ANNUAL REPORT

Roses: Fungicides for the control of powdery mildew black spot and rust - further testing and nursery trials

HNS 106a (extension to HNS 106)
Year 1 - 2001

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The results and conclusions in this report are based on an investigation conducted over two years (including the previous one-year project HNS 106). The conditions under which the experiments were carried out and the results obtained have been reported with detail and accuracy. However, because of the biological nature of the work it must be borne in mind that 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.

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Practical Section for Growers

Commercial benefits of the project

Four fungicides products, Folicur, Lyric, Flamenco and Twist have been identified as giving significantly improved control of rose black spot, rust and powdery mildew compared to other fungicides currently used by growers. Some of these products have been tested in comprehensive spray programmes involving other materials for downy mildew control. Some programmes appear to offer very cost effective improvements over currently used standards.

Background and objectives

In the first year of the project, two conazole fungicide products, Lyric (flusilazole) and Folicur (tebuconazole), gave excellent control of rust and black spot compared to a standard spray programme rotation of Systhane 20EW, Nimrod T, F238 + Bavistin DF. The strobilurins Twist (trifloxystrobin) and Amistar (azoxystrobin) also looked promising, but control may have been improved further if they had been applied protectively before the first signs of disease. There was sufficient indication that the higher of the two chemical rates tested was necessary to get the best control. Powdery mildew inoculations failed to develop during the trial and so efficacy for this disease could not be tested.

In addition to these fungicides, Indar 5EW (fenbuconazole), Tilt (propiconazole), Plover (difenoconazole), Flamenco (fluquinconazole) and Stroby WG (kresoxim-methyl) showed good crop safety when tested on several rose cultivars, and were sufficiently interesting for efficacy testing in 2001.

As well as identifying some more effective fungicides against foliar diseases of rose, it is important to extend the range available, particularly using active ingredients from other chemical groups, to reduce the risk of fungicide resistance developing. This requires the development of spray programmes where fungicides are rotated. This is particularly important for the rose crop typically sprayed frequently over a long season. The most effective fungicides have tended to be systemic chemicals from groups such as the conazoles, morpholines, and now strobilurins, where fungicide resistance can develop unless spray programmes are properly managed.

Work on downy mildew has been ongoing in a Defra funded project (HH1749SHN). Efficacy of fungicides for this disease is not specifically tested in this project. Nevertheless, the inclusion of downy mildew fungicides was considered necessary to develop integrated programmes, with the potential to reduce the number of spraying operations required, particularly as the new strobilurin group of products, for example, should have activity against both disease groups.

The overall objective of work in 2001, therefore, was to develop highly effective, yet economic, fungicide programmes with a high level of crop safety for the main foliar diseases of outdoor roses. Four experiments were undertaken with the following specific objectives:

1. Compare a range of fungicide programmes involving weekly or fortnightly sprays, for efficacy and crop safety. Efficacy tests will concentrate on black spot, rust (and powdery mildew if it develops) but effects of incorporating downy mildew fungicides will also be monitored. Phytotoxicity tests will compare a range of tank mix options across several cultivars.

2. Establish relative efficacy on black spot and rust of the new products tested only for phytotoxicity in 2000.

3. Test efficacy of several products against powdery mildew with a separate experiment under protection.

4. Obtain an estimation of costs of fungicide programmes.

Summary of results and conclusions

Evaluation of fungicide programmes (see table of treatments next page)

- All spray programmes, including the standard, kept plants disease free for the first three months (April – June).
- Untreated control plants in a separate area from the main experiment developed rust and black spot by early June, confirming conditions were suitable for these diseases.
- Rust developed first on the standard programme in late summer, followed by black spot in the autumn. No powdery or downy mildew was observed on these plants outdoors during the experiment.
- The standard control treatment (a fortnightly rotation of Systhane 20EW, Nimrod T and F238 + Bavistin DF) had significantly higher rates of disease and leaf drop by late summer and autumn compared to all other fungicide programmes.
- Although the fortnightly spray programme gave slightly less disease control than weekly sprays by November, there was relatively little difference between the range of new spray regimes. These programmes retained healthy leaves on the susceptible cv. Silver Wedding well into December.
- The weekly spray programme W3, which did not involve tank mixes and used fewer products, was as effective as the other weekly programmes against rust and black spot, but at less than half the cost of materials. Spray materials cost for W3 was similar to the much less effective fortnightly standard programme.

Rose Fungicide Programmes Experiment 2001

	= conazole
italic	= morpholine or pyridine
bold	= strobilurin
	= other protectant

PM	Powdery mildew
BS	Black spot
R	Rust
DM	Downy mildew

Treatment — Tank mixes used for 2 product applications

		W/c	16-Apr	23-Apr	30-Apr	7-May	14-May	21-May	28-May	4-Jun	11-Jun	18-Jun	25-Jun	2-Jul	9-Jul	16-Jul	23-Jul	30-Jul
		Week Number	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
W1 - Weekly 1	PM, BS & R		Folicur		*Nimrod T*	Lyric	*Dorado*	Systhane		Lyric	*Nimrod T*	Folicur		*Dorado*	Folicur		*Nimrod T*	Lyric
	DM		Aliette	**Amistar**	Elvaron	Ripost	captan	Invader	**Twist**	Aliette	Bravo	Fubol	**Amistar**	captan	Aliette	**Amistar**	Elvaron	Ripost
W2 - Weekly 2	PM, BS & R		*Nimrod T*	Lyric	*Dorado*	Systhane		Lyric	*Nimrod T*	Folicur		*Dorado*	Folicur		*Nimrod T*	Lyric	*Dorado*	Systhane
	DM		Elvaron	Ripost	captan	Invader	**Twist**	Aliette	Bravo	Fubol	**Amistar**	captan	Aliette	**Amistar**	Elvaron	Ripost	captan	Invader
W3 - Weekly 3	PM, BS & R		Folicur		*Nimrod T*		Lyric		*Dorado*		Folicur		*Nimrod T*		Lyric		*Dorado*	
	DM			**Amistar**		Invader		**Twist**		Ripost		**Amistar**		Invader		**Twist**		Ripost
F1 - Fortnightly 1	PM, BS & R		Folicur		*Dorado*		Lyric		Systhane		Folicur		*Nimrod T*		Lyric		Systhane	
	DM		Aliette		**Amistar**		Ripost		Invader		Aliette		**Twist**		Ripost		Invader	
F2 - Fortnightly 2	PM, BS & R			Systhane		Folicur		*Dorado*		Lyric		Systhane		Folicur		*Nimrod T*		Lyric
	DM			Invader		Aliette		**Amistar**		Ripost		Invader		Aliette		**Twist**		Ripost
F3 - Fortnightly 3	PM, BS & R		Folicur	?	*Dorado*	?	Lyric	?	Systhane	?	Folicur	?	*Nimrod T*	?	Lyric	?	Systhane	?
Reactive prog.	DM		Aliette		**Amistar**		Ripost		Invader		Aliette		**Twist**		Ripost		Invader	
? = additional curative sprays if diseases appear																		
S - Standard	PM, BS & R		Systhane		*Nimrod T*		*F238* Bavistin DF		Systhane		*Nimrod T*		*F238* Bavistin DF		Systhane		*Nimrod T*	

		6-Aug	13-Aug	20-Aug	27-Aug	3-Sep	10-Sep	17-Sep	24-Sep	1-Oct	8-Oct	15-Oct	22-Oct	29-Oct	5-Nov	12-Nov	19-Nov	26-Nov
		32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
W1 - Weekly 1		*Dorado*	Systhane		Lyric	*Nimrod T*	Folicur		*Dorado*	Folicur		*Nimrod T*	Lyric	*Dorado*	Systhane		Lyric	*Nimrod T*
		captan	Invader	**Twist**	Aliette	Bravo	Fubol	**Amistar**	captan	Aliette	**Amistar**	Elavaron	Ripost	captan	Invader	**Twist**	Aliette	Bravo
W2 - Weekly 2			Lyric	*Nimrod T*	Folicur		*Dorado*	Folicur		*Nimrod T*	Lyric	*Dorado*	Systhane		Lyric			
		Twist	Aliette	Bravo	Fubol	**Amistar**	captan	Aliette	**Amistar**	Elavaron	Ripost	captan	Invader	**Twist**	Aliette			**Amistar**
W3 - Weekly 3		Folicur		*Nimrod T*		Lyric		*Dorado*		Folicur		*Nimrod T*		Lyric		*Dorado*		Folicur
			Amistar		Invader		**Twist**		Ripost		**Amistar**		Invader		**Twist**		Ripost	
F1 - Fortnightly 1		Folicur		*Dorado*		Lyric		Systhane		Folicur		*Nimrod T*		Lyric		Systhane		Folicur
		Aliette		**Amistar**		Ripost		Invader		Aliette		**Twist**		Ripost		Invader		Aliette
F2 - Fortnightly 2			Systhane		Folicur		*Dorado*		Lyric		Systhane		Folicur		*Nimrod T*		Lyric	
			Invader		Aliette		**Amistar**		Ripost		Invader		Aliette		**Twist**		Ripost	
F3 - Fortnightly 3		Folicur	?	*Dorado*	?	Lyric	?	Systhane	?	Folicur	?	*Nimrod T*	Folicur	Lyric	*Nimrod T*	Systhane	?	Folicur
Reactive prog.		Aliette		**Amistar**		Ripost		Invader		Aliette		**Twist**		Ripost		Invader		Aliette
? = additional curative sprays if diseases appear																		
S - Standard		*F238* Bavistin DF		Systhane		*Nimrod T*		*F238* Bavistin DF		Systhane		*Nimrod T*		*F238* Bavistin DF		Systhane		*Nimrod T*

Efficacy of individual fungicides against black spot, rust and powdery mildew

- Even under polythene tunnels, levels of powdery mildew sufficient to compare fungicide treatments did not build up until late in the year on cv. Margaret Merril. Nevertheless, two fungicides, Folicur and Twist showed excellent activity against powdery mildew, with more than 85% of plants remaining clean. In contrast, Plover, Dorado and Bavistin DF gave poor control with less than 30% clean plants.
- The good results with Lyric against black spot and rust in 2000 were confirmed again this year. In addition, Flamenco was shown to have particularly good activity against these diseases.
- The conazoles Tilt, Indar and Plover, while giving moderate or good black spot control, failed to give good control of rust and have therefore been outclassed by Lyric, Folicur and Flamenco which show better all round performance.
- Of the strobilurin fungicides, Stroby appears to be the weakest for rose diseases giving little control of rust, and was not as good as Twist against powdery mildew or black spot. Amistar was not tested individually this year, but in 2000 it was not quite as effective as Twist.

Phytotoxicity of fungicides

- The cultivar Silver Wedding used to test fungicide programmes and the other single products tested outdoors showed no damage from the range of treatments and tank mixes used during the season.
- Fungaflor produced some necrotic spots on leaves of Margaret Merril in the powdery mildew experiment under protection, but other products used there were safe.
- Five other cultivars were used to test for phytotoxicity of a range of tank mixes in May and again in September and October when applied at the standard and double rates. Most treatments tested, appeared safe, but where there was damage, Fiesta, Kind Regards and Warm Wishes were the most sensitive, with L'Aimant and Dearest less so.
- High levels of rust on Fiesta, Kind Regards and Dearest in late summer made the autumn assessments difficult on these cultivars, but observation were possible on Warm Wishes and Dearest.
- Several of the tank mixtures involving Nimrod T caused some damage; either as puckering or curling of young leaves, or leaf spotting. Nimrod T + Elvaron or Twist was damaging at both the standard and double rates in May, but not in the autumn. Nimrod T + Lyric or Folicur caused some scorch on leaf tips of Warm Wishes, when tested in the autumn, but only after the double rate spray.
- In May, Folicur + Aliette and Folicur + Fubol caused some slight leaf marking, but this was mainly only on Fiesta, and only after the double rate spray.
- In general, none of the fungicides caused serious plant disfiguration, but some of the phytotoxicity symptoms may have been unacceptable for a container grown crop marketed within a few weeks of the occurrence of damage. For a field crop, mild or transient symptoms, are of little consequence to the quality of the marketed product.

Action points for growers

- Consider changing from the standard spray programme to an alternative – all gave better control and some may be cheaper.
- Incorporate Lyric, Folicur or Flamenco in spray programmes as effective conazole formulations, and Twist (or Amistar) as a strobilurin.
- Ensure sufficient rotation of fungicides from different chemical groups in programmes to avoid the development of fungicide resistance. Do not use more than two conazole sprays in succession, and limit the use of strobilurins to a maximum of one in three fungicide applications. Strobilurins should be used as protectants before diseases develop.
- Nimrod T and F238 should also be incorporated into spray rotations,.as they contain ingredients from pyridimidine and morpholine chemical groups. Note that Dorado, a morpholine, is due to be withdrawn from the market.
- A weekly spray programme alternating specific fungicides for rust, black spot and powdery mildew, with ones for downy mildew or dual activity, may be the most cost-effective option for containerised crops, as it avoids tank mixes and minimises the risk of phytotoxicity. For field crops, some of the fortnightly programmes with tank mixes may be more appropriate, particularly when spraying conditions and field access become more difficult in the autumn. Particular care should be taken with Nimrod T mixed with other fungicides, as some phytotoxicity may occur.
- Sprays of the fungicides tested, which do not have specific label recommendations for roses, are used at grower's risk under the Revised Long-Term Arrangements for Extension of Use (2000). Most can only be used on outdoor crops apart from those cleared for use under protection on roses or other crops.
- Rates of use for the new fungicides recommended for roses have been extrapolated from other crops but as high volume sprays at 1000 litres/ha. Sprays should be applied to give good coverage of foliage at the following concentrations: Folicur 1.0 ml/l; Lyric 2.0 g/l; Flamenco 1.25 ml/l; Twist 2.0 ml/l; and Amistar 1.0 ml/l.

Anticipated practical and financial benefits

Improved control of the main foliar diseases of roses 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 grown on in containers, or when planted out by the end user.

In the final year of the project, spray programmes will be further tested on commercial nurseries for efficacy and crop safety.

Science Section

Introduction

Background

In 2000, project HNS 106 concentrated on fungicide control of the three foliar diseases powdery mildew (*Sphaerotheca pannosa* var. *rosae* or *S. macularis*), black spot, (*Diplocarpon rosae*), rose rust (*Phragmidium mucronatum* and *P. tuberculosum*), tested on an outdoor containerised crop. The two main objectives were to:

1 Identify new, effective, and safe alternative fungicides the 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.

Two conazole fungicide products, Lyric (flusilazole) and Folicur (tebuconazole), gave excellent control of rust and black spot compared to a standard spray programme rotation of Systhane 20EW, Nimrod T, F238 + Bavistin DF. The strobilurins Twist (trifloxystrobin) and Amistar (azoxystrobin) also had useful activity, but control may have been improved further if they had been applied protectively before the first signs of disease. There was sufficient indication that the higher of the two chemical rates tested was necessary to get the best control. Powdery mildew inoculations failed to develop during the trial and so efficacy for this disease could not be tested.

At a review meeting of the project in November 2000, the highest priority identified for further work was to investigate fungicide programmes in order to maintain clean crops. This is particularly important for containerised roses, where quality standards demand disease free crops at marketing. Extrapolation to field grown crops should also then be possible with confidence.

Downy mildew (*Peronospora sparsa*) was also recognised as becoming increasingly widespread. It is difficult to test fungicide efficacy against this, at the same time as the other diseases, but developing spray programmes that incorporated downy mildew fungicides would be valuable, especially if tank mixes could be used to cut down on spraying operations.

Tests for phytotoxicity in 2000 showed good crop safety for all fungicides tested at both standard and double concentrations except for Tern (fenpropidin), which caused some leaf scorch in one test, and this fungicide was dropped from further testing. The 'positive control' treatment Corbel (fenpropimorph) was consistently damaging. The development of spray programmes often involves tank mixing products, and it was clear that phytotoxicity testing would be an important part of the work for 2001.

Four conazole products, Indar 5EW (fenbuconazole), Tilt (propiconazole), Plover (difenoconazole) and Flamenco (fluquinconazole), plus a strobilurin, Stroby WG (kresoxim-

methyl), were phytotoxicity tested only in HNS 106, but required further testing for efficacy in 2001.

Finally, weather conditions outdoors proved unreliable for the development of powdery mildew – at least using the test cultivar Silver Wedding at the same time as testing fungicides for black spot and rust. It was clear that a further experiment using a crop under protection to encourage disease development,was needed to examine the efficacy of fungicides against this disease.

Objectives

The overall objective of the work in 2001 was to develop highly effective, yet economic, fungicide programmes with a high level of crop safety, for the main foliar diseases of outdoor roses.

Specific objectives

a) Compare a range of fungicide programmes for efficacy and crop safety. Efficacy tests will concentrate on black spot, rust, (and powdery mildew if it develops) but effects of incorporating downy mildew fungicides will also be monitored.

b) Establish relative efficacy on black spot and rust of the new products tested only for phytotoxicity in 2000.

c) Test efficacy of several products against powdery mildew with a separate experiment under protection.

d) Obtain an estimation of costs of fungicide programmes.

Materials and Methods

Cultural details

Potting

Bare root rose plants were given a standard root and shoot pruning to 200 mm and 130 mm lengths from the bud union respectively, prior to containerising into deep 4.0 litre pots. The following growing medium was used:

100%	Nursery Stock grade medium / coarse shamrock peat
3.0 kg/m³	Osmocote Exact 8-9 month 15 + 9 + 9 + MgO and traces CRF
2.4 kg/m³	Magnesian limestone
0.75 kg/m³	SuSCon Green

Plants were potted between 6th and 20th March 2001 depending on experiment, and transferred to free draining outdoor growing-on beds immediately after watering in. They remained here for the duration of the experiments except for the powdery mildew trial plants, which were moved under tunnels on 18 July (see on for details).

Irrigation

Initial watering by hand was carried out by hand, but pot drippers (one per container) were installed once pots were laid out in their final plot positions on the growing beds.

Other pesticides

A herbicide application of oxadiazon granules as Ronstar 2G at 20 g/m² was applied on 28 March to all freshly potted plants.

Sprays for aphids, caterpillars and leafhoppers were applied, as required, on the following dates to all experiments. These were not tank mixed with any of the fungicide treatments.

26 April and 29 June	pirimicarb as Aphox at 0.5 g/litre
8 June	dimethoate as Dimethoate 40 at 0.85 ml/litre
24 August	heptenophos as Toppel 10 at 0.25 ml/litre
18 May and 19 October	deltamethrin as Decis at 0.7 ml/litre

Experimental treatments

Fungicide products and rates of use

The fungicides used in this year of the project are given in Table 1 below. The rates shown were used in all the experiments for each application, but in addition double rates were also used for the phytotoxicity screening experiment with fungicide mixtures. Rates used were, where applicable, based on recommended rates for nursery stock or ornamentals. With the 'new'

experimental fungicides, the 'standard' rate as used in the year 2000 experiments, was used again. These rates were extrapolated from other recommendations, e.g. cereals, where they were expressed as a product rate per has. 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, much higher volume sprays to run-off to give good coverage are often recommended for good control, and are probably more typical of applications to nursery stock areas, especially when hand lances are used. A standard HV rate of 1000 litres/ha was chosen as a basis to calculate standard rates for the project, and 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 an HV concentration of 1.0 ml/litre applied to run-off.

Table 1. Fungicides used in 2001: their chemical activity groups, and standard rate concentrations of products used in experiments.

Product	Active ingredient	Chemical activity group	Product rate / litre
Aliette 80 WG	fosetyl-aluminium 80% w/w	phosphonate	2.5 g
Amistar	azoxystrobin 250 g/l	strobilurin analogue	1.0 ml
Bavistin DF	carbendazim 50% w/w	MBC or benzimidazole	0.5 g
Bravo 500	chlorothalonil 500 g/l	chloronitrile	2.2 ml
Captan	captan 80% w/w	dicarboximide	1.25 g
Dorado	pyrifenox 200 g/l	pyridine	0.25 ml
Elvaron WG	dichlofluanid 50% w/w	sulphamide	5.0 g
F238	dodemorph 385 g/l	morpholine	2.5 ml
Flamenco	fluquinconazole 100 g/l	conazole	1.25 ml
Folicur	tebuconazole 250 g/l	conazole	1.0 ml
Fubol Gold WG	mancozeb + metalaxyl 64:4% w/w	dithiocarbamate + phenylamide	2.0 g
Indar 5EW	fenbuconazole 50 g/l	conazole	1.4 ml
Invader	dimethomorph + mancozeb 7.5:66.7% w/w	cinnamic acid (morpholine related) + dithiocarbamate	2.0 g
Lyric	flusilazole 250 g/l	conazole	0.625 ml
Nimrod T	bupirimate + triforine 62.5:62.5 g/l	pyrimidinol + piperazine	3.2 ml
Plover	difenoconazole 250 g/l	conazole	0.3 ml
Ripost Pepite	cymoxanil + mancozeb + oxadixyl 3.2:56:8% w/w	cyano-acetamide + dithiocarbamate + phenylamide	2.5 g
Stroby WG	kresoxim-methyl 50% w/w	strobilurin analogue	0.3 g
Systhane 20EW	myclobutanil 200 g/l	conazole	0.3 ml
Tilt	propiconazole 250 g/l	conazole	1.0 ml
Twist	trifloxystrobin 125 g/l	strobilurin analogue	2.0 ml

Treatment 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 l/ha to 3000 l/ha on the small plots used. It is expected, however, that lower volumes could achieve a similar level of

coverage if spraying had been carried out on a larger commercial area of containers because of less overlap with plot edges and better interception of drift by the rest of the crop. A portable plastic barrier was held between adjacent plots when applying treatments to avoid unwanted contamination from spray drift.

Inoculations to encourage disease development

The project in 2000 showed that inoculating plants with a suspension of black spot spores sprayed over the plants in the evening, particularly during dull, humid or wet weather, could be very effective in ensuring a high level of disease pressure evenly distributed over the trial area. The procedure involved collecting leaves showing black spot symptoms from roses grown elsewhere (e.g. a susceptible cultivar in the field), and 'incubating' them in polythene sacks for a day or two at ambient temperature in the shade, and then washing them in a tank of water. The strained solution was then simply sprayed onto the plants. The procedure was repeated for the 'Spray Programmes' and 'Efficacy' experiments in 2001. One spray was inoculation was made on 23 May, but microscopic examination of the spray solution indicated that only low spore numbers were present. There was little field inoculum available until mid September, so four further sprays were applied during September and mid October.

For the Powdery Mildew experiment, additional 'inoculator plants' of cvs Blue Moon and Margaret Merril were potted. Infection was encouraged to develop early on these plants by keeping them in a glasshouse, and keeping them fairly dry to encourage some stress on the plants. Powdery mildew spores were introduced by occasionally shaking bundles of infected shoots over the plants. Shoots of the climbing cv. Zephirine Drouhin, collected from a field crop, proved to be a useful source of inoculum. This was also repeated on occasions in August and September over all the trial plants once they had been introduced into the polythene tunnel plots.

Disease and phytotoxicity assessments

See individual experiment descriptions for details. Diseases were assessed by scoring individual plants within the plots on a 1 - 5 scale.

Statistical analyses

Mean disease scores were analysed by ANOVA. In addition a binomial analysis of the percentage of plants in a plot in different disease categories was carried out. In particular the proportion of plants that were clean, or with only a trace of disease, proved to be a sensitive analysis for distinguishing treatment differences.

Experiment 1 – Evaluation of fungicide programmes

Cultivar

Silver Wedding was used as it had proved very disease susceptible in the year 2000 trials.

Fungicide programmes

Fungicides against powdery mildew, black spot and rust were based around alternating conazole, strobilurin and pyrimidine / pyridine group fungicides. Guidelines from the Fungicide Resistance Action Group were followed to minimise the development of resistance. The two strobilurins, Amistar and Twist used in 2000 were also expected give protection against downy mildew. Aliette, Fubol, Invader and Ripost were systemic and protectant fungicides aimed at downy mildew control. The other protectant fungicides captan, Elvaron and Bravo were also included in the weekly programme primarily for downy mildew control, but captan was also expected to have some protectant activity against black spot and the last two against powdery mildew.

The details of the 7 fungicide programme treatments, and the products applied each week during the experiment are presented on the next page. The spray programme ran from 18 April - 18 November 2001.

Weekly and fortnightly programmes incorporating the new test fungicides were compared against the standard fortnightly rotation of Systhane, Nimrod T and F238 + Bavistin.

The weekly and fortnightly treatments W1, W2, F1 and F2 were identical, but shifted in time relative to each other to accommodate differences in weather pattern and disease development that could occur. W3 and F3 represented simpler and less aggressive spray programmes but which may nevertheless be as good and more cost effective. Rather than employing fungicide tank mixtures, W3 tested alternating weekly sprays aimed primarily against downy mildew one week and the other diseases the next. Treatment F3 was designed to incorporate additional 'curative' sprays if disease was noticed on plants. In fact only two additional sprays, Folicur in week 43 and Nimrod T week 45 were applied to F3, and until then it was identical to treatment F1.

Experiment design and layout

See Appendix 1, p 36 for details of experiment plan and plot layout.

Total 7 fungicide programme treatments x 4 replicates = 28 plots. A randomised block design was used with one bed per block. There were 9 assessed plants per plot surrounded by a ring of 16 guard plants. Plants were spaced at 300 mm x 300 mm with gaps of 1.0 m between plots down the bed giving access for spraying. Unsprayed inoculator plants of two year old potted roses were placed in the inter-plot gaps. Also, 4 plots of untreated plants of the same cv. Silver Wedding were placed on a bed about 15 away from the trial to monitor natural development of diseases on both this and the Efficacy experiment.

Rose Fungicide Programmes Experiment 2001

	= conazole	PM	Powdery mildew
italic	= morpholine or pyridine	BS	Black spot
bold	= strobilurin	R	Rust
	= other protectant	DM	Downy mildew

Treatment	Tank mixes used for 2 product applications	W/c	16-Apr	23-Apr	30-Apr	7-May	14-May	21-May	28-May	4-Jun	11-Jun	18-Jun	25-Jun	2-Jul	9-Jul	16-Jul	23-Jul	30-Jul
		Week Number	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
W1 - Weekly 1	PM, BS & R		Folicur		*Nimrod T*	Lyric	*Dorado*	Systhane		Lyric	*Nimrod T*	Folicur		*Dorado*	Folicur		*Nimrod T*	Lyric
	DM		Aliette	**Amistar**	Elvaron	Ripost	captan	Invader	**Twist**	Aliette	Bravo	Fubol	**Amistar**	captan	Aliette	**Amistar**	Elvaron	Ripost
W2 - Weekly 2	PM, BS & R		*Nimrod T*	Lyric	*Dorado*	Systhane		Lyric	*Nimrod T*	Folicur		*Dorado*	Folicur		*Nimrod T*	Lyric	*Dorado*	Systhane
	DM		Elvaron	Ripost	captan	Invader	**Twist**	Aliette	Bravo	Fubol	**Amistar**	captan	Aliette	**Amistar**	Elvaron	Ripost	captan	Invader
W3 - Weekly 3	PM, BS & R		Folicur		*Nimrod T*		Lyric		*Dorado*		Folicur		*Nimrod T*		Lyric		*Dorado*	
	DM			**Amistar**		Invader		**Twist**		Ripost		**Amistar**		Invader		**Twist**		Ripost
F1 - Fortnightly 1	PM, BS & R		Folicur		*Dorado*		Lyric		Systhane		Folicur		*Nimrod T*		Lyric		Systhane	
	DM		Aliette		**Amistar**		Ripost		Invader		Aliette		**Twist**		Ripost		Invader	
F2 - Fortnightly 2	PM, BS & R			Systhane		Folicur		*Dorado*		Lyric		Systhane		Folicur		*Nimrod T*		Lyric
	DM			Invader		Aliette		**Amistar**		Ripost		Invader		Aliette		**Twist**		Ripost
F3 - Fortnightly 3	PM, BS & R		Folicur	?	*Dorado*	?	Lyric	?	Systhane	?	Folicur	?	*Nimrod T*	?	Lyric	?	Systhane	?
Reactive prog.	DM		Aliette		**Amistar**		Ripost		Invader		Aliette		**Twist**		Ripost		Invader	
? = additional curative sprays if diseases appear																		
S - Standard	PM, BS & R		Systhane		*Nimrod T*		*F238* Bavistin DF		Systhane		*Nimrod T*		*F238* Bavistin DF		Systhane		*Nimrod T*	

		W/c	6-Aug	13-Aug	20-Aug	27-Aug	3-Sep	10-Sep	17-Sep	24-Sep	1-Oct	8-Oct	15-Oct	22-Oct	29-Oct	5-Nov	12-Nov	19-Nov	26-Nov
		Week Number	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
W1 - Weekly 1	PM, BS & R		*Dorado*	Systhane		Lyric	*Nimrod T*	Folicur		*Dorado*	Folicur		*Nimrod T*	Lyric	*Dorado*	Systhane		Lyric	*Nimrod T*
	DM		captan	Invader	**Twist**	Aliette	Bravo	Fubol	**Amistar**	captan	Aliette	**Amistar**	Elavaron	Ripost	captan	Invader	**Twist**	Aliette	Bravo
W2 - Weekly 2	PM, BS & R			Lyric	*Nimrod T*	Folicur		*Dorado*	Folicur		*Nimrod T*	Lyric	*Dorado*	Systhane		Lyric			
	DM		**Twist**	Aliette	Bravo	Fubol	**Amistar**	captan	Aliette	**Amistar**	Elavaron	Ripost	captan	Invader	**Twist**	Aliette			**Amistar**
W3 - Weekly 3	PM, BS & R		Folicur		*Nimrod T*		Lyric		*Dorado*		Folicur		*Nimrod T*		Lyric		*Dorado*		Folicur
	DM			**Amistar**		Invader		**Twist**		Ripost		**Amistar**		Invader		**Twist**		Ripost	
F1 - Fortnightly 1	PM, BS & R		Folicur		*Dorado*		Lyric		Systhane		Folicur		*Nimrod T*		Lyric		Systhane		Folicur
	DM		Aliette		**Amistar**		Ripost		Invader		Aliette		**Twist**		Ripost		Invader		Aliette
F2 - Fortnightly 2	PM, BS & R			Systhane		Folicur		*Dorado*		Lyric		Systhane		Folicur		*Nimrod T*		Lyric	
	DM			Invader		Aliette		**Amistar**		Ripost		Invader		Aliette		**Twist**		Ripost	
F3 - Fortnightly 3	PM, BS & R		Folicur	?	*Dorado*	?	Lyric	?	Systhane	?	Folicur	?	*Nimrod T*	Folicur	Lyric	*Nimrod T*	Systhane	?	Folicur
Reactive prog.	DM		Aliette		**Amistar**		Ripost		Invader		Aliette		**Twist**		Ripost		Invader		Aliette
? = additional curative sprays if diseases appear																			
S - Standard	PM, BS & R		*F238* Bavistin DF		Systhane		*Nimrod T*		*F238* Bavistin DF		Systhane		*Nimrod T*		*F238* Bavistin DF		Systhane		*Nimrod T*

Some of the guard plants used were second year Silver Wedding containerised roses which were pruned back and given extra feed as CRF tablets in the spring. These second year plants were distributed evenly throughout the plot guards.

Disease assessments

Plants receiving all seven treatments remained clean well into the summer, and there was insufficient disease present to undertake assessment records until the beginning of August. Plants had flowered by this time, and so guard plants were pruned back on 1 August, followed by the assessed plants on 23 August. Only a light pruning was given to remove the inflorescences and reduce the height of these shoots by about half. The intention was to retain a large proportion of the original foliage to observe any disease development on these leaves, as well as stimulate some new growth.

Disease assessments were made on 1 August prior to pruning, then on 22 October, 13 November, and on 26 November. Two later assessments for leaf drop were made on 3 and 17 December.

Disease and leaf drop scoring scales were as follows:

Black spot and rust

1 No leaves on the plant affected.
2 Trace/low level of infection (ie from one leaf with one pustule / spot up to 10% of the leaves affected).
3 Moderate infection.
4 Most mature leaves with one or more spots / pustules present.
5 Nearly all leaves severely affected. Where fallen leaves can be attributed to disease for the assessed plant, these also count as severely affected.

Leaf drop

1 No visible leaf drop.
2 Slight leaf drop.
3 Moderate leaf drop.
4 Severe leaf drop.
5 Most leaves dropped; a few remaining on leaf tips.

Experiment 2 – Phytotoxicity of fungicide tank mixes

Cultivars

The following cultivars were selected, representing a range of bush rose types, some of which are known to be sensitive to pesticide scorch from previous experience.

Table 2. 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
L'A	L'Aimant	pink	floribunda
Fi	Fiesta	scarlet / white	patio

Fungicide tank mixes

Tank mix treatments were selected from those being used in the Programmes experiment, but also some additional tank mixes that might be desirable in other programme permutations, such as Dorado + Amistar, or Systhane + Twist were also tried.

Tank mix treatments were first applied in on 15 May using the standard rates (Table 1), repeated one week later on 22 May but at twice the rate (double concentration). Plants were hard pruned on July 11 to generate new healthy foliage. Further applications followed on 20 September (standard rate) and 12 October (double rate) but substituting some tank mix treatments with others (underlined).

May treatments

Code	Fungicides
U	Untreated (water)
Fo+Al	Folicur + Aliette
Ly+Al	Lyric + Aliette
Ly+Ri	Lyric + Ripost
Do+Ca	Dorado + Captan
Sy+In	Systhane + Invader
Fo+Fu	Folicur + Fubol 75
Do+Am	Dorado + Amistar
NT+Tw	Nimrod T + Twist
NT+El	Nimrod T + Elvaron WG

September / October treatments

Code	Fungicides
U	Untreated (water)
Fo+Al	Folicur + Aliette
Ly+Al	Lyric + Aliette
Ly+NT	Lyric + Nimrod T
Do+Tw	Dorado + Twist
Sy+Tw	Systhane + Twist
Fo+NT	Folicur + Nimrod T
Do+Am	Dorado + Amistar
NT+Tw	Nimrod T + Twist
NT+El	Nimrod T + Elvaron WG

Experiment design and layout

See Appendix 1, p 37-38 for details of experiment plan and layout.

A total of 10 tank mixes x 3 replicates = 30 plots in a randomised block design. Each plot consisted of a row of 5 plants (one of each cultivar, randomised within the row). Plants were

spaced 300 mm apart in the row, leaving gaps of 850 mm between row centres (plots) to allow spray drift shields to be used.

Phytotoxicity damage assessments

Plants were observed before the first sprays were applied, and notes made of any significant leaf discolouration or damage present which could interfere with subsequent assessments of treatment effects.

Plants were observed every two or three days after the spray applications to observe any damage symptoms which developed. Some formal assessments of damage and spray deposits were made on 25 May for the spring applications, and on 22, 24, 27, 28 September and 4, 5 and 22 October for the late summer applications using the following scoring system:

Score	*Leaves affected*
0	Nil
0.5	Trace
1	5%+ leaves
2	10%+ affected
3	20%+
4	40%+
5	80%+

Photographs and descriptive notes were taken of damage symptoms observed.

Some additional applications of proven and safe fungicides, such as Systhane 20EW, were applied to all the plants on occasions during the experiment, but insufficient applications were made to prevent rust and black spot developing on cv. Kind Regards (most severely), followed by Fiesta and Dearest by late summer. This made the autumn phytotoxicity assessments very difficult on these cultivars except on the youngest leaves at the tops of the plants. However L'Aimant and Warm Wishes remained clean enough for some observations to be made on these cultivars.

Experiment 3 – Efficacy of other products against black spot and rust

Cultivar

Silver Wedding.

Fungicide treatments

The following fungicides, which were did not show damaging symptoms in the 2000 phytotoxicity screening were compared against the standard programme, using the rates shown in Table 1:

Code	Fungicides
A	Indar 5EW
B	Plover
C	Stroby
D	Lyric
E	Tilt
F	Flamenco
S	Standard rotation of Systhane 20EW, Nimrod T & F238 + Bavistin DF

Unlike the Programmes experiment where the objective was to maintain clean plants throughout the season, this Efficacy experiment was designed to test some eradicant properties of the fungicides as well as their protectant ability. Also, it was deemed undesirable to apply more repeat applications of the same product than really necessary to minimise the risk of disease resistance developing. As plants remained naturally very clean early in the season, sprays did not start until after plants had flowered and were hard pruned back on 10 July. Sprays were thus tested on the new flush of late summer shoot growth.

A total of nine spray applications were applied at approximately 14 day intervals from 17 July 2001 to 7 November as follows:

Spray	*Date*	*Standard treatment*
1	16/17 Jul	Systhane 20EW
2	3 Aug	Nimrod T
3	17 Aug	F238 + Bavistin DF
4	29 Aug	Systhane 20EW
5	12/13 Sept	Nimrod T
6	27 Sept	F238 + Bavistin DF
7	9/10 Oct	Systhane 20EW
8	23 Oct	Nimrod T
9	6/7 Nov	F238 + Bavistin DF

Experimental design and layout

See Appendix 1, for details of experiment plan and layout.

A total of 7 fungicide treatments x 3 replicates = 21 plots in a randomised block design. Plot sizes and layout were similar to the Programmes experiment, with a total of 25 plants per plot consisting of a ring of 16 guard plants and 9 assessed plants in the centre.

Disease assessments

Because the experiment concentrated upon assessing the late flush of growth after pruning plants on 10 July, the first disease assessment was made on 28 August when mainly rust began to develop on some plants followed by two further assessments on 12 and 31 October. A final leaf drop assessment was made on 22 November.

The same disease and leaf drop scoring scales as used for the Programmes experiment were applied.

Experiment 4 - Efficacy of products against powdery mildew

Cultivar

Margaret Merril was used as the trial cultivar, with Margaret Merril and Blue Moon used as additional inoculator plants in between plots.

Fungicide treatments

Of following fungicides selected for the experiment, Folicur and Twist had been used in the 2000 efficacy experiment, but powdery mildew had not developed that year on the outdoor crop. Plover, Flamenco, Stroby and Dorado had been tested for phytotoxicity only. Fungaflor and Elvaron WG were included as they already had label recommendations for roses. F238, Systhane and Nimrod T, were tested as individual products for their efficacy against powdery mildew. Although some products (e.g. Fungaflor), have label recommendations for use under protection, many of the fungicides used do not, and it is important to recognise that, as with the rest of the project, it is aimed at developing fungicide applications for use at grower's risk on outdoor crops only. Polythene tunnels were used only as an experimental procedure to get a more reliable environment in which powdery mildew could develop for testing the fungicides.

Code	Fungicides
Ba	Bavistin DF
Do	Dorado
El	Elvaron WG
F2	F238
Fl	Flamenco
Fo	Folicur
Fu	Fungaflor
Ni	Nimrod T
Pl	Plover
St	Stroby
Sy	Systhane 20EW
Tw	Twist

As with the Efficacy Experiment 3 above, plants were hard pruned on 11 July, and sprays were applied to the new growth. The plants were moved from the outdoor beds after pruning to three walk-in polythene tunnels (approx 5.5 m wide x 10 m long) on 18 July. The polythene tunnels had low netting sides, and doors at each end for ventilation, but polythene skirts were used to maintain warmth and humidity when necessary.

A total of nine fungicide treatment applications were applied at approximately 14 day intervals from 27 July 2001 to 14 November.

Experimental design and layout

See Appendix 1, p 40-41 for details of experiment plan and layout.

A total of 12 fungicide treatments x 3 replicates = 36 plots in a randomised block design. Each replicate was placed in a separate polythene tunnel. There were 9 assessed plants per plot arranged in a 3 x 3 layout at 250 mm x 300 mm spacings. Because of the protected environment, it was deemed unnecessary to include a guard ring of plants, and there was sufficient space between adjacent plots (with a spray drift shield) to minimise the risk of cross treatment contamination. As with Experiments 1 and 3, there were no untreated plants included in the trial design which would have caused a higher disease pressure to exist on adjacent plots. Instead, the untreated inoculator plants spread evenly throughout the experiment were used to help determine how suitable conditions were for disease development generally.

The plants were stood on sand beds covered with Tex-R ground cover fabric in the tunnels. However pot drip irrigation was used. It was found that the disease developed best when plants were allowed to dry out and become water stressed periodically throughout the experiment, while still providing sufficient irrigation to prevent permanent wilting or scorch.

Disease assessments

Despite the use of a protected environment, and the development of infection on unsprayed infector plants, powdery mildew on treated plots was still slow to develop in this experiment on Margaret Merril. However sufficient infections did eventually occur for assessments to be made on 11 and 24 October, and 8 and 11 November.

Powdery mildew was based on visible white sporulation or symptomatic leaf crinkling / reddening using the following scoring scale:

1 Clean - no sporulation visible on any leaves.
2 Trace - 1-2 true leaves affected.
(1-3 leaflets affected on same leaf counts as 1 affected leaf)
3 Slight - 3-8 leaves affected.
4 Moderate - >8 leaves affected up to maximum of 60% of foliage affected.
5 Severe - >60% foliage affected.

Results

See also Photographs in Appendix 2, p 42ff

Experiment 1 – Evaluation of fungicide programmes

Disease incidence and leaf fall

The spray programmes for all treatments kept plants very free of disease for the first three months (April - June). The earliest disease to develop was rust, and some traces were observed on plants in the Standard spray rotation treatment in mid - late July. On the four Untreated plots kept away from the main trial, which could not be formally included in the statistical analysis, both black spot and rust developed on these plants relatively early on during June and early July. By the time of the first disease assessment on 1 August, the Untreated observation plots averaged a score of 4.2 and 4.7 for black spot and rust respectively. After this time, even though these plants were pruned back, leaves on new shoots become diseased relatively quickly encouraging premature leaf fall, which made further assessments of the Untreated plots and comparisons with the experimental plots meaningless.

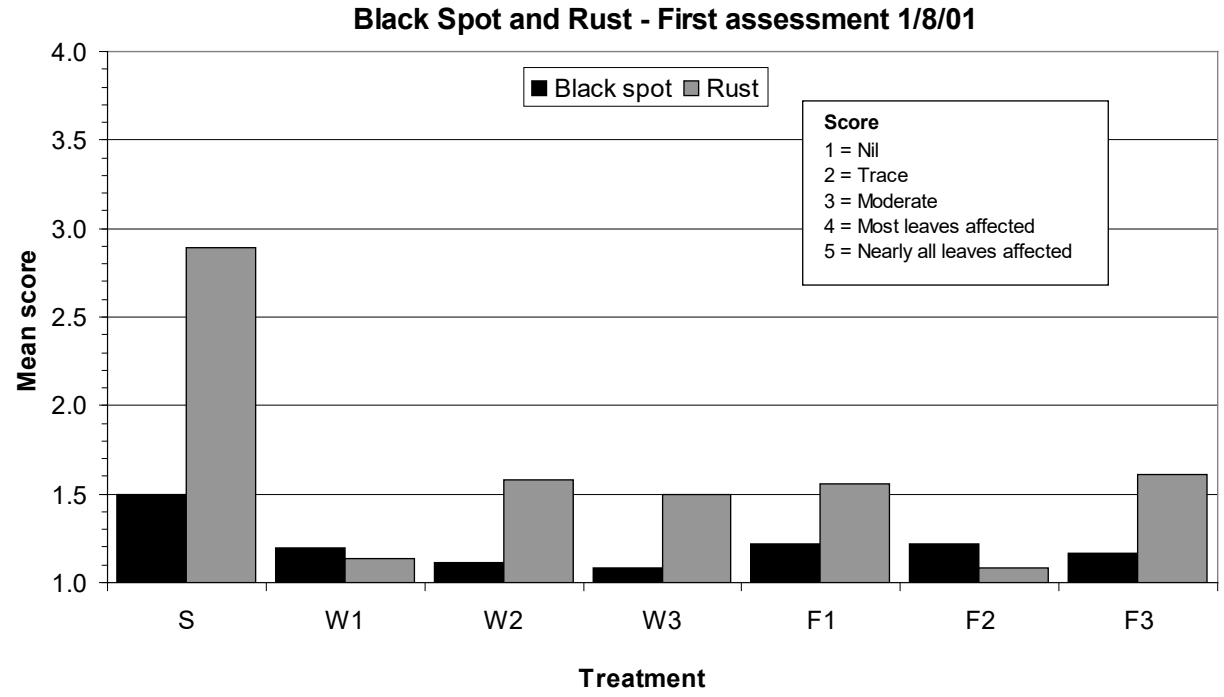
Table 1 below shows the mean scores for each disease and leaf drop assessment. By the time of the fourth assessment on 26 November, most leaves that had developed rust had fallen, particularly on the Standard treatment, making it impossible to adequately score for this disease. Figure 2 overleaf illustrates the mean scores for the first and third assessments.

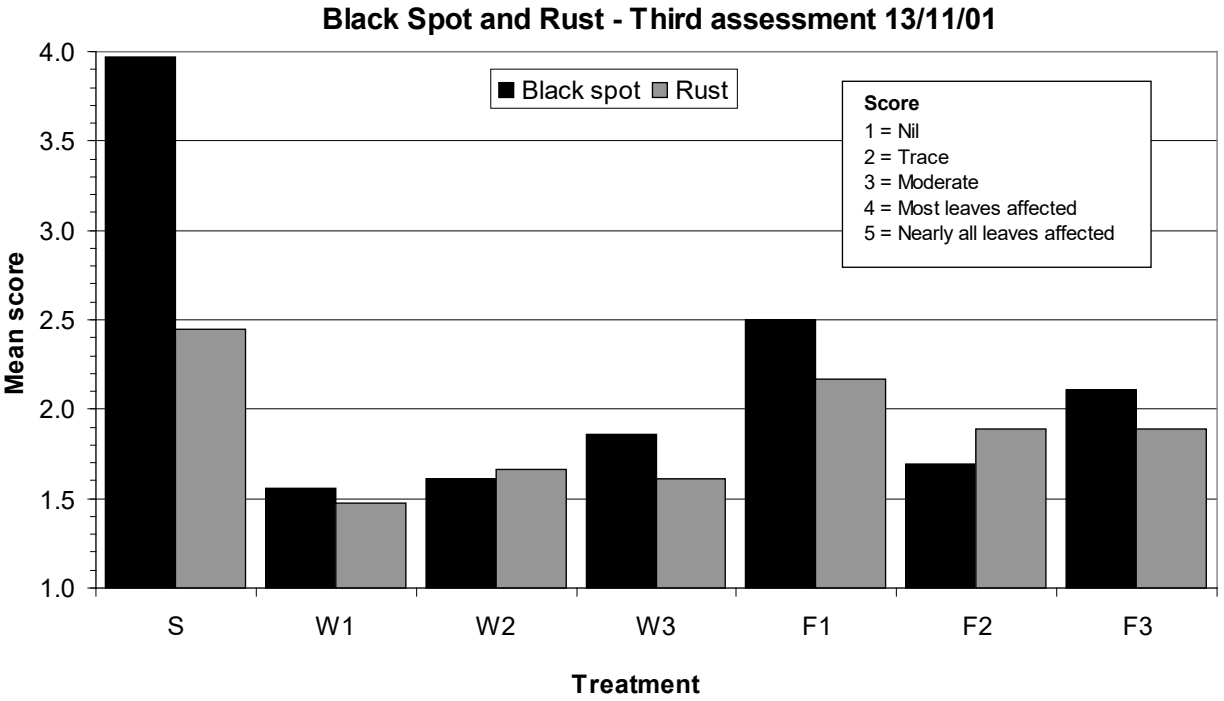
Table 3 Mean scores for black spot, rust and leaf drop (1 – 5 scale) for each assessment

	Black spot assessments				**Rust assessments**			**Leaf drop**	
Treatment	**1 Aug**	**22 Oct**	**13 Nov**	**26 Nov**	**1 Aug**	**22 Oct**	**13 Nov**	**3 Dec**	**17 Dec**
W1	1.22	1.17	1.60	1.68	1.17	1.12	1.52	1.92	2.23
W2	1.14	1.24	1.67	1.67	1.65	1.24	1.73	2.04	2.13
W3	1.08	1.31	1.86	1.94	1.50	1.36	1.61	1.97	2.06
F1	1.22	1.47	2.50	2.61	1.56	1.53	2.17	2.17	2.47
F2	1.22	1.31	1.76	1.86	1.08	1.41	1.95	2.05	2.27
F3	1.17	1.44	2.11	2.08	1.61	1.47	1.89	1.83	2.08
Mean	***1.18***	***1.32***	***1.92***	***1.98***	***1.43***	***1.36***	***1.81***	***2.00***	***2.21***
Standard	***1.50***	***2.89***	***3.97***	***4.11***	***2.89***	***1.89***	***2.44***	***4.25***	***4.39***
*LSD** *(18 df, 5%)*	*0.23*	*0.32*	*0.66*	*0.52*	*0.55*	*0.32*	*0.41*	*0.43*	*0.26*
Overall P	*0.009*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*0.003*	*0.004*	*<0.001*	*<0.001*

*Least significant difference for comparing mean of new programmes vs. Standard, and overall significance level from ANOVA. There were no significant differences between new programme treatments.

Figure 1 Programmes experiment. Mean black spot and rust scores for a summer and autumn assessment.

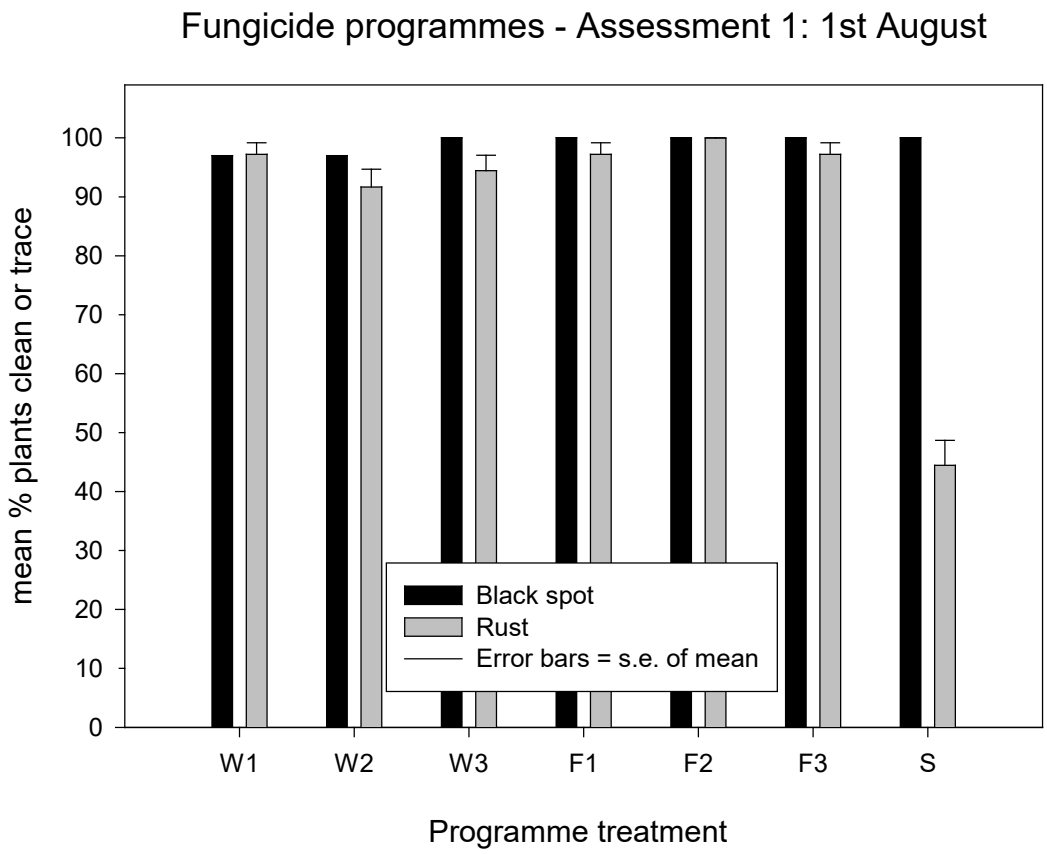




In each assessment there was a clear difference between the Standard treatment, which had higher levels of both diseases and leaf fall, compared to the rest. This was separated out in the statistical analysis as a consistent highly significant difference between the Standard treatment vs. the mean of the remainder. However, within the remaining treatments any differences between the mean scores were not significant.

Figures 2 and 3 below from the binomial analysis, show the mean proportions of plants in each treatment that had a score of 1 or 2, ie were either clean or with just a trace of disease. Note that in Figs 2 and 3, taller bars mean less disease, in contrast to Fig. 1.

Figure 2



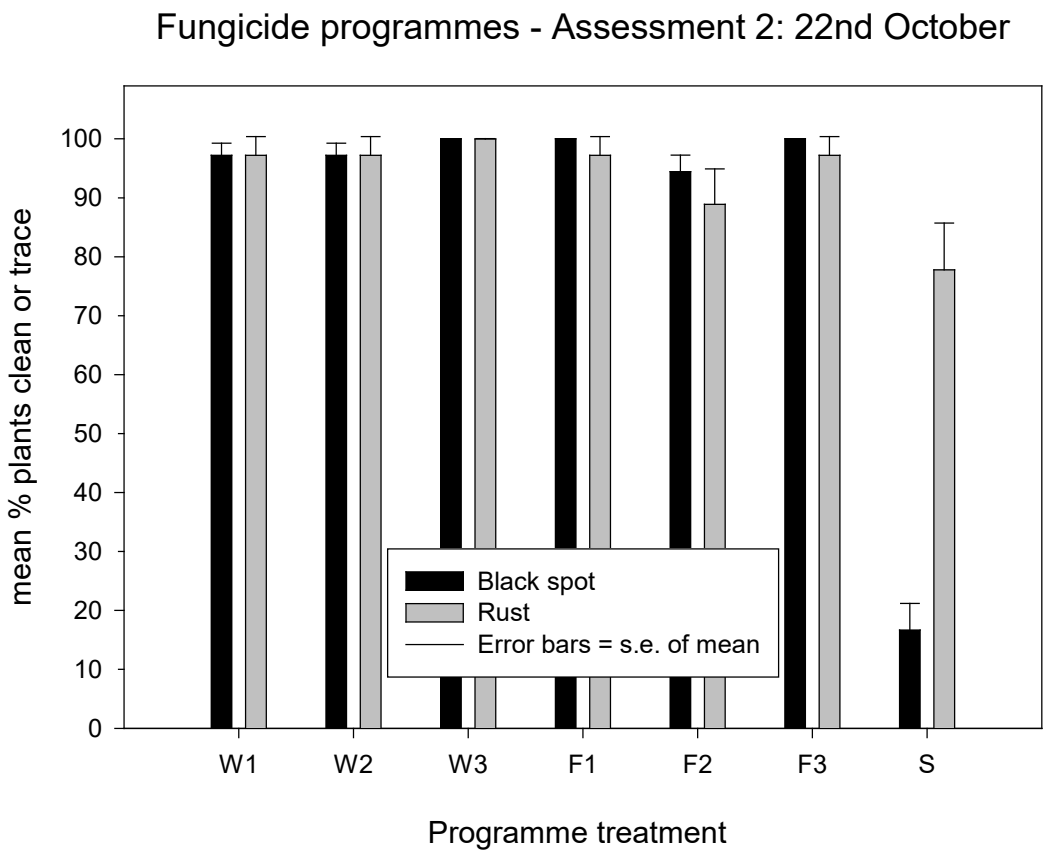
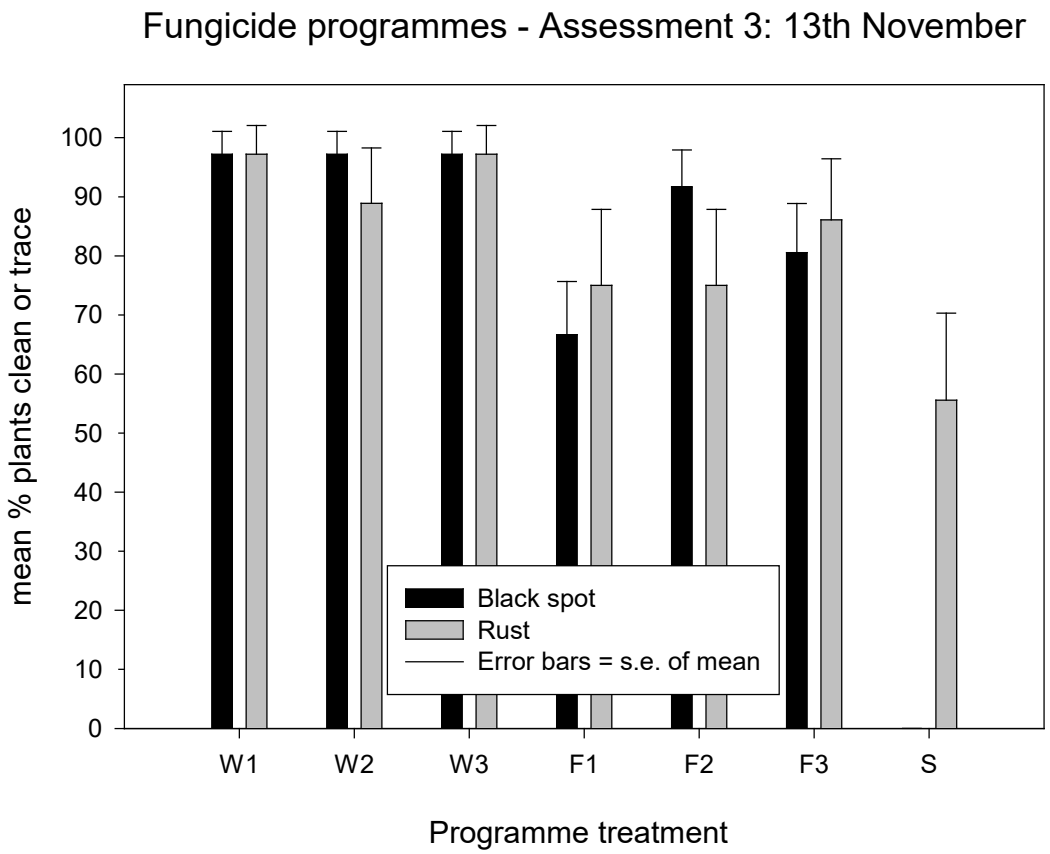
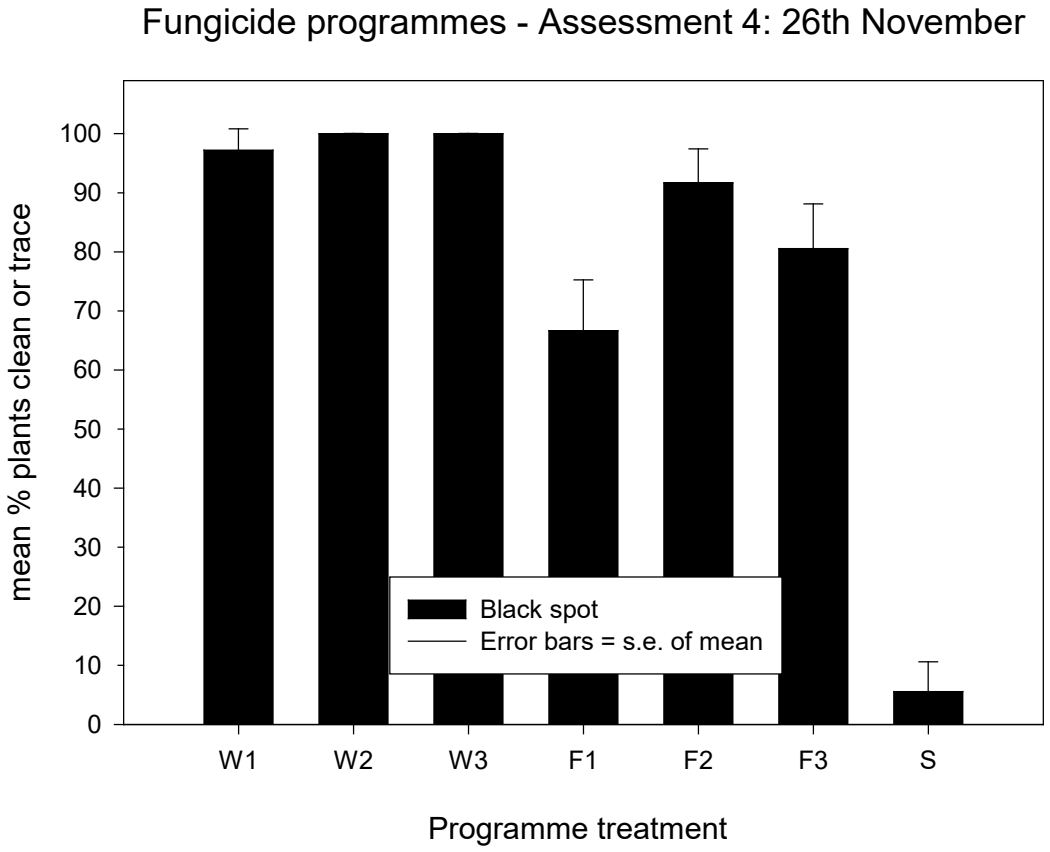


Figure 3





The analysis of the proportions of 'clean or trace' plants gives a clearer and more sensitive indication of how well the different programmes were maintaining clean plants, than the average amount of disease present. It shows that by the 1 August, plants in all treatments including the Standard were virtually free of black spot, but that for rust over half the plants in the Standard had at least moderate infection.

The following assessments in October and November included the shoot regrowth following the light pruning in late August. Black spot was more prevalent in these autumn assessments than earlier in the summer. By 22 October, there were only a few plants 'nearly clean' of black spot on the Standard treatment, and virtually none thereafter. There was evidence (Fig 3) that by the third and fourth assessments in November, that the three Fortnightly treatments F1, F2 and F3 had not maintained as high proportion of clean plants for black spot or rust as the Weekly treatments, W1, W2 and W3. The mean scores in Table 1 and Fig 1b also indicate this, even though statistically significant differences could not be demonstrated.

There was no evidence to show that the weekly programme W3, which used fewer fungicide products and did not use any tank mixes, performed any poorer than W1 and W2 in this experiment.

For black spot in particular, F1 appeared to give slightly poorer control than F2 or F3. However, closer examination of the data revealed this was mainly due to higher levels of disease in a single replicate (plot 8). There is no obvious explanation for this in terms of plot location. Although a critical missed spray is a possibility, due care was taken with the application procedure to mark up and cross check plots as each treatment was sprayed. It is also unclear whether the two extra sprays given to F3 on 22 October and 5 November as part of the reactive programme contributed to it giving any better control than F1.

In general, all the W and F spray programmes retained a high proportion of healthy foliage for a remarkable length of time on this very disease susceptible cultivar where a large proportion of leaves were still present well into December. Discolouration and leaf fall eventually followed due to frosts (see also photographs in Appendix 2. p 43-45).

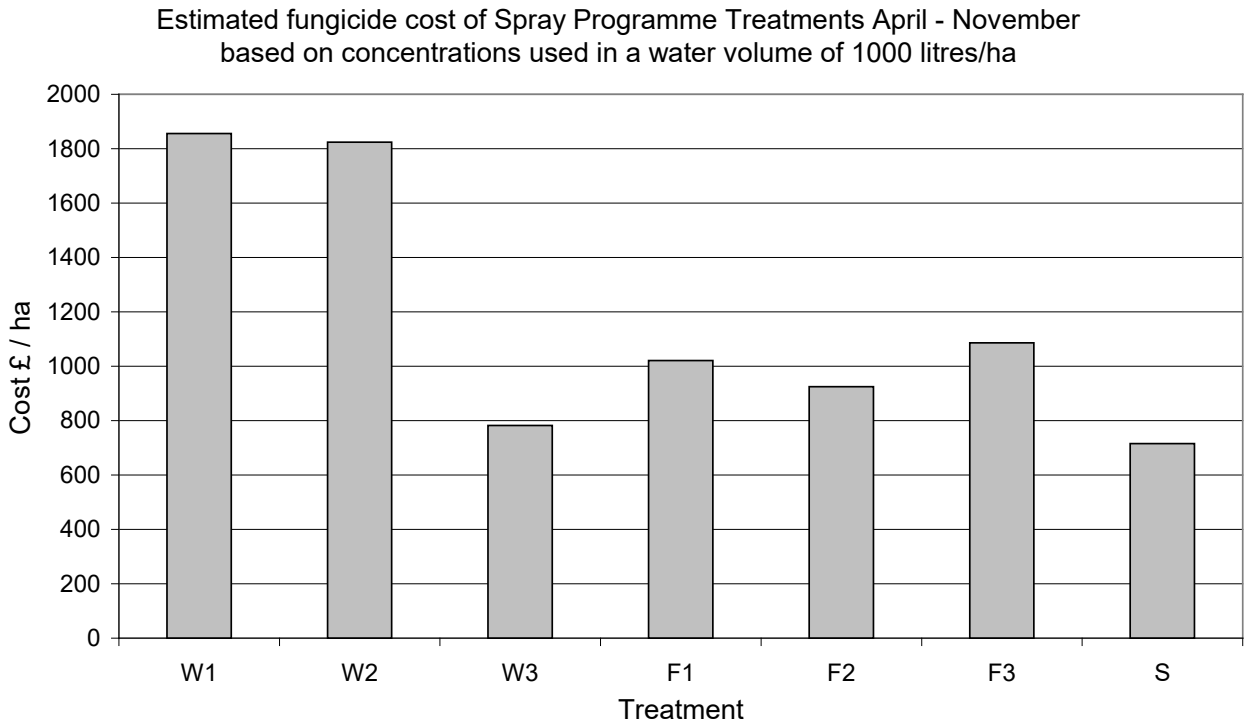
Costs of fungicide programmes

Some example costs of fungicides (ex VAT) are presented in Table 4 below. It is important to emphasise that these were obtained from several different distributors and may not accurately reflect costs to individual nurseries or for quantity purchases. However, they are useful as an approximation, and were used to estimate the material costs of the fungicide programmes used over the period of the experiment (Figure 4).

Table 4 Fungicide prices and cost per application based on a 1000 l/ha HV spray

Product	Pack price £	Qty / pack	litres / kg	p/ml or p/g	Rate g or ml/l	Cost £/ha
Aliette 80 WG	29.90	1	kg	2.99	2.50	74.75
Amistar	152.06	5	litre	3.04	1.00	30.41
Bavistin DF	6.60	1	kg	0.66	0.50	3.30
Bravo 500	25.30	5	litre	0.51	2.20	11.13
Captan	26.00	5	kg	0.52	1.25	6.50
Dorado	88.99	1	litre	8.90	0.25	22.25
Elvaron WG	19.72	1	kg	1.97	5.00	98.60
F238	25.20	1	litre	2.52	2.50	63.00
Flamenco	60.00	3	litre	2.00	1.25	25.00
Folicur	21.25	1	litre	2.13	1.00	21.25
Fubol Gold WG	105.93	5	litre	2.12	2.00	42.37
Indar 5EW	30.00	3	litre	1.00	1.40	14.00
Invader	82.00	10	kg	0.82	2.00	16.40
Lyric	81.00	3	litre	2.70	0.63	16.88
Nimrod T	13.59	1	litre	1.36	3.20	43.49
Plover	24.20	1	litre	2.42	0.30	7.26
Ripost Pepite	54.40	5	kg	1.09	2.50	27.20
Stroby WG	138.00	1	kg	13.80	0.30	41.40
Systhane 20EW	68.31	1	litre	6.83	0.30	20.49
Tilt	20.00	1	litre	2.00	1.00	20.00
Twist	31.00	5	litre	0.62	2.00	12.40

Figure 4



Experiment 2 – Phytotoxicity of fungicide tank mixes

See photographs in Appendix 2, p 45-46

Early summer applications

The weather on application of the first spray on 15 May was dry and sunny with a slight breeze. On the second application of the double rate sprays on 22 May, the weather was sunny and also hot, providing rigorous conditions under which to test spray safety.

Both Nimrod T + Elvaron and Nimrod T + Twist caused puckering or curling of young leaves on some plants of all cultivars two to three days after the single rate spray. Also some slight leaf spotting on fully expanded leaves was observed on Fiesta and Kind Regards. At an assessment three days after the double rate application, 40%+ leaves of plants of Fiesta, Kind Regards, Dearest and Warm Wishes, and up to 20% of leaves of L'Aimant were showing some signs of leaf spotting or scorch. Some leaf tips on some plants (e.g. in Warm Wishes) subsequently developed some brown necrosis where spray run-off had concentrated on drying.

With Folicur + Aliette, there was some slight leaf marking on Fiesta, and trace of damage on Warm Wishes and Kind Regards after the double rate spray. However nothing significant was observed following the single rate spray. With Folicur + Fubol, there was a trace of leaf spotting on Fiesta after the double rate spray.

No other spray mixtures used were observed as causing any phytotoxicity from the early summer applications.

No phytotoxicity was observed throughout the Fungicide Programmes experiment on cv. Silver Wedding from any of the mixtures used there (at standard rate), including Nimrod T + Elvaron.

Autumn applications

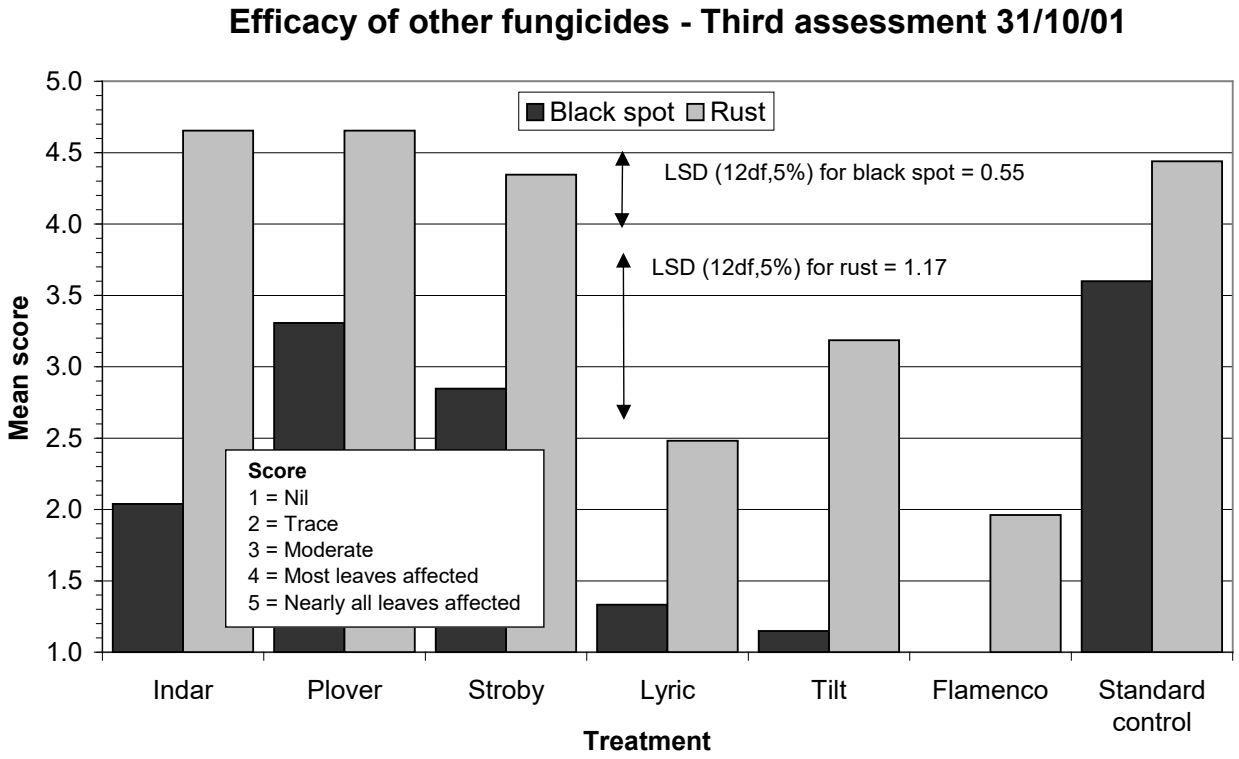
Apart from L'Aimant and Warm Wishes, it was very difficult to make meaningful assessments of phytotoxicity in the autumn because of the high level of rust in particular which had affected the other cultivars. However, despite assessments on several occasions, there was no clear indication of any phytotoxicity from the any of the standard rate spray on 20 September, including Nimrod T + Elvaron or Nimrod T + Twist.

After the double rate spray on 12 October, these two treatments also remained unharmed, but on cv Warm Wishes, there was scorch on some leaf tips and margins where sprays droplets had concentrated on drying for Lyric + Nimrod T and Folicur + Nimrod T treatments. These two tank mixtures were not used in the Programmes experiment, and had not been tested in the spring, but were included as possible options for combining fungicides active against powdery mildew, black spot and rust, from different chemical groups, in a single spray.

Experiment 3 – Efficacy of other products against black spot and rust

The first assessment took place on 28 August after plants had been hard pruned back on 10 July, and had received three fungicide sprays at two week intervals. By this time there were some clear treatment differences in the amount of rust present on treatment plots. Black spot at this stage was either absent or at trace levels (Stroby and Standard treatments). The relative pattern for mean treatment scores remained similar throughout the three assessments although overall disease levels increased. The pattern for the final assessment is summarised in Figure 5, and also reflected in the leaf drop assessment undertaken three weeks later in November (Fig. 6).

Figure 5



As with the programmes experiment, the analyses of the mean percentage of plants that remained clean, or with just a trace of disease, gave a good picture of the fungicides' performance throughout the autumn (Figs 7 & 8).

Lyric, Tilt and Flamenco gave exceptional control of black spot in this experiment, and were significantly better than the other new fungicides and the standard programme. The conazole fungicide Plover, and the strobilurin Stroby, were disappointing in their control of black spot, and these two, together with Indar, also failed to give any useful control of rust even early on. While Tilt gave good early control of rust, it had failed to maintain a high proportion of clean plants by the end of October. The conazoles Lyric and Flamenco, however, maintained over half the plants very clean of rust under very testing conditions by this stage.

No phytotoxicity was observed in this experiment, but an unusual phenomenon was the development of darker green foliage with smaller leaflets in the Tilt treatment (see Appendix 2, p 47-49).

Figure 6

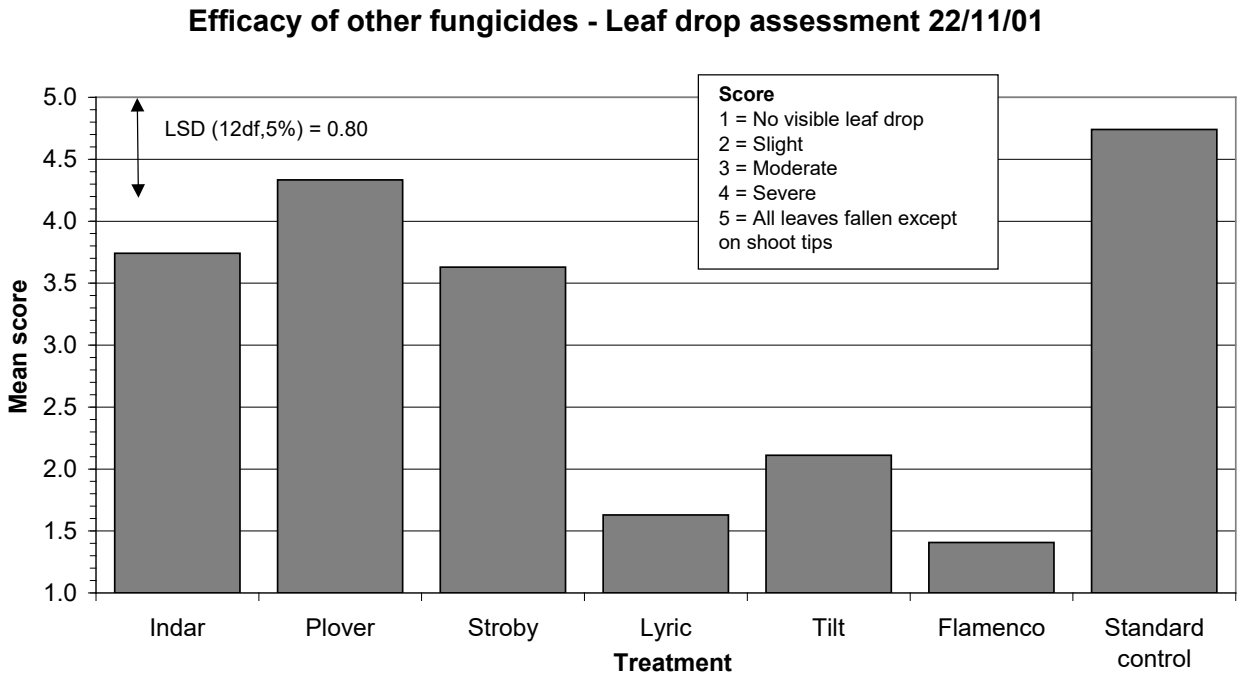


Figure 7

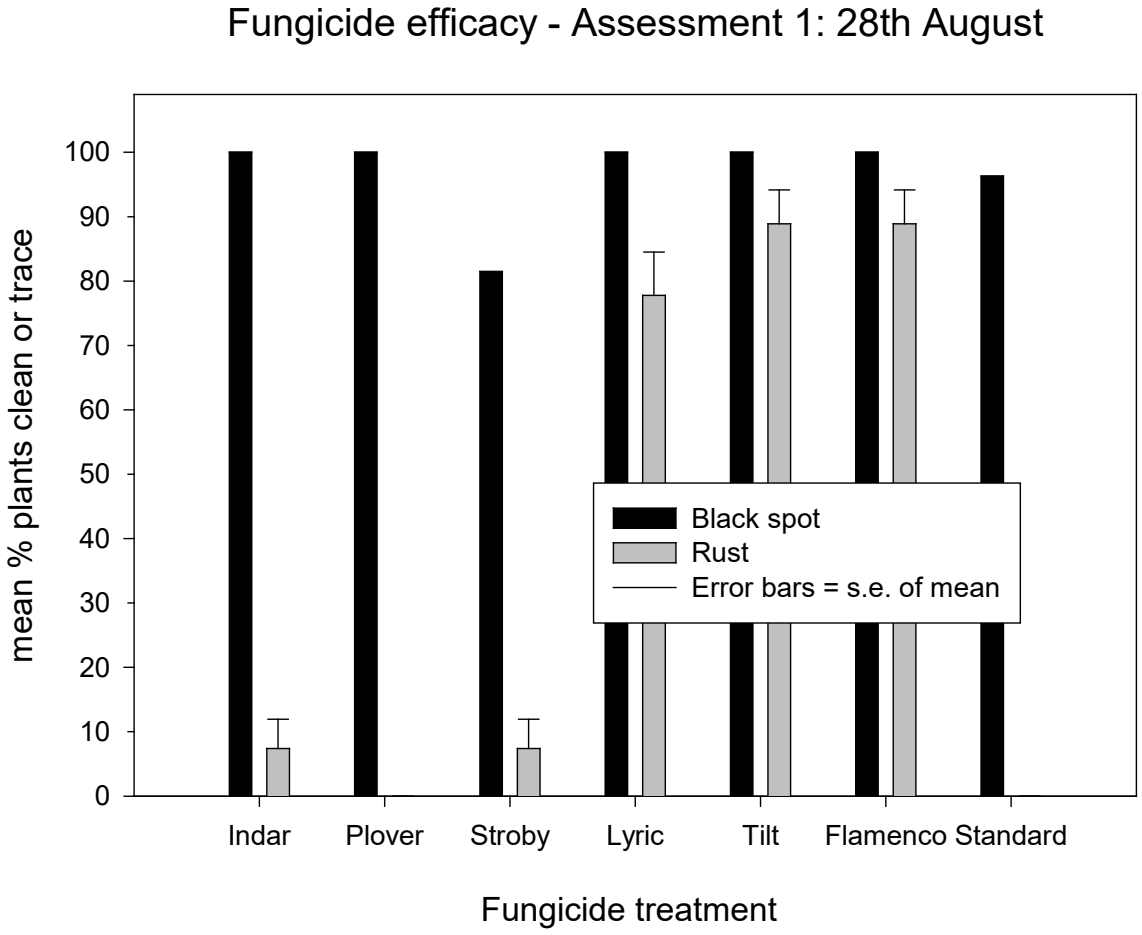
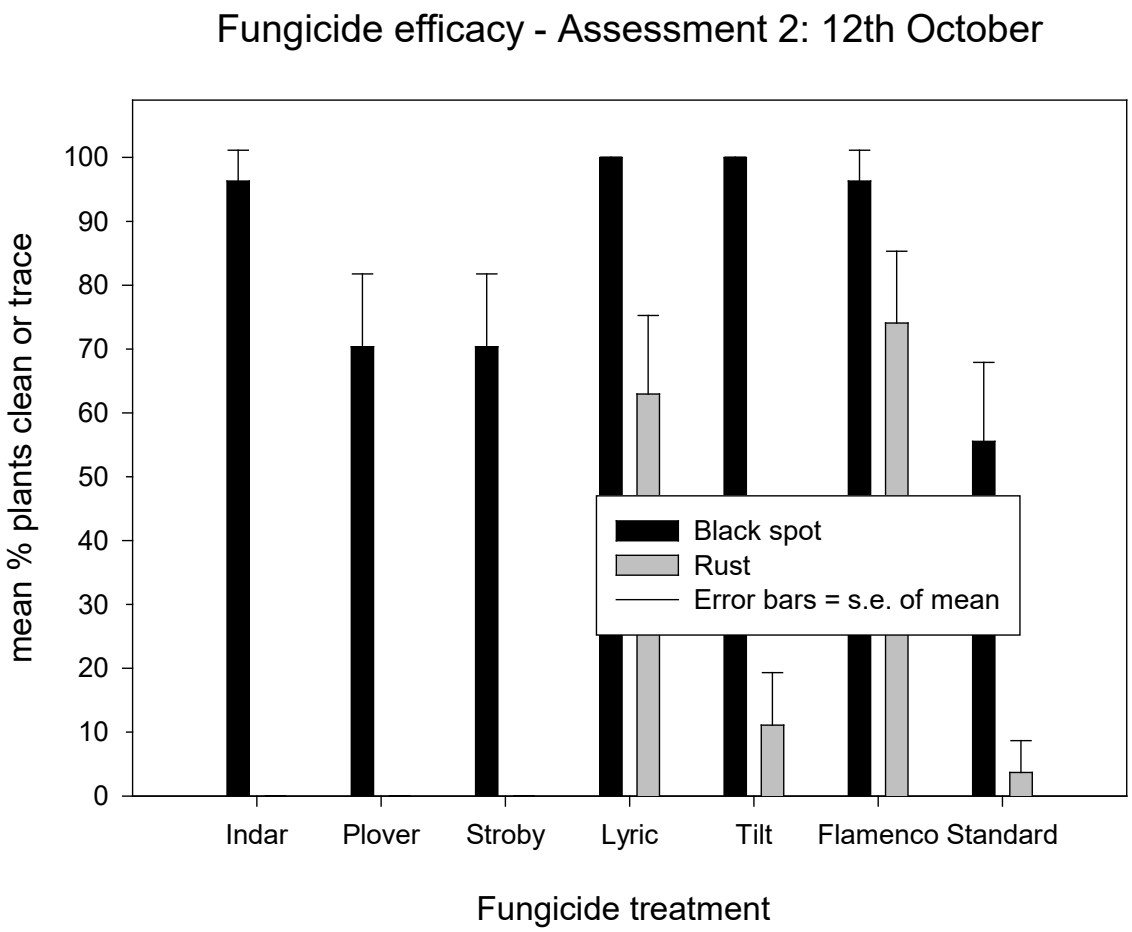
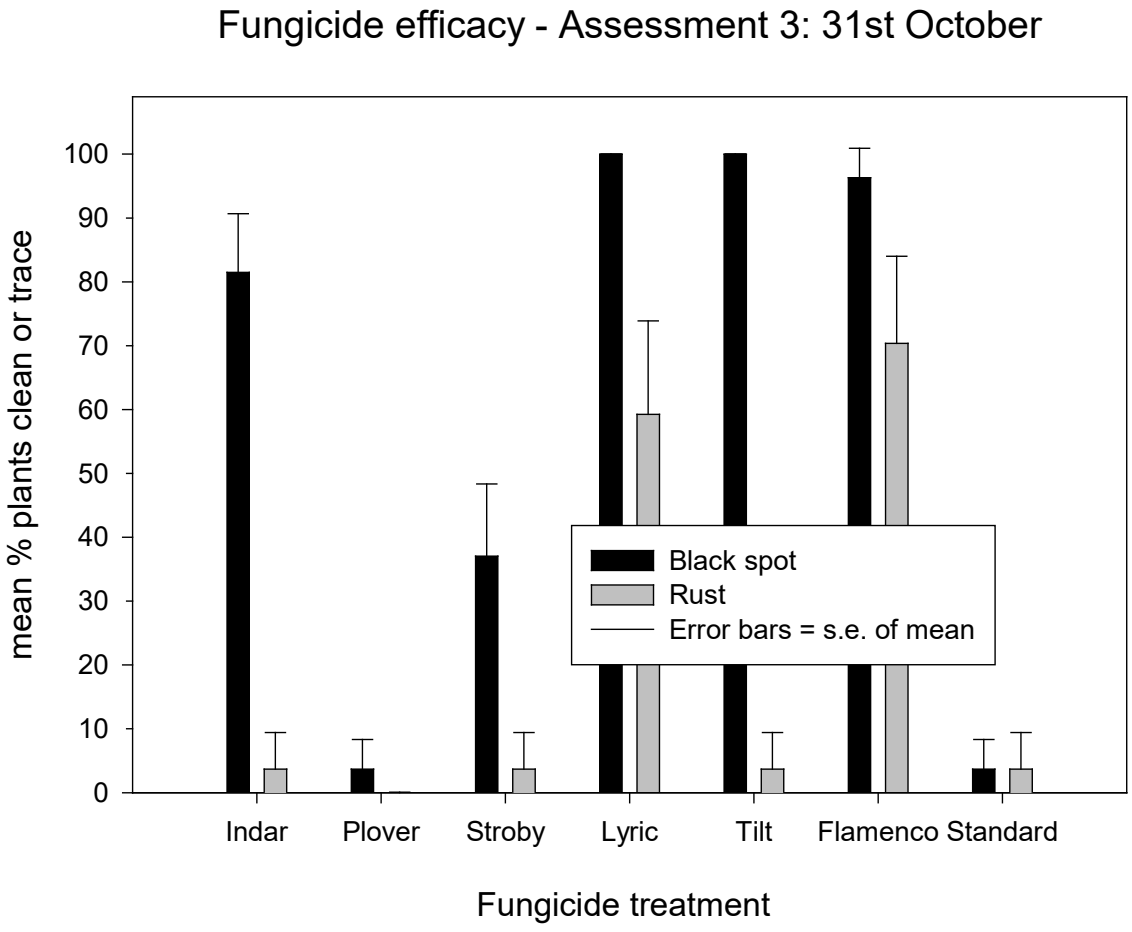


Figure 8





Experiment 4 - Efficacy of products against powdery mildew

See also photographs in Appendix 2, p 49-50.

Powdery mildew was established on the inoculator plants started off under glass, but it was very slow to develop on the sprayed cv. Margaret Merril plants in this experiment, even after letting the plants get very dry to near wilting point in order to stress the plants . Mean levels of powdery mildew only reached a score of 3 ('slight infection') for one of the poorest treatments. Although differences in control between fungicide treatment were not as marked as in the other experiments, differences in mean scores reached statistical significance at $P<0.05$ - $P<0.001$ across all four assessments from 11 October - 20 November.

The relative pattern of control between treatments was broadly similar and the results can be summarised by Assessment 2 in Figures 9 and 10.

Figure 9

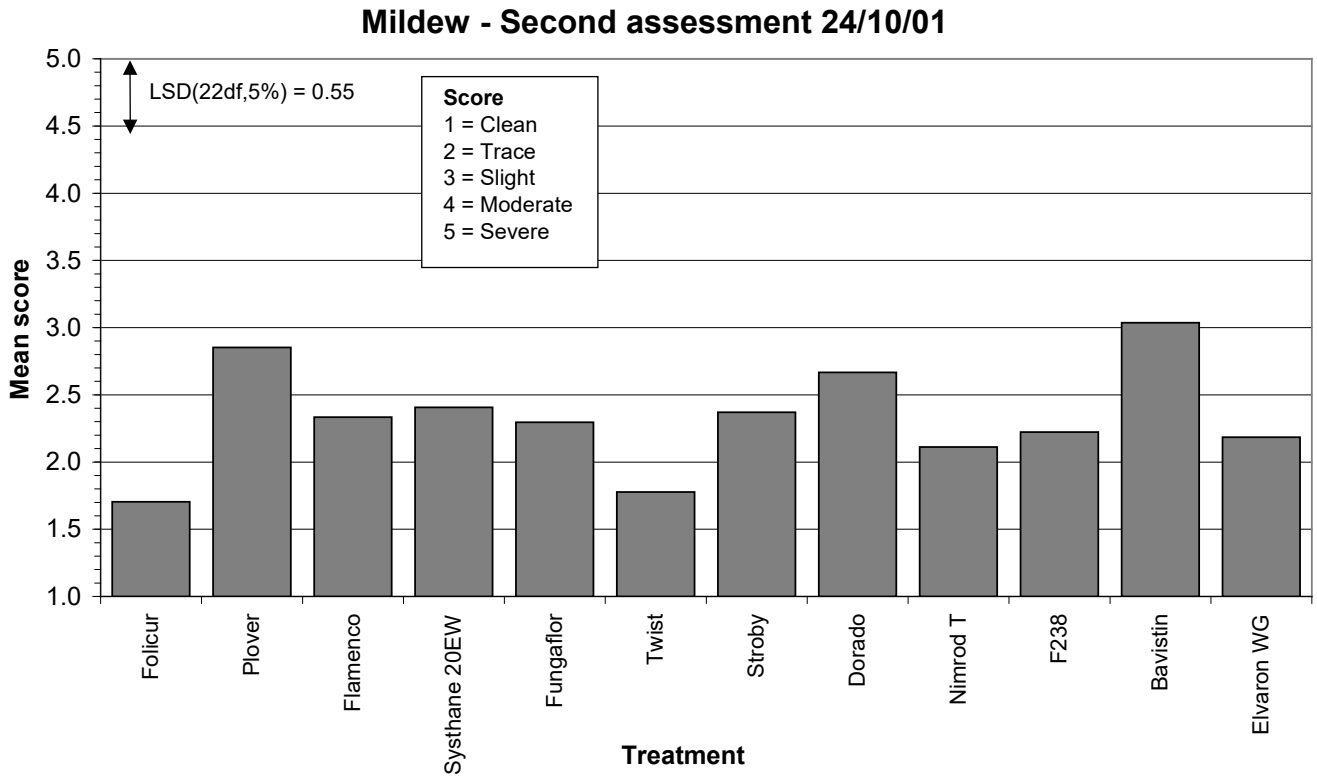
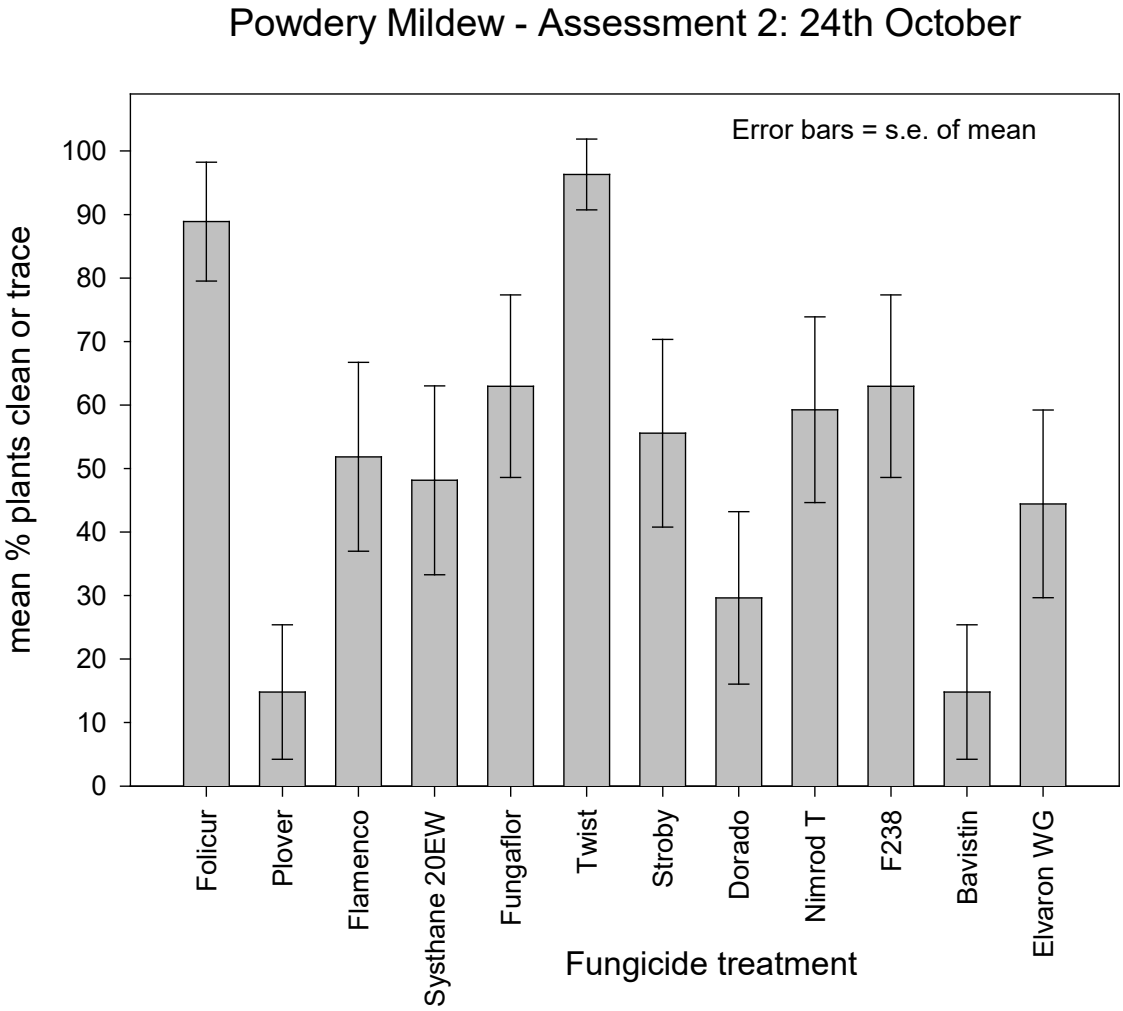


Figure 10



Bavistin, Plover and Dorado had higher mean levels of disease, and fewer cleaner plants than the other treatments. Folicur and Twist stood out as giving the best control of powdery mildew in this experiment.

Phytotoxicity was not a problem with most of the fungicides in this experiment, even though they were applied to plants under protection. An exception was with Fungaflor where some necrotic leaf spotting occurred in early October. Elvaron WG developed heavy white spray deposits on the leaves. Although some spray deposits occurred with Elvaron treatments outside, they typically weathered off after a short period.

Discussion

Efficacy of fungicides against black spot, rust and powdery mildew

The conazoles Lyric (flusilazole) and Folicur (tebuconazole), and the strobilurin Twist (trifloxystrobin), were identified in 2000 as giving very good results against black spot and rust, and so featured heavily in the range of programmes tested this year.

Conazoles

Folicur has, additionally, shown excellent activity against powdery mildew this year that strengthens its position as a new conazole for roses with good all round performance.

The good result for Lyric against black spot and rust in 2000 were ratified in the Efficacy experiment this year. Lyric is also expected to be strong against powdery mildew, although there was not space to include it in the tunnel experiment this year.

Flamenco (fluquinconazole) has emerged as another conazole with particularly good activity against black spot and rust. Based on a single year's experiment, it appeared to have as good activity against powdery mildew as the well established fungicides such as Systhane, Nimrod T and F238, but it was not as effective as Folicur.

Plover (difenoconazole) gave poor control of both powdery mildew and rust, and Indar, included in the outdoor Efficacy experiment, while performing well for black spot, was not effective against rust. Given the better all round performance of the other conazoles listed above, there is little merit in pursuing these further for roses. Also Tilt (propiconazole), did not maintain as good control of rust as Lyric or Flamenco in the Efficacy experiment, and for outdoor rose crops may also now have been outclassed.

Strobilurins

In 2000, Twist (trifloxystrobin) gave slightly better control of black spot and rust than Amistar (azoxystrobin) in the outdoor efficacy experiment that year, although neither performed as well as Lyric or Folicur. However, fungicide sprays had started after the first signs of disease had appeared, and it was recognised that strobilurins are most effective when used as protectants before diseases appear. Twist has shown good activity against powdery mildew this year, which adds evidence to its value as an effective all-round fungicide for roses. Although Amistar was included in the Programmes experiment alternated with Twist, it was not possible to evaluate it further as an individual fungicide, and further work would be needed to confirm its benefit. Stroby (kresoxim-methyl), appears to be the weakest of the strobilurins for roses. It was poorer than Twist against powdery mildew, not particularly effective against black spot, and gave little control of rust.

Fungicide programmes and phytotoxicity

Only a limited number of the range of fungicides and possible permutations could realistically be tested. The experiment was aimed at providing some guidelines for developing improved rose fungicide programmes, rather than being prescriptive.

The inclusion of the newer conazole and strobilurin fungicides in all the programmes, whether weekly or fortnightly, clearly gave much better rust and black spot control than the standard control programme of a two week rotation of Systhane, Nimrod T and F238+Bavistin. The retention of disease free foliage on a susceptible cultivar into December from a March potted crop was certainly proof of effective control.

For these two diseases, programme W3 gave equally as good control as W1 and W2. W3 alternated a downy mildew fungicide with the one for the other three diseases weekly, but with a strobilurin application every 5 weeks, which was active against both disease groups. W3 was also a very cost-effective programme for materials, being less than half the cost of the other weekly programmes, and also cheaper than F1, F2 and F3. W3, which involved no tank mixes, also has the advantage of minimising any risk of phytotoxicity. What is unknown from this work, however, is the relative efficacy of W3 for downy mildew compared to the other weekly programmes.

The Programmes experiment ran sprays over 33 weeks in total, which is a longer season than would normally occur commercially. For commercial crops of container roses, weekly applications could be justified where crops are typically sold by mid summer. Their higher value, and the direct damage to the marketed plant that phytotoxicity would incur, may well justify the extra labour cost of spraying weekly instead of fortnightly. For field crops, however, fortnightly, or 10-day spray intervals, are more practical, particularly as suitable land and weather conditions for spraying become more difficult later in the season at the very time when disease pressure can increase. Provided phytotoxicity symptoms are not severe, the risk of some slight or transient leaf damage might be more acceptable where a 14-day programme employing tank mixes is used.

Apart from two extra sprays, the reactive programme F3 was identical to F1. Nevertheless, it is a sound principal to apply a protectant programme at two week intervals, particularly early in the season when there is less disease pressure, but apply additional sprays of products with good curative activity (e.g. some of the conazoles) if any diseases appear later in the season.

When formulating programmes, a strategy to avoid resistance is important. Guidelines for the use of strobilurins on ornamentals state that they should not make up more than one in three fungicide applications. Likewise conazoles, morpholines and pyridine group fungicides should also be rotated, although it would be acceptable to use up to two conazole sprays in succession.

Most of the observations of phytotoxicity with tank mixes on some cultivars involved Nimrod T, even though it appeared safe in the Programmes experiment on Silver Wedding when mixed with

Elvaron or with Twist. It is always a wise precaution to test out tank mixes on small numbers of untested cultivars first, but this appears particularly important for Nimrod T. In general, none of the fungicides caused serious plant disfiguration, but some of the phytotoxicity symptoms will have been unacceptable for a container grown crop marketed within a few weeks of the occurrence of damage. For a field crop, mild or transient symptoms are of little consequence to the quality of the marketed product. It is also important to note that all the fungicides used in this project have been applied at concentrations consistent with a HV spray to give good leaf coverage. Without further testing it is possible the risk of phytotoxicity might be increased if higher concentrations and lower water volumes, to give the same dose rate per unit area, were used (e.g. following typical practices for other field and arable crops).

Availability of fungicides

Dorado is due to be withdrawn from the market before long and there are no other formulations of the a.i., pyrifenox, available. Dorado is in the pyridine group of fungicides and represents one of the few other alternatives to the conazole group with activity against powdery mildew, and black spot, so its loss will restrict some of the options for rotation of fungicides. Substituting Dorado in programmes with the morpholine F238 (dodemorph) is one possible option.

Elvaron (dichlofluanid) is also being phased out in the UK in favour of Elvaron Multi, containing the closely related active ingredient tolylfluanid. Elvaron was included in the Programmes experiment mainly as a broad-spectrum protectant fungicide with expected activity against downy mildew as well as suppression of powdery mildew.

Possible future work

Further testing of fungicide programmes, for efficacy and for phytotoxicity across a wider range of cultivars will be carried out in the final year of the project in 2002 in nursery trials.

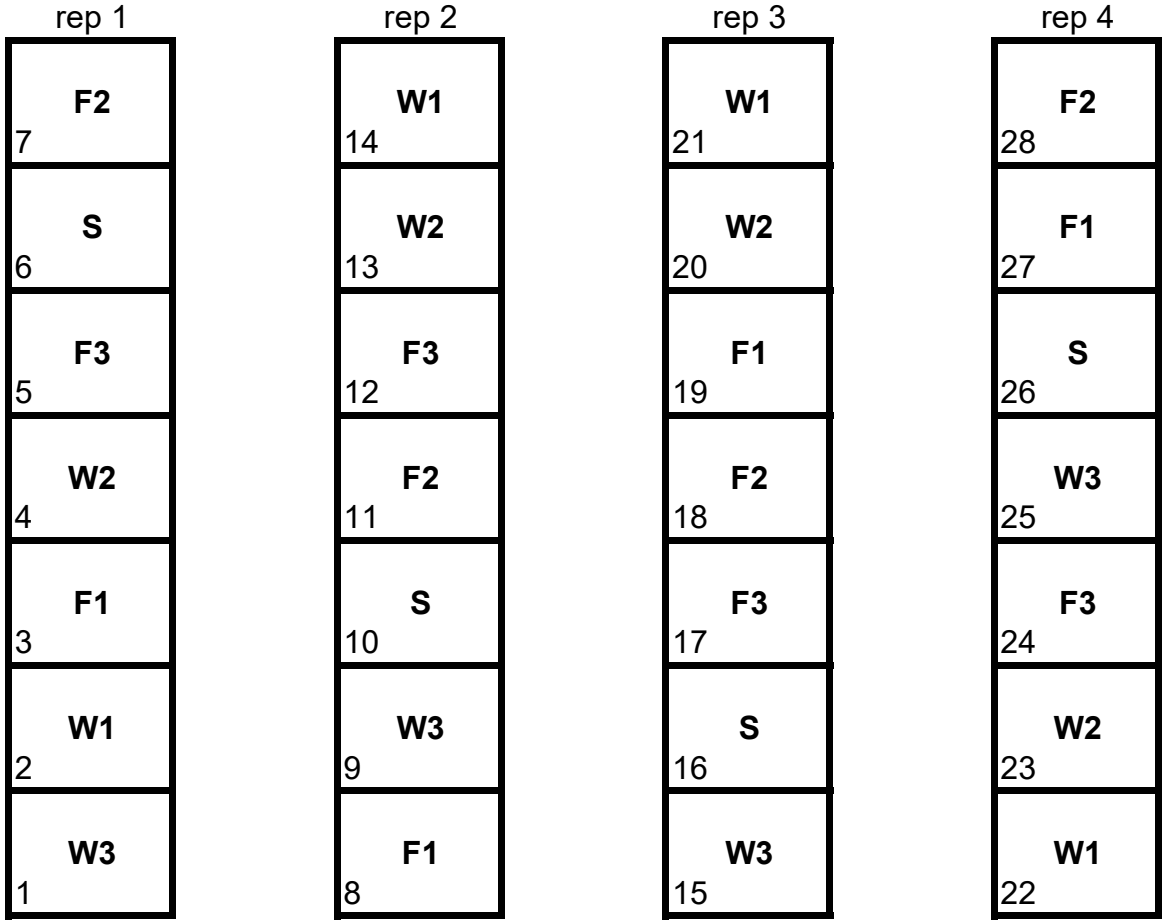
Other areas, beyond the scope of the current project but that could be considered in future work includes the use of spray additives such as oils and wetters that might improve both the efficacy of fungicides, and allow them to be used at lower rates more safely.

So far all the products tested other than Nimrod T have contained single active ingredients. However, there are many agricultural fungicides containing mixtures of active ingredients from different chemical groups, including those containing the effective ai's tested in this project. Further efficacy and phytotoxicity testing for roses with these would be worthwhile if they were shown to be a safer and more convenient alternative to some tank mixes.

Appendix 1 – Experiment Plans and Layout

HDC ROSE FUNGICIDE 2001 **IAS 32243** **HNS 106a**

Top Tunnel Site **FUNGICIDE PROGRAMMES EXPERIMENT**



TREATS

W1=WEEKLY 1
W2=WEEKLY 2
W3=WEEKLY 3
F1=FORTNIGHTLY 1
F2=FORNIGHTLY 2
F3=FORTNIGHTLY 3
S=STANDARD
U=UNTREATED PLOTS (4 plots on far west bed)

Plot Details

c.v Silver Wedding
25 plants/plot
Central 9 recorded
Outside 16 guards include some 2 year old plants.
spacing approx 30cm x 30cm.
1m gap between plots.
Drip irrigated.

O O O O O
O X X X O
O X X X O
O X X X O
O O O O O

O = GUARD
X = RECORDED

recorded plants numbered front to back left to right.

HNS 106 **HDC ROSE FUNGICIDE 2001** **PHYTOTOXICITY OF FUNGICIDE PROGRAMMES**

IAS 32243

Summer Treatments 2001

rep 1

	Spare Area				
	Rep II				
Fo+Fu	15 FI	L'A	DE	WW	KR
NT+El	14 FI	KR	DE	L'A	WW
NT+Tw	13 WW	L'A	FI	KR	DE
Ly+Al	12 KR	WW	L'A	DE	FI
Do+Am	11 KR	DE	WW	L'A	FI
NT+El	10 FI	KR	L'A	DE	WW
Fo+Fu	9 WW	L'A	FI	DE	KR
U	8 KR	WW	L'A	FI	DE
Ly+Ri	7 KR	DE	WW	L'A	FI
Fo+Al	6 L'A	FI	KR	DE	WW
Ly+Al	5 L'A	WW	DE	FI	KR
Do+Ca	4 WW	FI	DE	KR	L'A
Sy+In	3 DE	WW	FI	L'A	KR
NT+Tw	2 WW	FI	DE	KR	L'A
Do+Am	1 FI	WW	L'A	DE	KR
	Rep I				
	bed 10				

rep 2

	Spare Area				
	Rep III				
U	30 DE	L'A	WW	FI	KR
Fo+Fu	29 L'A	FI	KR	WW	DE
NT+El	28 DE	WW	L'A	FI	KR
Sy+In	27 KR	L'A	DE	WW	FI
NT+Tw	26 DE	KR	L'A	FI	WW
Ly+Al	25 KR	DE	L'A	WW	FI
Fo+Al	24 WW	FI	L'A	KR	DE
Ly+Ri	23 L'A	DE	FI	KR	WW
Do+Ca	22 FI	KR	DE	WW	L'A
Do+Am	21 DE	KR	WW	FI	L'A
Sy+In	20 WW	L'A	KR	FI	DE
U	19 KR	FI	L'A	DE	WW
Fo+Al	18 KR	DE	FI	L'A	WW
Ly+Ri	17 WW	KR	DE	FI	L'A
Do+Ca	16 DE	L'A	WW	KR	FI
	Rep II (cont)				
	bed 11				

TOP TUNNEL SITE

Plot Details

15 Rows of 5 plants

0.85m between pot centres down row.

Treatments

Cultivars

DE = Dearest	code-Purple
KR = Kind Regards	code-Pink
WW = Warm Wishes	code-Yellow
L'A = L' Aimant	code-Orange
FI = Fiesta	code-Red

Fungicides

Al - Aliette	In = Invader
Am = Amistar	Ly = Lyric
Ca = Captan	NT = Nimrod T
Do = Dorado	Ri = Ripost
El = Elvaron	Sy = Systhane 20EW
Fo = Folicur	Tw = Twist
Fu = Fubol	U = Untreated

IAS 32243

Autumn Treatments 2001

TOP TUNNEL SITE

Spare Area

Rep II

Ly+NT	15 FI	L'A	DE	WW	KR
NT+El	14 FI	KR	DE	L'A	WW
NT+Tw	13 WW	L'A	FI	KR	DE
Ly+Al	12 KR	WW	L'A	DE	FI
Do+Am	11 KR	DE	WW	L'A	FI
NT+El	10 FI	KR	L'A	DE	WW
Ly+NT	9 WW	L'A	FI	DE	KR
U	8 KR	WW	L'A	FI	DE
Sy+Tw	7 KR	DE	WW	L'A	FI
Fo+Al	6 L'A	FI	KR	DE	WW
Ly+Al	5 L'A	WW	DE	FI	KR
Do+Tw	4 WW	FI	DE	KR	L'A
Fo+NT	3 DE	WW	FI	L'A	KR
NT+Tw	2 WW	FI	DE	KR	L'A
Do+Am	1 FI	WW	L'A	DE	KR

Rep I
bed 10

Spare Area

Rep III

U	30 DE	L'A	WW	FI	KR
Ly+NT	29 L'A	FI	KR	WW	DE
NT+El	28 DE	WW	L'A	FI	KR
Fo+NT	27 KR	L'A	DE	WW	FI
NT+Tw	26 DE	KR	L'A	FI	WW
Ly+Al	25 KR	DE	L'A	WW	FI
Fo+Al	24 WW	FI	L'A	KR	DE
Sy+Tw	23 L'A	DE	FI	KR	WW
Do+Tw	22 FI	KR	DE	WW	L'A
Do+Am	21 DE	KR	WW	FI	L'A
Fo+NT	20 WW	L'A	KR	FI	DE
U	19 KR	FI	L'A	DE	WW
Fo+Al	18 KR	DE	FI	L'A	WW
Sy+Tw	17 WW	KR	DE	FI	L'A
Do+Tw	16 DE	L'A	WW	KR	FI

Rep II (cont)
bed 11

Plot Details
15 Rows of 5 plants

0.85m between pot centres down row.

Treatments

Cultivars

DE = Dearest	code-Purple
KR = Kind Regards	code-Pink
WW = Warm Wishes	code-Yellow
L'A = L' Aimant	code-Orange
FI = Fiesta	code-Red

Fungicides

Al - Aliette	In = Invader
Am = Amistar	Ly = Lyric
Ca = Captan	NT = Nimrod T
Do = Dorado	Ri = Ripost
El = Elvaron	Sy = Systhane 20EW
Fo = Folicur	Tw = Twist
Fu = Fubol	U = Untreated

HNS 106 HDC ROSE FUNGICIDE 2001 **IAS 32243**

Top Tunnel Site **FUNGICIDE EFFICACY EXPERIMENT (Black Spot and Rust) YEAR 2**

rep 1	rep 2	rep 3
D 7	D 14	B 21
C 6	B 13	D 20
E 5	F 12	F 19
B 4	A 11	A 18
S 3	S 10	C 17
A 2	E 9	E 16
F 1	C 8	S 15
bed 6	bed 7	bed 8

Plot Details

c.v Silver Wedding
25 plants/plot
Central 9 recorded
Outside 16 guards
include some 2 year old plants.
spacing approx 30cm x 30cm.
1m gap between plots.
Drip irrigated.

O O O O O
O X X X O
O X X X O
O X X X O
O O O O O

O = GUARD
X = RECORDED

recorded plants numbered front to back left to right.

TREATMENTS

A=INDAR 5EW 1.4 ml/litre
B=PLOVER 0.3 ml/litre
C=STROBY 0.3 g/litre
D=LYRIC 0.625 ml/litre
E=TILT 1.0 ml/litre
F=FLAMENCO 1.25 ml/litre

S=STANDARD ROTATION
i) Systhane 20EW 0.3 ml/l
ii) Nimrod T 3.2 ml/litre
iii) F238 2.5 ml/litre +
Bavistin DF 0.5 g/litre

Fungicides applied every 2 weeks from mid July 2001 after pruning back first flush growth

HDC ROSE FUNGICIDE 2001 **IAS 32243** **HNS 106a**

Top Tunnel Site **POWDERY MILDEW TRIAL** (see separate plan for plot detail)

Pl 4	**F2** 8	**Fl** 12
El 3	**Sy** 7	**St** 11
Tw 2	**Ni** 6	**Fo** 10
Fu 1	**Do** 5	**Ba** 9

rep 1

Sy 16	**Do** 20	**Ni** 24
St 15	**F2** 19	**Ba** 23
Fl 14	**Fo** 18	**El** 22
Pl 13	**Fu** 17	**Tw** 21

rep 2

Do 28	**F2** 32	**Ni** 36
El 27	**Ba** 31	**St** 35
Tw 26	**Sy** 30	**Pl** 34
Fu 25	**Fl** 29	**Fo** 33

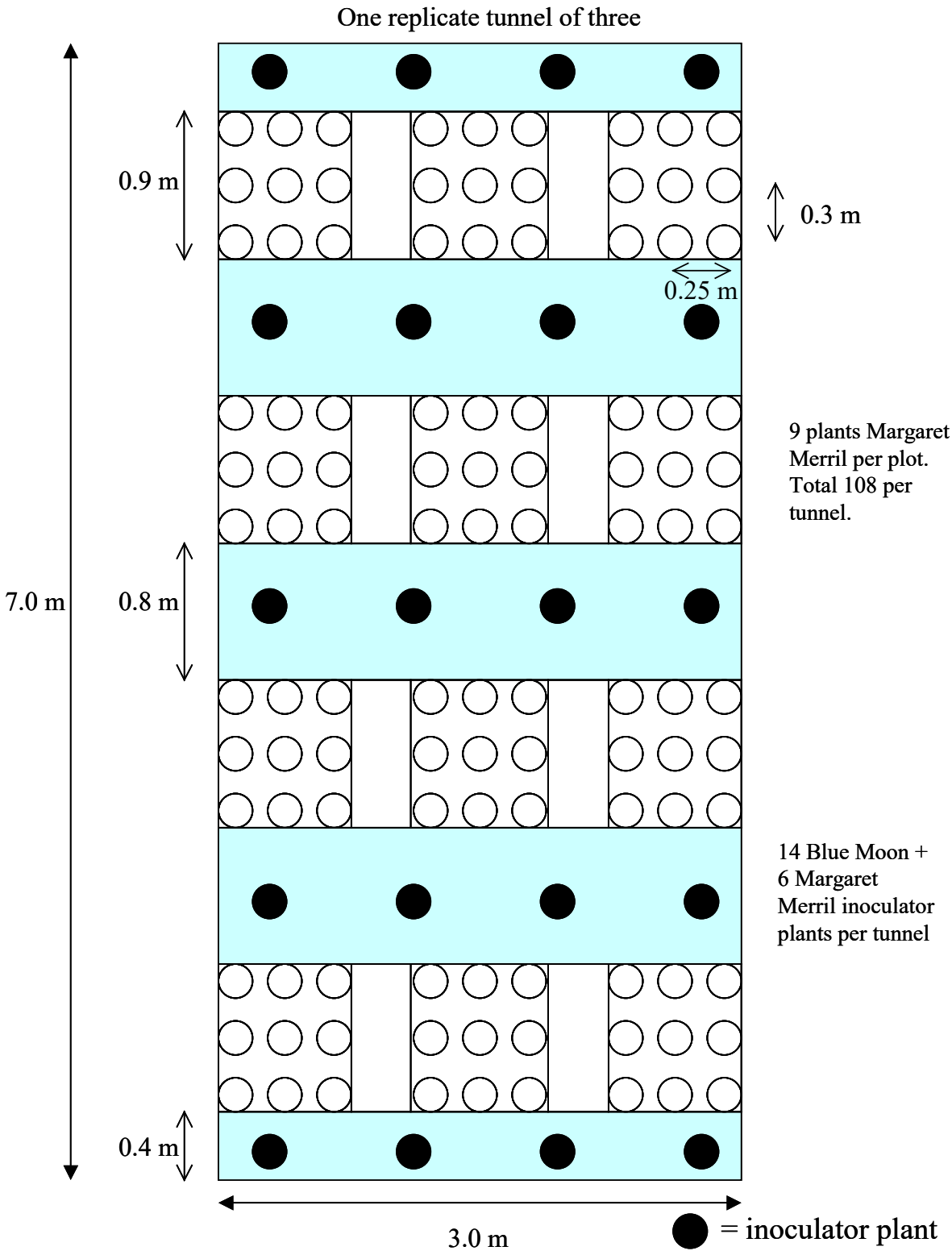
rep 3

TREATMENTS

Fo	Folicur 1ml/litre	Tw	Twist 2.0ml/litre	Ba	Bavistin DF 0.5g/litre
Pl	Plover 0.3ml/litre	St	Stroby 0.3ml/litre	El	Elvaron WG 5.0g/litre
Fl	Flamenco 1.25ml/litre	Do	Dorado 0.25ml/litre		
Sy	Systhane 20 EW 0.3ml/litre	Ni	Nimrod T 3.2ml/litre	U	Untreated - Inoculator plants
Fu	Fungaflor 1.5ml/litre	F2	F238 2.5ml/litre		

Sprayed every two weeks from late July to mid November

HNS 106 - 2001 - Rose Powdery Mildew Experiment in Tunnels TT Site south



Appendix 2 – Photographs

Fungicide Programmes experiment (foreground) with Efficacy experiment for rust and blackspot (background), 16/7/01.

Spraying Efficacy experiment (above)

Late flush of growth and flower on Phytotoxicity experiment, 7/9/01 (right)

Fungicide Programmes experiment

Standard treatment showing significant leaf drop (foreground) vs. W3 treatment plot behind, 12/11/01.

Severe black spot on Standard treatment

Fortnightly treatment F3, 12/11/01. Very little disease or leaf drop; some bronzing of leaves due to frost.

Comparison of degree of leaf drop on Programmes experiment by 14/12/01.

Treatment F1 (left) vs Standard (right).

Leaf drop assessment; score 1 – 5, left to right.

Phytotoxicity symptoms from Nimrod T + Elvaron following the double rate spray in spring, on Fiesta (left), and Warm Wishes (right)

Mild puckering or curling of leaves on Kind Regards (top) and Fiesta (bottom), following the spray in spring at the single rate

Spray damage on Warm Wishes four days following autumn applied sprays at double rate of Nimrod T + Lyric (left) and Nimrod T + Folicur (right)

Efficacy experiment for rust and black spot

Summer growth before significant disease development. Front plot Stroby (normal coloured leaves), Tilt plot with dark foliage behind.

Foliage colour differences persisted throughout the trial. Plant from Lyric treatment (left) with lighter foliage compared to Tilt treatment photographed 21/11/01.

Efficacy experiment – treatment effects by 21/11/01

Indar

Plover

Efficacy experiment – treatment effects by 21/11/01 (cont.)

Powdery mildew experiment under protection

One replicate of three tunnels

Plot layout in tunnel Margaret Merril with Blue Moon inoculator plants in front

Heavy infection on Blue Moon Inoculator plant

'Slight' infection on Systhane treated plant (Score 3) 9/10/01

Phytotoxicity from Fungaflor spray on Margaret Merril under protection

Heavy spray deposits from Elvaron WG