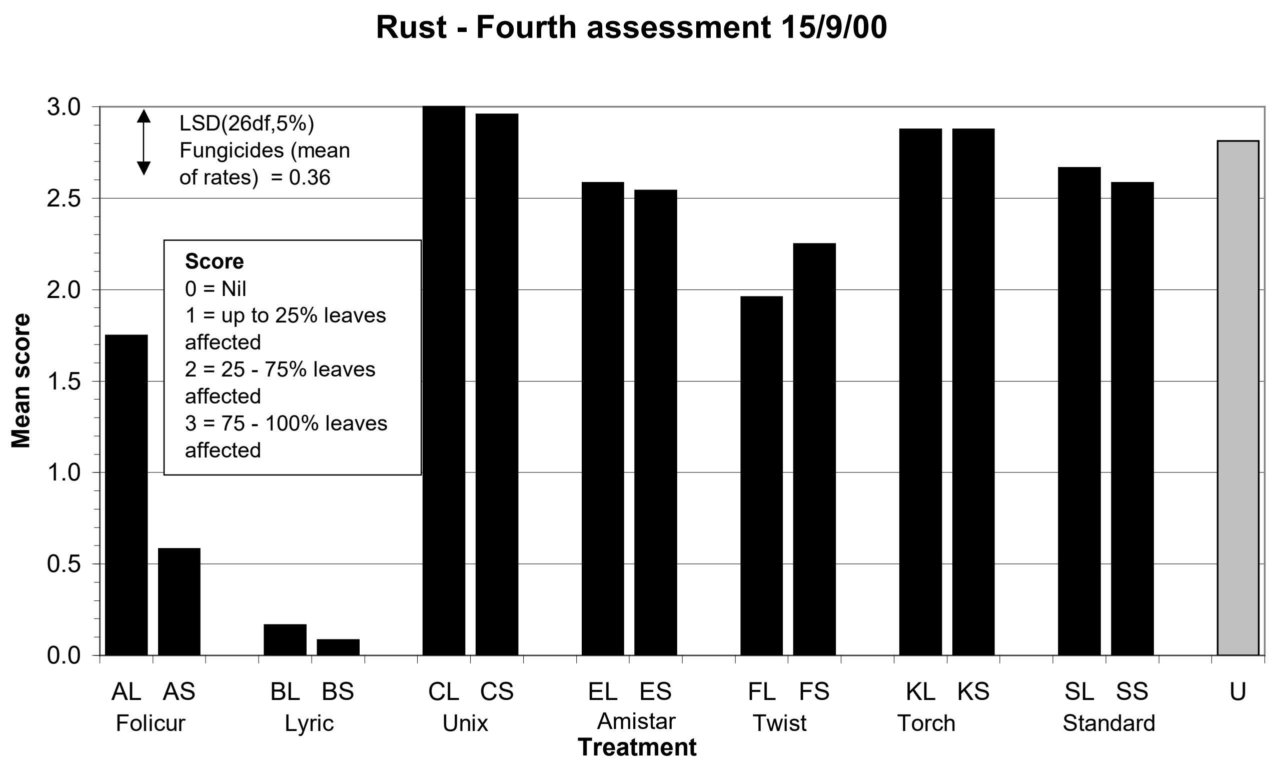
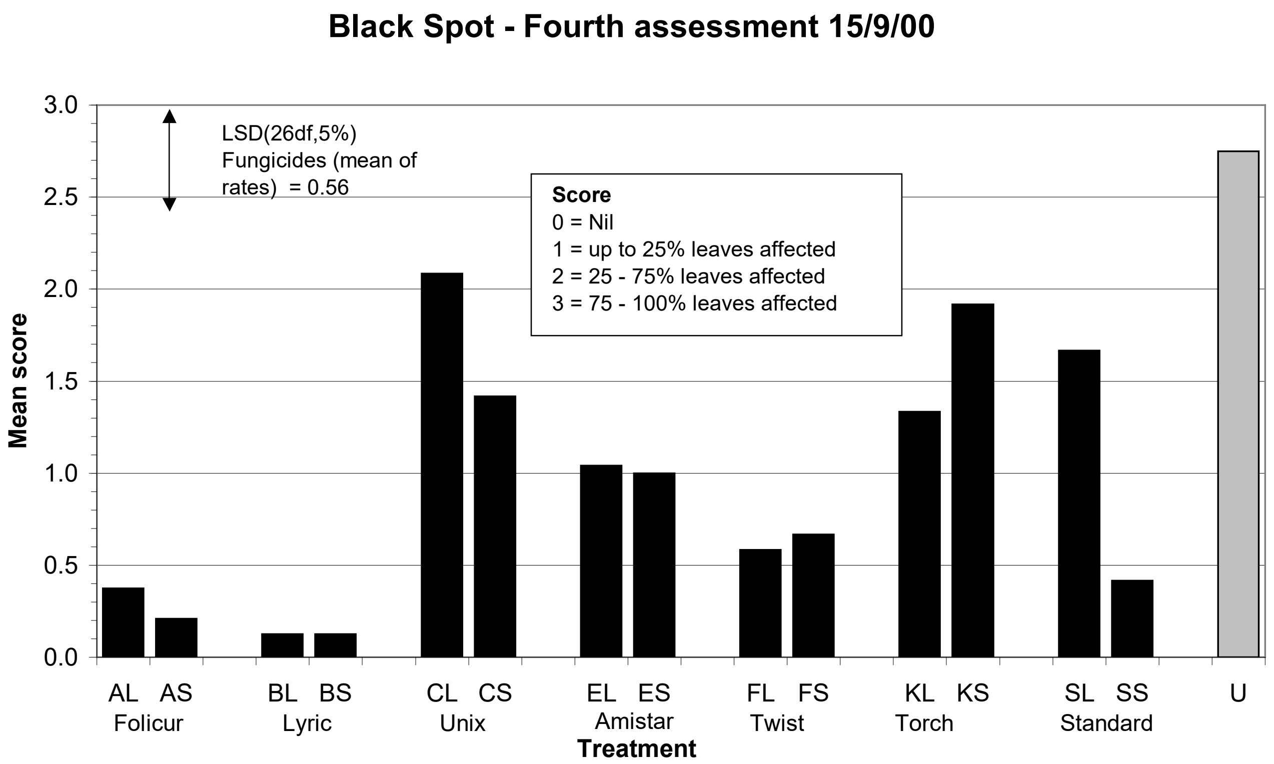


Figure 9



© 2001 Horticultural Development Council

The fungicides were giving better control of black spot than rust by mid September, where the untreated plants had a mean score of 2.8, or some 75% of leaves affected with spots (Figure 9, p.22). Although it appeared that the standard rate of the Standard and Unix programmes were giving better control than the low rate, the trend was reversed for Torch. The rate x fungicide treatment effect was almost, but not quite, statistically significant at P<0.05 (Table A 6, p.38). Taking the fungicide effect overall (mean of rates), which was significant at P<0.001, Folicur and Lyric maintained plants with very low levels of black spot infection (mean scores 0.3 and 0.1 respectively) and were significantly better than the Standard programme (mean score 1.0). Unix and Torch were worse than the Standard programme (mean 1.8 and 1.6). Twist appeared to be performing quite well, and better than Amistar (mean scores of 0.6 and 1.0 respectively), but differences between the two strobilurins or versus the Standard programme were not significant at P<0.05.

Fifth (final) assessment

Following four more fungicide sprays up to mid October, the pattern of treatment effects on rust was similar to the fourth assessment a month earlier (Figure 10, p.24 vs. Figure 8, p.22). Although the effect of rates x fungicide were significant at P<0.05 overall, this only applied to Folicur, where the standard rate was controlling rust better than the low rate (Table A 7, p.39). For Unix, Amistar and Twist, the standard rate had slightly *higher* mean scores than the low rate, however rate differences for these, Torch and the Standard programme were not significant. The overall fungicide effect (mean of rates) was highly significant (P<0.001). Folicur and Lyric remained the best performers, and were keeping plants remarkably clean considering the level of infection pressure present. While rust levels on the Twist treatment were 'moderate' (mean score 3.1), it was still better than the Standard programme (mean 3.8, P<0.01). Rust on Amistar and Torch were similar to Standard, while Unix had significantly more rust (mean 4.5, P<0.05) with most leaves severely infected.

Black spot, likewise, followed a broadly similar pattern of infection to a month earlier (Figure 11, p.24 vs. Figure 9, p.22). In this case rates x fungicides were significant overall (P<0.01, Table A 7, p.39). For Folicur, Lyric, Unix and the Standard programme, the standard rate of fungicide was giving significantly lower scores than the low rate. This was probably only of practical significance for Folicur and Lyric, however, where the standard rates were keeping plants virtually clean, compared to trace or low infection levels at the low rate. Twist was maintaining plants at low levels of infection, and significantly better than the Standard programme. However, for the Standard, Unix, Amistar and Torch treatments, disease control had largely been lost by this stage with most leaves on plants showing black spot lesions.

A leaf drop assessment well illustrated the combined effect of both rust and black spot disease on the plants in mid October (Figure 12, p.25 & Table A 7, p.34). Fungicide x rate effects were not significant, but large differences between fungicide treatments overall were present (P<0.001). Folicur and Lyric followed by Twist, had much less leaf drop than the Standard programme, which in turn had less than Unix and Torch on average, but not Amistar.

© 2001 Horticultural Development Council

Figure 10

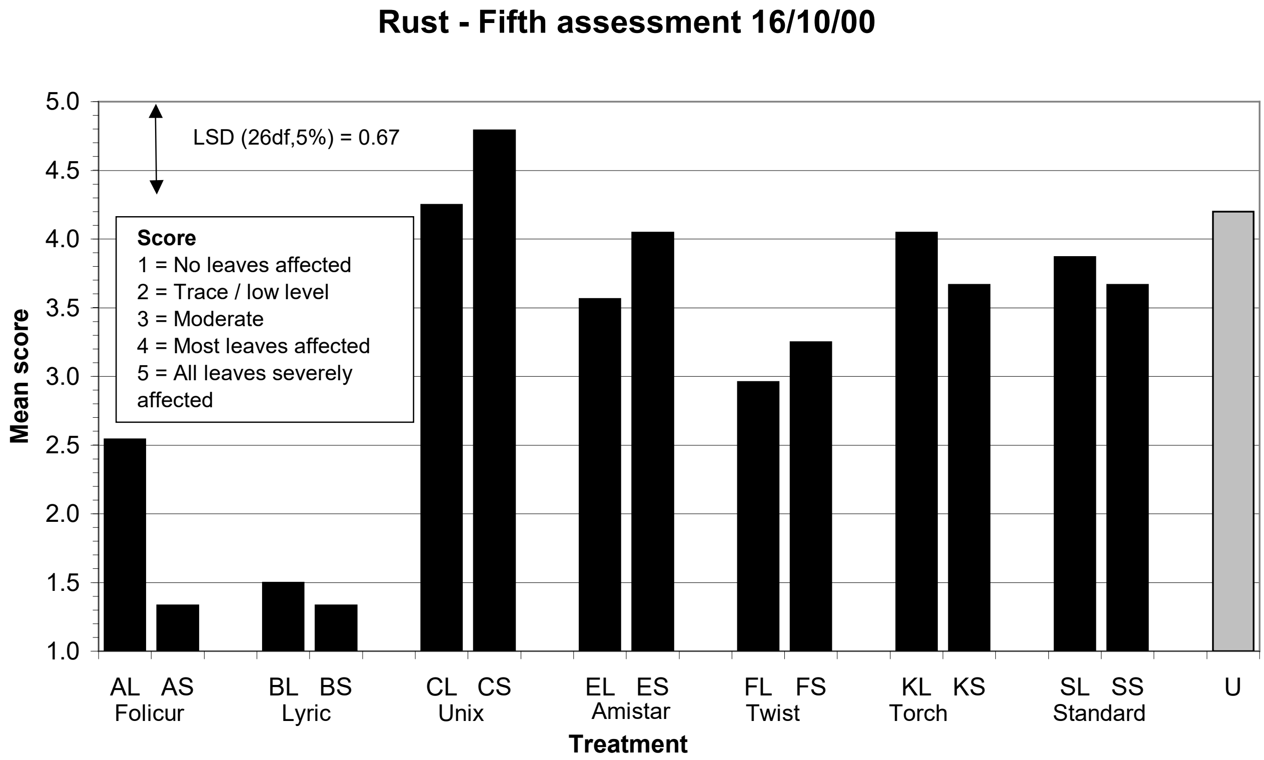
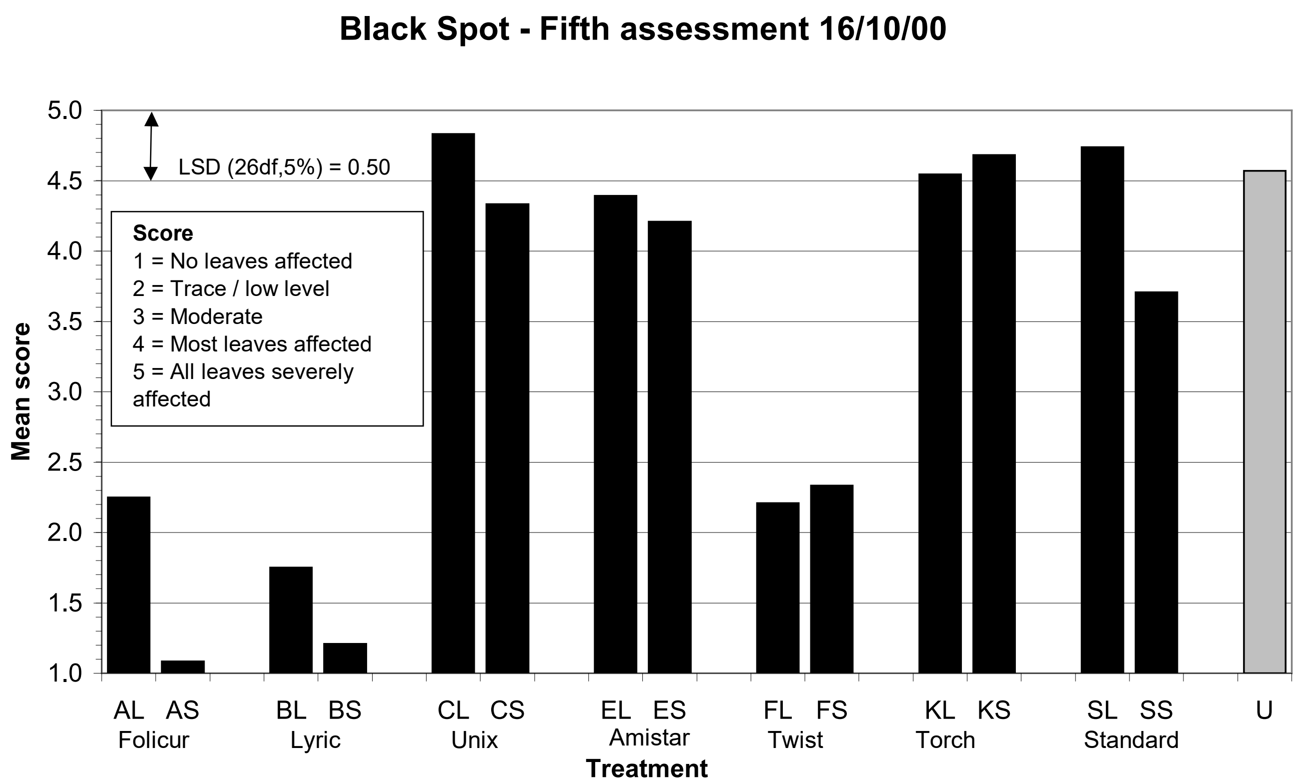
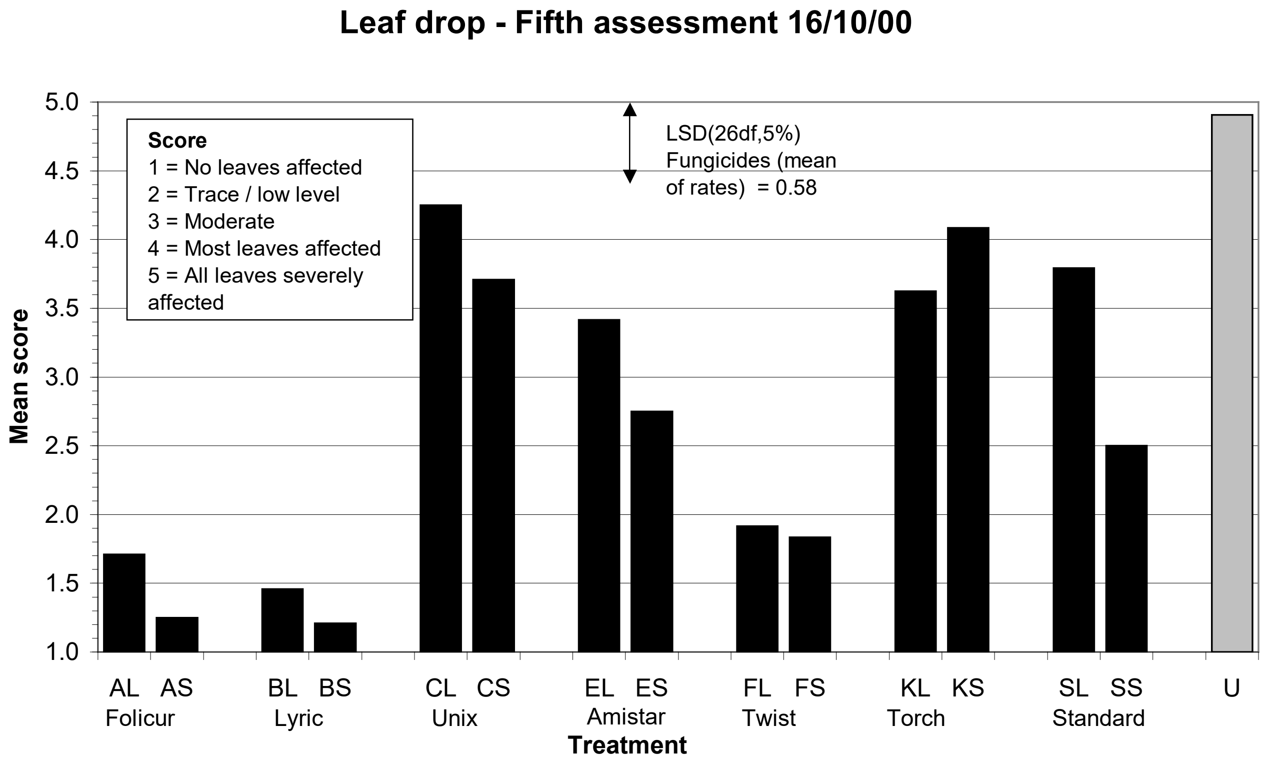


Figure 11



© 2001 Horticultural Development Council

Figure 12



The difference in the amount of leaf drop between Lyric and Twist was almost significant at P<0.05.

The photographs in Appendix 3 graphically illustrate the large treatment effects that these two diseases had on the health of the plants in terms of leaf drop. **Error! Reference source not found.**, p.**Error! Bookmark not defined.** shows the grades used. Photos 6 – 9 show some treatment differences at the time of the final assessment. Three weeks later, differences in leaf drop between good and poor plots were even more pronounced, and the Unix, Torch and the Standard programme treatments had lost nearly all their leaves, whereas even the low rate Lyric and Folicur plots had retained most of their foliage (**Error! Reference source not found.** - 15, p.**Error! Bookmark not defined. - Error! Bookmark not defined.**). The healthy plots continued to retain some old leaf into January / February 2001, even though plants were clearly dormant.

© 2001 Horticultural Development Council

Discussion

The project has another two years to run. However, useful results have already arisen from the first season.

Phytotoxicity screening

It was encouraging that there was little evidence of phytotoxicity from the 'new' fungicides tested, except Tern. The active ingredient in Tern, fenpropidin, is a morpholine analogue, and it is known that some fungicides from the morpholine group can be damaging to certain crops. Fenpropimorph, the a.i. in Corbel, is also a morpholine, and it frequently causes damage on ornamental roses, although some growers have used it on rose rootstocks. Corbel does have a label recommendation for use with strawberries, where one might expect a greater sensitivity to leaf damage, so generalisations between crops and even cultivars are risky.

At the time of writing, one grower had reported yellowing on young leaves with some cultivars from the use of Amistar, but this effect was transient and no permanent crop damage occurred. No such effects were observed at Efford in 2000.

Phytotoxicity tests can only ever give an indication of crop safety, and, unless label approval is adopted in future, use of these products will remain at growers' risk. A limited selection of cultivars were tested, so the usual advice about growers undertaking their own small scale trials on other cultivars before adoption should be considered, particularly if previous experience indicates a cultivar may be susceptible to damage from other sprays. The other important factor that could affect crop safety (as well as efficacy) is the volume in which the fungicide is applied. In this project, we used high volume sprays to run-off to get good coverage, as a practical way of testing a wide range of products on a consistent basis on small plots. It is permissible to apply the fungicides in higher concentrations at lower volumes up to the maximum concentration and equivalent rate per ha stated on the label for other outdoor crops. However, higher concentrations may increase, (or in some cases decrease), the risk of phytotoxicity.

Artificial inoculation with disease spores

Achieving both a high enough and uniform disease pressure over experimental plots is important if disease control experiments are to give reliable results. The simple technique used for black spot in this experiment was very successful, and would be easy to adopt when screening cultivars for black spot susceptibility in field trials. It is not clear how well this works for rust inoculation, as uredospores or teliospores were not observed in the single leaf rinse solution examined in the experiment. It is likely that the rust infection readily developed naturally.

The leaf rinsing method was not appropriate for powdery mildew. The failure of powdery mildew to establish on plants outside from shaking infected shoots overhead was almost certainly due to unfavourable environmental conditions for spore germination and infection, rather than the inoculation technique as such.

© 2001 Horticultural Development Council

Efficacy of products

The two conazoles tested, tebuconazole (as Folicur) and flusilazole (as Lyric) were clearly highly effective against both black spot and rust in this project, and outperformed the Standard spray rotation of Systhane 20EW, Nimrod T and F238 + Bavistin. Spraying started at the first signs of disease in the spring set of applications, and there was some evidence that Folicur and Lyric were having some useful curative as well as protectant effect. The newer upper leaves remained cleaner with these two products by the second assessment, particularly for rust (Figure 4, p. 19). In contrast, the two strobilurins, azoxystrobin (as Amistar) and trifloxystrobin (as Twist) were not effective early on. With other crops, it is known that they are most effective when used in spray programmes as a protectant before disease appears. Twist was, nevertheless, showing some activity, at least for black spot by the third assessment. Amistar's performance was disappointing throughout the trial compared to Twist.

Cyprodinil (as Unix) and spiroxamine (as Torch) did not give any useful control against either rust or black spot in the experiment. It is not clear whether they would have performed better had spraying started before any disease at all was apparent, or if they would have been more effective against powdery mildew if it had been present. However, the total lack of efficacy against black spot and rust means that they are probably not worth pursuing for use in rose spray programmes.

For the second set of applications after the summer pruning, spraying started when new leaves were just expanding. Spraying was stopped for a month from mid August to mid September when attempts were made to establish powdery mildew on the plants to test fungicides against that disease. However, when rainy weather persisted, which was more favourable to black spot and rust, it was decided to pursue another set of assessments on them. The excellent protection afforded by Folicur and Lyric at the standard rate, over the remainder of the growing season highlighted their potential as two useful new products for roses. Twist, also looked promising and may perform better still when used as a protectant as part of a spray programme. Even though Amistar appeared the less effective strobilurin, it is probably worth further evaluation in a programme with other fungicides.

Rates of use

The chosen rates for each product should have been adequate to identify their efficacy potential. Although rate effects were not always consistent, there was sufficient evidence with Folicur, Lyric and Twist to indicate that the standard rate was giving better control than the half rate. Although the benefit from the higher rate may sometimes appear marginal, it is important to recognise that lower volumes and lower rates of product / ha could be applied in commercial practice, which might reduce efficacy. Also, until further information is available, it is probably best to keep to these standard rates to avoid the potential development of fungicide resistance, particularly with the strobilurins. Finally, a high level of disease control for container crops through to the point of sale is now a generally accepted market requirement. The use of lower rates might be a false economy if control was sub-optimal.

© 2001 Horticultural Development Council

Spray programmes and rotations

Treatments used repeated applications of single fungicides, except for the Standard programme control treatment. This was necessary to establish the efficacy of individual chemicals, but to avoid the development of disease resistance would never be recommended commercially. It is therefore important that growers adopting any of these new fungicides should rotate them in a programme with other products, including those from other chemical groups where possible. Spray programmes will be examined further in 2001, meanwhile the following guidelines for spray rotations should be considered:

1. Use a maximum of one strobilurin spray (e.g. Amistar, Twist and Stroby WG) out of three fungicide applications.

2. Do not use consecutive applications of strobilurins, but apply them in alternation with fungicides from a different cross-resistance group (e.g. conazoles, morpholines, pyridines, MBC etc.)

3. Two successive, but different, conazole fungicides may be used in succession, e.g. Systhane followed by Folicur or Lyric, as the conazoles cover a wide range of active ingredients. But then a product from another chemical group, e.g. Nimrod T, Dorado, F238 or one of the strobilurins, should be chosen.

4. Consider using some of the ‘older’ protectant fungicides with multi-site activity in the spray programme, particularly if disease pressure is low, or a frequent (e.g. weekly) spray programme is adopted. These include chlorothalonil (e.g. Bravo or Repulse), dichlofluanid (Elvaron WG), mancozeb, dinocap (e.g. Karathane), and captan.

An area for further work, but not identified as a priority in the current project, is to examine the use of spray adjuvants (wetters, spreaders, plant oils etc.) to enhance the uptake and activity of pesticides. For example, work from the USA with a formulation of azoxystrobin, has shown improved activity against black spot when surfactants have been added. Surfactants or spreaders may improve crop safety if they enable lower rates of product to be applied while maintaining efficacy, however some spray adjuvants may themselves exacerbate phytotoxicity if they damage the protective leaf cuticle.

© 2001 Horticultural Development Council

Conclusions

- High volume sprays of the conazole fungicides flusilazole (as Lyric at 0.625 ml/litre), and tebuconazole (as Folicur at 1.0 ml/litre), gave excellent control of rose rust and black spot with curative and protectant action. They outperformed the Standard programme consisting of a rotation of Systhane 20EW, Nimrod T and F238 + Bavistin DF.

- The strobilurin trifloxystrobin (as Twist at 2.0 ml/litre) also gave good control, and should be considered for incorporation into spray programmes, where its performance as a protectant should be improved further. Azoxystrobin, as Amistar at 1.0 ml/litre, gave poorer results than Twist, but is worth further testing in programmes with other fungicides.

- Cyprodinil (as Unix) and spiroxamine (as Torch) gave little or no control of rust or black spot, and even if they have better activity against powdery mildew, are not sufficiently beneficial for adding to the existing armoury of rose fungicides.

- Fenpropidin (as Tern) showed evidence of phytotoxicity, and its use is not recommended. Other fungicides screened for phytotoxicity showed no damage. These were fenbuconazole (as Indar 5EW), propiconazole (as Tilt), difenoconazole (as Plover), fluquinconazole (as Flamenco), pyrifenox (as Dorado) and kresoxim-methyl (as Stroby WG). They will require future evaluation for efficacy.

Further work

The main priority for work in 2001 will be to examine spray programmes with the aim of maintaining clean plants over the whole growing season. One and two week spray intervals, choice of product, and tank mixtures to incorporate fungicides suitable for downy mildew control will be looked at, together with the cost of different options.

Some of the products tested in the phytotoxicity screening will be also examined in 2001 for efficacy. Most are conazoles, but the other strobilurin, Stroby WG has shown promising results against rose black spot in trials in mainland Europe. Dorado, has a general label recommendation for powdery mildew in hardy nursery stock, and this will also be trialled further on roses.

Finally, the project extension in 2001 will also look at powdery mildew control in a separate experiment under polythene, where the right conditions for infection should be more easily achieved. However, commercially, only fungicides with approval for use on a crop under protection, can be used for roses under cover.

© 2001 Horticultural Development Council

Appendix 1 - Experiment Plans and Layout

ROSE PHYTOTOXICITY SCREENING 2000

N (north arrow)

Bed 7 (top: rep:1; bottom: rep:1)

Plot	Treatment					
19	KH	KR	GT	WW	De	SD
18	HH	SD	GT	KR	De	WW
17	DH	GT	WW	SD	De	KR
16	FH	De	KR	SD	WW	GT
15	KS	WW	GT	SD	De	KR
14	GS	GT	De	SD	KR	WW
13	MS	KR	GT	SD	De	ww
12	MH	SD	WW	De	KR	GT
11	CS	SD	KR	De	WW	GT
10	AH	WW	SD	KR	De	GT
9	EH	GT	KR	WW	De	SD
8	FS	De	WW	SD	GT	KR
7	U2	SD	WW	KR	De	GT
6	IH	GT	KR	De	WW	SD
5	GH	GT	KR	WW	De	SD
4	BH	GT	De	WW	SD	KR
3	JS	WW	GT	KR	SD	De
2	JH	KR	De	SD	WW	GT
1	DS	WW	GT	KR	SD	De

Bed 8 (top: rep:2; bottom: rep:1)

Plot	Treatment					
37	CH	SD	GT	De	KR	WW
36	HS	KR	GT	WW	De	SD
35	MS	KR	De	SD	GT	WW
34	LH	KR	De	SD	WW	GT
33	BH	KR	GT	WW	SD	De
32	AH	De	GT	KR	WW	SD
31	JH	GT	WW	De	SD	KR
30	HH	WW	KR	GT	SD	De
29	IS	KR	GT	De	WW	SD
GAP						
28	BS	GT	De	KR	WW	SD
27	IS	KR	SD	GT	WW	De
26	CH	KR	De	WW	SD	GT
25	AS	SD	GT	WW	KR	De
24	LS	GT	De	KR	SD	WW
23	U1	WW	GT	SD	De	KR
22	LH	SD	KR	De	GT	WW
21	HS	WW	GT	SD	De	KR
20	ES	WW	De	KR	SD	GT

Bed 9 (top: rep:2; bottom: rep:2)

Plot	Treatment					
56	GS	GT	WW	KR	SD	De
55	KS	De	KR	WW	GT	SD
54	EH	SD	GT	KR	WW	De
53	KH	WW	KR	De	SD	GT
52	U2	WW	GT	SD	De	KR
51	BS	GT	De	WW	SD	KR
50	DH	SD	KR	WW	GT	De
49	MH	De	KR	WW	SD	GT
48	CS	SD	GT	KR	De	WW
47	IH	KR	De	WW	SD	GT
46	ES	GT	WW	KR	De	SD
45	U1	SD	De	GT	KR	WW
44	FS	GT	KR	De	SD	WW
43	FH	SD	GT	KR	De	WW
42	LS	WW	KR	De	GT	SD
41	DS	De	GT	KR	WW	SD
40	GH	GT	KR	De	SD	WW
39	JS	De	WW	SD	GT	KR
38	AS	WW	SD	GT	De	KR

Bed 10 (top: rep:3; bottom: rep:3)

Plot	Treatment					
75	U1	KR	WW	GT	SD	De
74	BH	GT	KR	SD	WW	De
73	HH	KR	De	WW	GT	SD
72	AH	KR	GT	WW	SD	De
71	DS	WW	KR	De	GT	SD
70	ES	De	KR	SD	GT	WW
69	LS	KR	WW	De	GT	SD
68	KS	GT	De	WW	SD	KR
67	AS	SD	GT	De	KR	WW
66	LH	KR	SD	GT	De	WW
65	IH	SD	WW	GT	KR	De
64	EH	GT	WW	SD	De	KR
63	FS	KR	WW	SD	De	GT
62	JS	KR	GT	WW	De	SD
61	U2	GT	WW	SD	KR	De
60	JH	WW	KR	SD	GT	De
59	FH	KR	SD	De	GT	WW
58	MS	KR	De	WW	GT	SD
57	CH	SD	KR	GT	WW	De

Bed 11 (top: rep:4; bottom: rep:3)

Plot	Treatment					
93	JH	WW	KR	SD	De	GT
92	U2	KR	WW	GT	De	SD
91	HH	SD	GT	De	KR	WW
90	JS	KR	SD	WW	De	GT
89	FS	KR	GT	SD	WW	De
88	BS	KR	De	WW	SD	GT
87	EH	GT	De	SD	KR	WW
86	BH	WW	De	SD	KR	GT
85	DH	WW	KR	GT	SD	De
GAP						
84	IS	WW	De	SD	GT	KR
83	HS	De	WW	GT	KR	SD
82	KH	KR	GT	De	SD	WW
81	DH	GT	De	WW	KR	SD
80	BS	SD	De	WW	KR	GT
79	CS	GT	WW	De	SD	KR
78	GH	GT	De	SD	WW	KR
77	GS	SD	De	GT	WW	KR
76	MH	GT	De	SD	WW	KR

Bed 12 (top: rep:4; bottom: rep:4)

Plot	Treatment					
112	KS	WW	SD	KR	De	GT
111	U1	GT	KR	WW	SD	De
110	MH	De	SD	WW	KR	GT
109	GS	SD	De	GT	KR	WW
108	CH	SD	De	WW	KR	GT
107	IH	De	WW	KR	GT	SD
106	KH	KR	SD	GT	De	WW
105	AH	De	SD	KR	WW	GT
104	LS	GT	De	KR	WW	SD
103	IS	KR	GT	WW	De	SD
102	HS	KR	WW	SD	GT	De
101	LH	SD	De	GT	WW	KR
100	AS	De	GT	WW	SD	KR
99	MS	SD	KR	GT	WW	De
98	ES	De	GT	SD	KR	WW
97	FH	KR	De	WW	SD	GT
96	DS	De	WW	SD	GT	KR
95	GH	De	GT	SD	KR	WW
94	CS	De	GT	WW	SD	KR

0.85 m row centres

XH

GT	GT	GT	GT
SD	SD	SD	SD
De	De	De	De
KR	KR	KR	KR
WW	WW	WW	WW

XS

GT	GT	GT	GT
SD	SD	SD	SD
De	De	De	De
KR	KR	KR	KR
WW	WW	WW	WW

Fungicides

* H = High rate

* S =Standard rate

Version 3 6/6/00

A - Folicur (tebuconazole)
B - Lyric (flusilazole)
C - Unix (cyprodonil)
D - Tern (fenpropidin)
E - Amistar (azoxystrobin)
F - Twist [F239] (trifluoxystrobin)
G - Indar 5EW (fenbuconazole)
H - Tilt (propiconazole)
I - Plover (difenoconazole)
J - Flamenco (fluquinconazole)
K - Torch (spiroxamine)
L - Stroby WG (kresoxim-methyl)
M - Dorado (pyrifenox)
U - Untreated (water) (double replicated controls)
X - Corbel (fenpropimorph) (extra +ve control)

Cultivars

De	Dearest
KR	Kind Regards
WW	Warm Wishes
SD	Sweet Dream
GT	Gentle Touch

© 2001 Horticultural Development Council

HNS 106 **ROSE EFFICACY EXPERIMENT 2000**

Top Tunnel Site

N

7CL	**14BL**	**21AS**	**28EL**	**35CL**	**42BL**	**46U**
6AS	**13CS**	**20SL**	**27FL**	**34SS**	**41AL**	
5ES	**12AL**	**19SS**	**26ES**	**33SL**	**40CS**	**45U**
4SL	**11EL**	**18KL**	**25CS**	**32KL**	**39BS**	
3FS	**10KS**	**17FS**	**24BL**	**31ES**	**38EL**	**44U**
2BS	**9SS**	**16AL**	**23KS**	**30FS**	**37AS**	
1KL	**8FL**	**15BS**	**22CL**	**29FL**	**36KS**	**43U**
REP1		REP2		REP3		

AS Folicur(tebuconazole) 1.0 ml/litre
AL 0.5 ml/litre

BS Lyric(flusilazole) 0.625 ml/litre
BL 0.313 ml/litre

CS Unix(cyprodinil) 1.0 g/litre
CL 0.5 g/litre

ES Amistar(azoxystrobin) 1.0ml/litre
EL 0.5 ml/litre

FS Twist (trifloxystrobin) 2.0 ml/litre
FL 1.0 ml/litre

KS Torch(spiroxamine) 1.5 ml/litre
KL 0.75 ml/litre

SS Standard programme
SL

U Untreated (water)

Standard programme rotation:

SS Systhane 20EW (myclobutanil) 0.3ml/litre
SL 0.15 ml/litre

SS Nimrod T (bupirimate + triforine) 3.2ml/litre
SL 1.6 ml/litre

SS F238 + Bavistin DF 2.5ml/litre + 0.5g/litre
SL (dodemorph + carbendazim) 1.25ml/litre + 0.25 g/litre

© 2001 Horticultural Development Council

Appendix 2 - Efficacy Experiment Results Tables

Table A 1. Rust – Assessment 1 – 12/6/00

Fungicide effect, Standard vs. Other Treatments (mean of Rates)
Square root transformed data (untransformed mean scores in brackets)
Means of 5 leaves / plant, 8 plants / plot and 3 replicate plots

Treatment	**Lower leaves**		**Upper leaves**	
A Folicur	1.59	(2.63)	0.54	(0.42)
B Lyric	1.67	(2.94)	0.63	(0.47)
C Unix	1.55	(2.62)	0.70	(0.60)
E Amistar	1.47	(2.26)	0.47	(0.33)
F Twist	1.44	(2.28)	0.49	(0.36)
K Torch	1.70	(3.06)	0.66	(0.56)
S Standard	1.76	(3.23)	0.69	(0.56)
SED (19 df)	*0.128*		*0.097*	
LSD (19 df, 5%)	-		-	
P, Standard vs. Other trts.	*NS*		*NS*	
U Untreated	-	(3.30)	-	(1.09)

Table A 2. Black Spot – Assessment 1 – 12/6/00

Fungicide effect, Standard vs. Other Treatments (mean of Rates)
Square root transformed data (untransformed mean scores in brackets)
Means of 5 leaves / plant, 8 plants / plot and 3 replicate plots

Treatment	**Lower leaves**		**Upper leaves**	
A Folicur	1.00	(1.32)	0.84	(0.76)
B Lyric	0.93	(0.99)	0.81	(0.72)
C Unix	1.38	(2.12)	0.84	(0.77)
E Amistar	0.83	(0.88)	0.76	(0.63)
F Twist	0.70	(0.72)	0.67	(0.60)
K Torch	0.82	(0.91)	0.79	(0.67)
S Standard	0.66	(0.59)	0.76	(0.63)
SED (19 df)	*0.144*		*0.079*	
LSD (19 df, 5%)	*0.30*		-	
P, Standard vs. Other trts.	*<0.01*		*NS*	
U Untreated	-	(1.87)	-	(0.59)

© 2001 Horticultural Development Council

Table A 3. Rust – Assessment 2 – 23/6/00

Effect of Standard vs. Other Treatments (mean of Rates) and individual Fungicides x Rates
Square root transformed data (untransformed mean scores in brackets)
Means of 5 leaves / plant, 8 plants / plot and 3 replicate plots

Treatment		**Lower leaves**		**Upper leaves**	
A Folicur	Std rate	1.64	(2.82)	0.35	(0.23)
	Low rate	2.08	(4.38)	0.79	(0.79)
	Mean	*1.86*	*(3.60)*	*0.57*	*(0.51)*
B Lyric	Std rate	1.57	(2.59)	0.68	(0.64)
	Low rate	2.14	(4.67)	0.92	(1.03)
	Mean	*1.86*	*(3.63)*	*0.80*	*(0.83)*
C Unix	Std rate	2.36	(5.61)	1.55	(2.63)
	Low rate	2.29	(5.38)	1.60	(2.78)
	Mean	*2.32*	*(5.50)*	*1.58*	*(2.70)*
E Amistar	Std rate	2.37	(5.66)	1.50	(2.36)
	Low rate	2.11	(4.63)	1.14	(1.55)
	Mean	*2.24*	*(5.15)*	*1.32*	*(1.95)*
F Twist	Std rate	2.12	(4.61)	1.27	(1.83)
	Low rate	2.21	(4.97)	1.15	(1.66)
	Mean	*2.17*	*(4.79)*	*1.21*	*(1.74)*
K Torch	Std rate	2.25	(5.12)	1.48	(2.43)
	Low rate	2.33	(5.52)	1.55	(2.59)
	Mean	*2.29*	*(5.34)*	*1.51*	*(2.51)*
S Standard	Std rate	2.14	(4.67)	1.11	(1.30)
	Low rate	2.28	(5.24)	1.26	(1.82)
	Mean	*2.21*	*(4.95)*	*1.18*	*(1.56)*
Comparing Fungicides (means of Rates) Std vs. Other trts					
SED (26 df)		*0.108*		*0.152*	
LSD (26 df, 5%)		*0.22*		*0.31*	
P, Standard vs. Other trts		*<0.001*		*<0.001*	
Comparing Rates x Fungicides					
SED (26 df)		*0.153*		*0.215*	
LSD (26 df, 5%)		*0.31*		-	
P, Fungicide x Rate		*<0.01*		*NS*	
U Untreated		-	(5.40)	-	(2.21)

© 2001 Horticultural Development Council

Table A 4. Black Spot – Assessment 2 – 23/6/00

Effect of Standard vs. Other Treatments (mean of Rates) and individual Fungicides x Rates

Square root transformed data (untransformed mean scores in brackets)

Means of 5 leaves / plant, 8 plants / plot and 3 replicate plots

Treatment		**Lower leaves**		**Upper leaves**	
A Folicur	Std rate	1.05	(1.43)	1.02	(1.30)
	Low rate	1.31	(1.83)	1.26	(1.71)
	Mean	*1.18*	*(1.63)*	*1.14*	*(1.51)*
B Lyric	Std rate	0.97	(1.03)	1.06	(1.24)
	Low rate	0.90	(1.00)	1.25	(1.72)
	Mean	*0.94*	*(1.01)*	*1.15*	*(1.48)*
C Unix	Std rate	1.22	(1.72)	1.28	(1.73)
	Low rate	1.52	(2.54)	1.43	(2.13)
	Mean	*1.37*	*(2.13)*	*1.36*	*(1.93)*
E Amistar	Std rate	1.25	(1.68)	1.29	(1.73)
	Low rate	1.30	(1.89)	1.27	(1.67)
	Mean	*1.28*	*(1.79)*	*1.28*	*(1.70)*
F Twist	Std rate	1.24	(1.68)	1.24	(1.61)
	Low rate	1.05	(1.28)	1.20	(1.47)
	Mean	*1.15*	*(1.48)*	*1.22*	*(1.54)*
K Torch	Std rate	1.24	(1.78)	1.32	(1.84)
	Low rate	1.10	(1.38)	1.27	(1.70)
	Mean	*1.17*	*(1.58)*	1.30	*(1.77)*
S Standard	Std rate	1.10	(1.27)	1.20	(1.53)
	Low rate	1.25	(1.68)	1.30	(1.73)
	Mean	*1.18*	*(1.48)*	*1.25*	*(1.63)*
Comparing Fungicides (means of Rates) Std vs. Other trts					
SED (26 df)		*0.183*		*0.118*	
LSD (26 df, 5%)		-		-	
P, Standard vs. Other trts		*NS*		*NS*	
Comparing Rates x Fungicides					
SED (26 df)		*0.259*		*0.167*	
LSD (26 df, 5%)		-		-	
P, Fungicide x Rate		*NS*		*NS*	
U Untreated		-	(2.54)	-	(2.21)

Table A 5. Rust and Black Spot – Assessment 3 – 17/7/00

Main Effect of Fungicides (mean of rates) and Fungicides x Rates interaction

Means of 3 replicate plots (scored on whole plots for Rust), and of 8 plants / plot and 3 replicate plots (Black Spot)

Treatment		Rust	Black Spot
A Folicur	Std rate	1.33	0.92
	Low rate	2.33	1.63
	Mean	*1.83*	*1.27*
B Lyric	Std rate	1.67	0.75
	Low rate	1.67	1.75
	Mean	*1.67*	*1.25*
C Unix	Std rate	3.00	2.71
	Low rate	3.00	2.96
	Mean	*3.00*	*2.83*
E Amistar	Std rate	3.00	2.04
	Low rate	2.67	2.21
	Mean	*2.83*	*2.13*
F Twist	Std rate	2.33	1.67
	Low rate	2.33	1.38
	Mean	*2.33*	*1.52*
K Torch	Std rate	2.33	2.29
	Low rate	3.00	2.92
	Mean	*2.67*	*2.60*
S Standard	Std rate	2.67	2.50
	Low rate	2.67	2.71
	Mean	*2.67*	*2.60*
Comparing Fungicides (means of Rates) Std vs.Other trts			
SED (26 df)		*0.289*	*0.152*
LSD (26 df, 5%)		*0.59*	*0.31*
P, Standard vs. Other trts		*<0.001*	*<0.001*
Comparing Rates x Fungicides			
SED (26 df)		*0.409*	*0.215*
LSD (26 df, 5%)		-	*0.44*
P, Fungicide x Rate		*NS*	*>0.01*
U Untreated		3.00	3.00

Table A 6. Rust and Black Spot – Assessment 4 – 15/9/00

Main Effect of Fungicides (mean of rates) and Fungicides x Rates interaction

Means of 8 plants/plot and 3 replicate plots

Treatment		**Rust**	**Black Spot**
A Folicur	Std rate	0.58	0.21
	Low rate	1.75	0.38
	Mean	*1.17*	*0.29*
B Lyric	Std rate	0.08	0.13
	Low rate	0.17	0.13
	Mean	*0.13*	*0.13*
C Unix	Std rate	2.96	1.42
	Low rate	3.00	2.08
	Mean	*2.98*	*1.75*
E Amistar	Std rate	2.54	1.00
	Low rate	2.58	1.04
	Mean	*2.56*	*1.02*
F Twist	Std rate	2.25	0.67
	Low rate	1.96	0.58
	Mean	*2.10*	*0.63*
K Torch	Std rate	2.88	1.92
	Low rate	2.88	1.33
	Mean	*2.88*	*1.63*
S Standard	Std rate	2.58	0.42
	Low rate	2.67	1.67
	Mean	*2.63*	*1.04*
Comparing Fungicides (means of Rates) Std vs.Other trts			
SED (26 df)		*0.177*	*0.273*
LSD (26 df, 5%)		*0.36*	*0.56*
P, Standard vs. Other trts		*<0.001*	*<0.001*
Comparing Rates x Fungicides			
SED (26 df)		*0.250*	*0.387*
LSD (26 df, 5%)		*0.51*	*(0.80)*
P, Fungicide x Rate		*<0.01*	*(0.063)*
U Untreated		2.81	2.75

© 2001 Horticultural Development Council

Table A 7. Rust, Black Spot & Leaf Fall– Assessment 5– 16/10/00

Main Effect of Fungicides (mean of rates) and Fungicides x Rates interaction

Means of 3 replicate plots (scored on whole plots for Rust), and of 8 plants / plot and 3 replicate plots (Black Spot)

Treatment		**Rust**	**Black Spot**	**Leaf Fall**
A Folicur	Std rate	1.33	1.08	1.25
	Low rate	2.54	2.25	1.71
	Mean	*1.94*	*1.67*	*1.48*
B Lyric	Std rate	1.33	1.21	1.21
	Low rate	1.50	1.75	1.46
	Mean	*1.42*	*1.48*	*1.33*
C Unix	Std rate	4.79	4.33	3.71
	Low rate	4.25	4.83	4.25
	Mean	*4.52*	*4.58*	*3.98*
E Amistar	Std rate	4.07	4.21	2.75
	Low rate	3.57	4.39	3.42
	Mean	*3.82*	*4.30*	*3.08*
F Twist	Std rate	3.25	2.33	1.83
	Low rate	2.96	2.21	1.92
	Mean	*3.10*	*2.27*	*1.88*
K Torch	Std rate	3.66	4.69	4.08
	Low rate	4.00	4.58	3.63
	Mean	*3.83*	*4.64*	*3.85*
S Standard	Std rate	3.67	3.71	2.50
	Low rate	3.88	4.73	3.79
	Mean	*3.77*	*4.22*	*3.15*
Comparing Fungicides (means of Rates) Std vs.Other trts				
SED (26 df)		*0.231*	*0.172*	*0.282*
LSD (26 df, 5%)		*0.47*	*0.35*	*0.58*
P, Standard vs. Other trts		*<0.001*	*<0.001*	*<0.001*
Comparing Rates x Fungicides				
SED (26 df)		*0.326*	*0.243*	*0.398*
LSD (26 df, 5%)		*0.67*	*0.50*	-
P, Fungicide x Rate		*<0.05*	*<0.01*	*NS*
U Untreated		4.20	4.57	4.91

© 2001 Horticultural Development Council

Appendix 3 - Photographs

**Photo 1 Phytotoxicity experiment showing 5 cultivars per plot.
7 September 2000.**

Photo 2 Phytotoxicity symptoms from high rate of 'positive control' treatment Corbel on cv. Dearest, 5 June, three days after spraying.

Photo 3 Leaf scorch on all cultivars from Corbel, 5 September.

© 2001 Horticultural Development Council

Photo 4 White spray deposits from high rate of Unix, 5 June.

Photo 5 'Grade plants' for leaf drop. Scores 1 to 5, L to R, 16 October.

Photo 6 Clean foliage on Folicur standard rate plot, 13 October. Unsprayed inoculator plant in front.

Photo 7 Central 8 assessed plants on low rate Folicur plot also showing largely healthy foliage, 13 October.

© 2001 Horticultural Development Council

Photo 8 Central 8 assessed plants on standard rate Unix plot showing

Photo 9 Twist standard rate plot

(rear) vs.

high infection levels and leaf drop, 13 October.

Torch standard rate plot (front),

13 Oct.

Photo 10 Severe black spot on leaves of plant from a low rate

Photo 11 Standard spray

programme Torch plot, 13 October.

treatment (std. rate) showing black spot.

Photo 12 Low rate Folicur plot by 3 November showing good health and leaf retention.

Photo 13 Low rate Lyric plot by 3 November showing good health and leaf retention.

© 2001 Horticultural Development Council

Photo 14 High level of leaf drop on Standard programme (standard rate) by 3 November.

Photo 15 Virtual complete defoliation of standard rate Unix plot by 3/11/00.

© 2001 Horticultural Development Council