Final Report (April 1999)

Project number:	FV 207
Title:	Outdoor crisp lettuce: Evaluation of existing and novel fungicides for the control of foliar pathogens and *Pythium* root rot

Project leaders:

Dr T M O'Neill
ADAS Arthur Rickwood
Mepal
Ely
Cambridgeshire
CB6 2BA

Tel: 01354 692531
Fax: 01354 694488

Dr G M McPherson
HRI Stockbridge House
Cawood
Selby
North Yorkshire
YO8 3TZ

Tel: 01757 268275
Fax: 01757 268996

Project co-ordinator:

Mr Roy Roberts
Len Wright Marketing Ltd
Rutland Farm
Taylors Meanygate
Tarleton Moss
Preston
Lancashire
PR4 6XB

Tel: 01772 812647
Fax: 01772 815920

Location of project:	ADAS Arthur Rickwood HRI Stockbridge House
Date project commenced:	1 April 1997
First report issued:	1 April 1998
Date completion due:	30 March 1999
Key words:	crisp lettuce, botrytis, downy mildew, pythium, fungicides

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

AUTHENTICATION

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

Dr T M O'Neill
Senior Research Consultant
ADAS Arthur Rickwood

Signature .... Date ....

Dr G M McPherson
Research Plant Pathologist
HRI Stockbridge House

Signature .... Date ....

Report authorised by:

Dr M Heath
Team Manager
ADAS Arthur Rickwood

Signature .... Date ....

Mr M R Bradley
Site Director
HRI Stockbridge House

Signature .... Date ....

CONTENTS

	Page
PRACTICAL SECTION FOR GROWERS	
Objectives and background	1
Summary of results	1
Action points for growers	3
Practical and anticipated financial benefits	3
SCIENCE SECTION	
Introduction	5
Materials and methods	6
Results	13
Discussion	23
Conclusions	26
Acknowledgements	28
References	28
Figures	29

PRACTICAL SECTION FOR GROWERS

Objectives and background

Plant diseases are a constant threat to the UK outdoor lettuce crop, particularly in areas of intensive production. Growers rely heavily on the use of fungicides for prevention and control of downy mildew (*Bremia lactucae*), grey mould (*Botrytis cinerea*) and sclerotinia (*Sclerotinia sclerotiorum*). In addition, vascular wilt and root rots caused by *Pythium* spp., particularly *P. tracheiphilum*, appear to be of increasing importance in field lettuce and may warrant increased control measures in the future.

Effective control of downy mildew has been difficult since the occurrence of metalaxyl-insensitive strains of *B. lactucae*. The introduction of outdoor cultivars with appropriate R-(Dm) genes has helped, though the development of a further metalaxyl-insensitive strain during 1998 has, temporarily at least, created further problems for the industry.

Unfortunately, the presence of downy mildew often exacerbates the development of secondary opportunists such as *B. cinerea,* which cause further deterioration and quality loss, particularly to the lower leaves and stem base region. Dicarboximide fungicides (e.g. Rovral, Ronilan) have been used widely in the past but now insensitive strains are common in *B. cinerea* populations and these fungicides are much less effective than previously. Moreover, the revocation of use of Ronilan on lettuce has had a deleterious impact not only for *Botrytis* control but also for the control of *Sclerotinia*, which as a persistent soil-borne disease, continues to cause increasing problems in outdoor crops.

Root rot caused by *Pythium* species is occasionally problematic during the propagation of lettuce, delaying emergence and subsequent establishment. In addition, vascular wilt, caused by the fungus *P. tracheiphilum*, appears to be increasing and may be the primary incitant of the butt-rot problems experienced in recent years, and which has previously been attributed to bacterial soft-rotting *Erwinia* spp.

With current changes in pesticide legislation, some older fungicides are under review by the regulators and it is anticipated that, in some cases, either increased restrictions on their use will be imposed or they will be lost altogether. It is essential therefore that a development programme is undertaken to identify alternative fungicides to maintain effective disease control and to formulate an effective resistance management strategy. Broad-spectrum products, effective against the range of common lettuce pathogens, and specific fungicides effective against single target pathogens, are needed to replace the older products which may be unsupported in the future.

The **commercial objective** of this project therefore is to evaluate a range of novel fungicides alongside various products currently holding UK approval for the control of leaf and stem base diseases of outdoor lettuce, both in the laboratory and the field.

Summary of results

In the first year of the project, a range of novel fungicides, with claimed activity against either *B. cinerea* and/or *B. lactucae*, were evaluated in laboratory studies. The most promising candidate fungicides were subsequently evaluated in field trials.

Botrytis

In the laboratory studies, five out of the 14 fungicides tested (iprodione, Rovral; prochloraz, Octave; tebuconazole, Folicur; difenconazole, Plover and fenpropidin, Opus) completely inhibited mycelial growth of *B. cinerea* at 2 mg/litre. In addition, fungicides in two novel groups (anilinopyrimidines and strobilurins), reported to have activity against this fungus gave 33-52% inhibition of growth when tested at this concentration using standard procedures. The most promising candidate materials were taken forward to field evaluation in a replicated trial at ADAS Arthur Rickwood in autumn 1997. Development of *B. cinerea* was slight during the growing period on the cv. Saladin and did not provide a sufficiently stern test by which to measure the relative performance of the fungicides. Programmes consisting of four sprays of fungicide gave no statistically significant control of Botrytis at harvest, although four treatments of iprodione (Rovral), prochloraz (Octave), tebuconazole (Folicur) and fenpropimorph (Corbel) appeared to give some control. One experimental product (resistance elicitor) significantly reduced the severity of downy mildew.

Downy mildew

Preliminary studies to evaluate fungicide performance against *B. lactucae* (a metalaxyl sensitive isolate) were conducted *in vivo* using a bioassay on young lettuce plants. Using this procedure the most effective fungicides identified were metalaxyl + thiram (Favour), propamocarb hydrochloride (Filex), fosetyl-al (Aliette), dimethomorph + mancozeb (Invader), azoxystrobin (Amistar), cymoxanil + mancozeb + oxadixyl (Trustan), propamocarb-HCl + mancozeb (Tattoo), etridiazole (Aaterra), dichlofluanid (Elvaron) and chlorothalonil (Bravo). Again, the most effective treatments were taken forward into a replicated field trial at HRI, Stockbridge House during autumn 1997. A moderate infection of downy mildew occurred in untreated plots during the course of the study. Several of the fungicides provided control of the disease, the most effective being cymoxanil + mancozeb + oxadixyl (Trustan), propamocarb-HCl (Filex) and an integrated programme comprising Bravo, Amistar, Invader, and Trustan. Highly significant differences were recorded in both disease incidence and yield at harvest.

In the second year of the project, a range of fungicide programmes based on the best products identified in year one, were evaluated in replicated trials in two commercial crops, one in Cambridgeshire and one in Lancashire. Additionally, the pathogenicity of *Pythium* isolates to lettuce was determined and efficacy of fungicides against *Pythium* butt rot was assessed.

Cambridgeshire trial

Both botrytis and downy mildew occurred in a field trial in an August-planted crop of cv. Saladin in Cambridgeshire, although severity of both diseases remained low throughout the crop life. However, some statistically significant results were derived from disease assessment data. Interim results showed that iprodione (Rovral) initially provided significant control of *B. cinerea* (no infection found) compared with the untreated control (7.5% of plants infected). Incidence of botrytis remained low until harvest when levels had increased to 41.7% (Rovral treated) and 57.3% (untreated). None of the treatments gave significant control of botrytis at harvest. Azoxystrobin (Amistar), oxadixyl + cymoxanil + mancozeb (Trustan) and dimethomorph + mancozeb (Invader) reduced downy mildew at harvest. None of the fungicide treatments affected mean head weight and none had any phytotoxic effects on the growth of the crop.

Lancashire trial

A severe attack of downy mildew occurred in a field trial in a July-planted crop of cv. Roxette in Lancashire. The fungus was identified as the new (1998 A) metalaxyl-resistant strain which in 1998 caused significant damage to crops in Lancashire, Yorkshire, Norfolk and Fife. Good control was given by Invader, used in alternation with Favour or alone, Amistar and Trustan. Treatment with Favour alone was largely ineffective.

Botrytis basal rot occurred at a low level and was significantly reduced following treatment with Amistar and not by other treatments. Control with Amistar was probably an indirect effect, resulting from a reduction in the amount of downy mildew damaged tissue, a common site for botrytis invasion. A low incidence of *Sclerotinia* occurred in the trial and appeared to be less on plants treated with Amistar, though the data was too sparse for statistical analysis. Significant increases in head weight occurred where downy mildew was effectively controlled. No evidence of crop damage was observed following use of any of the experimental chemicals.

Pythium studies

No symptoms of butt rot developed on plants artificially inoculated with two isolates of *Pythium tracheiphilum* at either ADAS Arthur Rickwood or HRI Stockbridge House. Moderate levels of butt rot occurred at crop maturity at the Lancashire trial site and *P. tracheiphilum* was isolated from rotting bases. None of the fungicide treatments appeared to affect incidence of butt rot.

It is recommended that further work should concentrate on development of integrated programmes for control of both botrytis and downy mildew. This should be based on the most appropriate products (e.g. Amistar, Scala, Invader) identified in this work used at a range of timings. Additionally, information should be gathered on the occurrence of butt rot, and possible predisposing conditions, in commercial lettuce crops.

Action points for growers

1. The fungicides Amistar, Trustan and Invader have been shown to provide good control of downy mildew in initial bioassays and in field trials. It is recommended that an application is made to secure approval for use of one or more of these products on lettuce.

2. The level of botrytis control provided by iprodione (e.g. Rovral Flo) was moderate. If botrytis is, or becomes, a common problem in your crop, it is recommended that isolates are tested for sensitivity to this fungicide.

3. Amistar gave good control of botrytis in one trial where plants were badly affected by downy mildew. This was probably an indirect effect, with the fungicide reducing the amount of downy mildew damaged tissue, which is prone to botrytis infection. Growers should be aware that an initial attack of downy mildew can lead to subsequent problems with botrytis.

4. An experimental integrated disease control programme consisting of four sprays (Rovral/Favour/Scala/Invader), targeted to control both botrytis and downy mildew, gave no control at harvest of either disease. It would appear that a calendar-based spray schedule, where the most effective sprays for each disease were applied at 28 day intervals, is insufficient to achieve good disease control. Programmes based on products or mixtures active against both botrytis and downy mildew, or shorter intervals between sprays, are more likely to provide effective control of both diseases.

5. Conditions favouring development of butt rot are unknown. Butt rot occurred naturally in one of the field trials (and a *Pythium* species was regularly isolated), but two isolates of *P. tracheiphilum* obtained from culture collections failed to cause the disease when inoculated on to plants. Information an occurrence of butt rot and testing of lettuce plants showing butt rot symptoms should help to identify situations when this problem is likely to occur. None of the foliar spray treatments applied for leaf diseases had any significant effect of butt rot.

Practical and anticipated financial benefits

The value of the UK outdoor lettuce crop is estimated to be worth £96.6 million (MAFF Census, 1996). Losses due to leaf disease and basal rots vary from season to season, but can be as high as 30-40% in individual crops. Infection of the outer leaves due to downy mildew can reduce quality leading to extra trimming and secondary rotting. ADAS surveys of field lettuce from 1988-1991 indicated that annual national losses to diseases, primarily botrytis and downy mildew alone, ranged in value from £2.8 million (1989) to £7.5 million (1988). Similarly, losses due to *Sclerotinia* infection can be very high in some localities, particularly in wet seasons, though it is difficult to predict. Currently, losses due to *Pythium* are hard to estimate as severe disease symptoms are uncommon. Delayed establishment and reduced vigour are likely to be the primary effects from this group of pathogens, though *P. tracheiphilum*, if widespread, can potentially cause total collapse of plants as a result of vascular wilt. There is therefore a large potential benefit to the industry in developing effective disease control strategies in this crop.

SCIENCE SECTION

INTRODUCTION

Previous studies on control of downy mildew in field-grown lettuce have demonstrated the efficacy of propagation treatments with Aliette and post-planting treatment with Favour 600 SC, Filex, and zineb (HDC Project FV 95). Favour 600 SC has a label recommendation for use on outdoor lettuce with up to five sprays permitted and a 14 day harvest interval. Filex has an off-label approval for use on field lettuce (1625/95, valid until 30 November 2000) and up to three sprays are permitted with a 14 day harvest interval. Zineb has a label recommendation for use on outdoor lettuce, with a 14 day harvest interval. In Project FV 95 in 1991, a programme of 2 sprays of Filex gave moderately good control of downy mildew (41%) through to harvest whilst programmes of 4 sprays of Favour 600 SC or Zineb gave little or no control. In a trial in 1993, where moderately severe downy mildew occurred, programmes of 4 sprays of Filex, Favour 600 SC, Mancozeb, Thiram and Zineb reduced the disease by 71-91%, with Mancozeb the most effective. In the first year of this project, 10 fungicides were shown to have good activity against downy mildew in a laboratory bioassay. Significant control was shown in a field trial using Trustan, Filex and an integrated programme (Bravo, Amistar, Invader, Trustan).

Although there has been no recent work evaluating fungicides for control of botrytis in outdoor crisp lettuce, evaluations on protected lettuce (HDC Project PC 117) have revealed good control with four sprays of azoxystrobin (Amistar), pyrimethanil (Scala), cyprodinil and a carbendazim and diethofencarb mixture; iprodione (Rovral), prochloraz-Mn (Octave) and thiram (Unicrop Thiram) were less effective. In the first year of this project, 5 out of 14 fungicides completely inhibited growth of *B. cinerea* in agar plate tests. Fungicides in two novel groups (anilinopyrimidines and strobilurins) gave 33-52% inhibition. Four treatments appeared to give some control in a field trial, although disease levels were low and no differences were statistically significant.

Pythium root rot has been described in field lettuce in Quebec (2.4% losses in 1986; Reelder & Charbonneau, 1987), in the USA (15% losses in 1974) and in Germany (Zinkernagel & Krober, 1978), and pathogenicity of *P. tracheiphilum* to lettuce has been confirmed (Blok & van der Plats-Niterink, 1978). In the UK, *P. tracheiphilum* has been recovered from both protected and outdoor crisp lettuce exhibiting vascular wilt symptoms for several years (McPherson, pers. comm.) though there has been little or no work on its control in lettuce, either in the UK or elsewhere.

For full results of the laboratory work and field trials carried out in 1997, please see the first annual report, issued April 1998.

The **specific objectives** in the second year of this project are:

1. To evaluate the efficacy of novel fungicides with good activity against *B. lactucae* in controlling downy mildew on outdoor crisp lettuce.

2. To evaluate the efficacy of novel fungicides with good activity against *B. cinerea* in controlling botrytis on outdoor crisp lettuce.

3. To obtain isolate(s) of *P. tracheiphilum* pathogenic to lettuce, to develop an inoculation procedure on lettuce and to investigate fungicides for their efficacy against vascular wilt.

MATERIALS AND METHODS

Fungicide products and programmes for control of botrytis and downy mildew

Trial 1-Cambridgeshire

Site and crop details

The trial was located at G's Fresh Salads, Newgant Farm near Swaffham Prior, Cambridgeshire on a heavy organic peat soil. The crop cv. Saladin was planted in 4 row beds at a spacing of 25 cm in rows and 35 cm between rows. Plants were propagated in peat blocks and planted at the 4 true leaf stage. No fungicides were applied during propagation. No fungicides were applied to the trial area other than experiment treatments listed below.

Experimental design and analysis

The experiment was of a randomised block design with four replicates of each treatment and eight replicates of the untreated control. Plot size was 1.5m x 4.3m (6.45m²) and consisted of 68 plants. Results were analysed by analysis of variance; data transformation before analysis was undertaken where required. Statistically significant differences between treatments are shown as:

* $P < 0.05$; ** $P < 0.01$; *** at $P < 0.001$ and NS = not significant ($P > 0.05$)

Treatments

Eight fungicides were and two programmes evaluated. Treatments 2, 4, 5, 6 and 10 were aimed at the control of botrytis, treatments 3, 7, 8 and 9 at downy mildew, and treatment 11 at both diseases. Treatments were:

1. Untreated control (double replication)
2. Rovral Flo (iprodione) at 2.3 l/ha
3. Favour 600 SC (metalaxyl + thiram) 1-3 l/ha*
4. Scala (pyrimethanil) at 2.0 l/ha
5. A-P5353 (mepanipyrim) at 0.6 kg/ha
6. Folicur (tebuconazole) at 0.75 l/ha
7. Amistar (azoxystrobin) at 0.8 l/ha
8. Invader (dimethomorph + mancozeb) at 2.0 kg/ha
9. Trustan (oxadixyl + cymoxanil + mancozeb) at 3.0 kg/ha
10. Botrytis programme: Rovral, Scala, Rovral, #
11. Full programme: Rovral, Favour, Scala, #

#Rates as specified in individual treatment
*Favour applied at 1.0 l/ha from two to five true leaves, 1.5 l/ha from five leaves to rosette and 3.0 l/ha from rosette to mature plant.

Fungicide applications

Fungicides were applied on three occasions, at approximately 14 day intervals, commencing 9 days after planting with the final spray 14 days before harvest. Sprays were applied at 400 litres/ha using an Oxford Precision sprayer. Rates used were label recommendations (Favour, Rovral), the SOLA (1230/97) rate for Folicur on leafy herbs, or as recommended by the chemical suppliers for use on other crops, and found to have no phytotoxic effect on lettuce in the first year of this project.

Crop diary (1998)

01 August	Crop planted
10 August	Fungicide application 1
25 August	Fungicide application 2
11 September	Interim disease assessment
14 September	Fungicide application 3
28/29 September	Trial harvested: Final disease assessment

Assessments

All plants were assessed for disease at interim assessments. The central 24 plants were individually assessed at harvest.

The following assessments were made:

(i) Downy mildew
Incidence of plants affected
Severity of downy mildew using 0-3 index:

0 - No visible infection
1 - Total of 1 to 5 spots (approx.) of mildew, on the lower leaves
2 - Total of more than 5 spots, on the lower leaves
3 - Total of more than 5 spots, some on upper leaves (i.e. not removed on trimming of basal leaves)

(ii) Botrytis
Incidence of plants affected
Severity of botrytis using a 0-3 index:

0 - No visible infection
1 - Part or all of one leaf affected
2- Several leaves in basal layer affected (leaves which will be trimmed off)
3 - Botrytis also affecting green tissue in the head

(iii) Butt rot
Incidence of plants affected
Severity of butt rot using 0-3 index:

0 - No visible infection
1 - Glassiness in butt
2 - Browning in butt
3 - Soft, pungent green or brown rot within butt

Disease severity indices (0-100) were calculated using the formula:

$$\text{Disease index} = \frac{\text{Sum of severity scores per plot}}{\text{No. of plants assessed}} \times \frac{100}{3}$$

Head weight was recorded on the central 24 plants after trimming to remove all diseased leaves.

Trial 2 - Lancashire

Site and crop details

The field trial was located in Lancashire at Rutland Farm, Taylors Meanygate, Tarleton Moss, Preston, Lancashire PR4 6XB. Seeds of cv. Roxette were sown into 3.8 cm peat modules, covered and placed in a cold store at 1-2°C for 24 hours to aid germination. The seeded blocks were moved to a glasshouse and grown following the usual commercial practice.

Trial design and analysis

The field trail was laid out as a randomised black design with four replicates of each treatment. Each plot consisted of 4 rows, each row containing 15 plants, with a total of 60 plants per plot. The outer plants in each plot acted as a picture-frame guard area. Plant spacing was 37 cm between each row and 35 cm between each plant.

Analysis of variance on the results from the agronomic assessments and binomial analysis of the disease assessments were carried out by Biometrics, HRI Wellesbourne, determined at a 5% level of probability (P= 0.05). Significance is indicated by:

NS no significant difference
* Significance at the 95% level of probability
** Significance at the 99% level of probability
*** Significance at the 99.9% level of probability

Differences between treatments can be compared (at the 95% probability level) using the Standard Error of Difference (SED) figure at the bottom of each column.

Treatments

1. Untreated control (Double replication).

   Note: The unsprayed control treatment provides the base line on which to assess the performance of the various fungicide treatments in the trial.

2. Rovral Flo (iprodione 255g/litre product) marketed by Rhone Poulenc Agriculture. Applied as a high volume spray to run off at a rate of 2.3 litres product in 400l water/ha, 7 days after planting and repeated at 14 day intervals with a maximum of 4 applications.

3. Favour 600 SC (metalaxyl 100g + thiram 500g/litre product) marketed by Novartis Crop Protection (UK) Ltd. Applied at a rate of 1-3 litres product in 400l water/ha. Applied as a high volume spray to run-off 7 days after planting and repeated at 14 day intervals with a maximum of 4 applications.

4. Scala (pyrimethanil 400g/litre product) marketed by Promark. Applied as a high volume spray to run-off at a rate of 2.0 litres product in 400 l water/ha, 7 days after planting and repeated at 14 day intervals with a maximum of 4 applications.

5. A-P5353 (mepanipyrim 350g/litre product), an experimental fungicide. Applied as a high volume spray to run-off at a rate of 0.6 kg product in 400l water/ha, 7 days after planting and repeated at 14 day intervals with a maximum of 4 applications.

6. Folicur (tebuconazole 250 g/litre product) marketed by Bayer. Applied as a high volume spray to run-off at a rate 0.75 litre product in 400l water/ha, 7 days after planting and repeated at 14 day intervals with a maximum of 4 applications.

7. Amistar (azoxystrobin 250 g/litre product) marketed by Zeneca. Applied as a high volume spray to run-off at a rate of 0.8 litre product in 400l water/ha, 7 days after planting and repeated at 14 day intervals with a maximum of 4 applications.

8. Invader (7.5% dimethomorph + 66.7% mancozeb) marketed by Cyanamid. Applied as a high volume spray to run-off at a rate of 2.0 kg product in 400l water/ha, 7 days after planting and repeated at 14 day intervals with a maximum of 4 applications.

9. Trustan (3.2% cymoxanil, 56% mancozeb, and 8% oxadixyl) marketed by Du Pont. Applied as a high volume spray to run-off at a rate of 3.0 kg product in 400l water/ha, 7 days after planting and repeated at 14 day intervals with a maximum of 4 applications.

10. Integrated "downy mildew programme" comprising an alternating programme of Favour (T3), Invader (T8), Favour (T3), Invader (T8) at the rates specified above.

11. Integrated "full programme" (for downy mildew and botrytis) comprising alternating programme of Rovral (T2), Favour (T3), Scala (T4), Invader (T8) at the rate specified above.

<u>Fungicide Application</u>

The fungicides were applied as a high volume spray using an Oxford Precision Knapsack sprayer (E-Bar Engineering) with boom attachment at a pressure of two bars. Four spray applications were made post-planting, at ca. 14 day intervals, with the first spray 7 days after planting and the final spray 10 days before harvest.

<u>Crop diary (1998)</u>

Planting date:	23 July
Fungicide spray application 1:	30 July
Fungicide spray application 2:	13 August
Disease assessment (1):	20 August
Fungicide spray application 3:	27 August
Disease assessment (2):	3 September
Fungicide spray application 4:	10 September
Harvest:	21 September
Final Disease Assessment (3):	21 September

Assessments

(i) Downy mildew

During cropping, once there were signs of downy mildew infection on experimental plants, two interim assessments were made visually from above the crop using a 0-3 scale of severity on 20 individual plants per plot.

0 = No visible mildew infection
1 = Some of the lower leaves affected only
2 = Moderate infection - mostly on the lower leaves causing yellowing
3 = Severe infection - yellowing and sporulation across the head

At harvest, downy mildew assessments were made on 20 individual plants when cut thereby allowing closer examination of the lower leaves. On each plant the leaf area infected with *Bremia lactucae*, including yellowing of the foliage and areas of sporulation, and was assessed using a 0-3 scale.

0 = No visible mildew infection
1 = 1- 5% leaf area affected by mildew
2 = 6-20% leaf area affected by mildew
3 = 21-50% leaf area affected by mildew

(ii) Botrytis bottom rot

At harvest, bottom rot assessments were made on 12 individual plants when cut. On each plant, the number of leaves affected by Botrytis was assessed using a 0-3 scale.

0 = No bottom rot
1 = 1-2 leaves affected by Botrytis bottom rot
2 = 3-4 leaves affected by Botrytis bottom rot
3 = 5 and above leaves affected by Botrytis bottom rot

The disease indices for downy mildew and Botrytis infection were calculated from 0-3 assessments as follows:

$$\frac{1(\text{No in category 1}) + 2(\text{No in 2}) + 3(\text{No in 3})}{\text{No of plants assessed}} \times \frac{100}{3}$$

The range of this index was, therefore, zero (no disease) to 100 (most severe disease).

(iii) Other diseases

Twenty plants in each individual plot were assessed for symptoms of *Sclerotinia* and butt rot at the time of harvest.

(iv) Agronomic assessments

At harvest, 12 plants in each plot were cut and bulk weighed to give a mean untrimmed lettuce head weight. Each lettuce was then trimmed to a commercial standard, removing the infected leaf tissue from the base to provide a clean frame. The lettuce heads were then re-weighed to provide a mean trimmed lettuce head weight. The difference between the untrimmed and trimmed yield was therefore regarded as the weight loss as a result of leaf infection by downy mildew and botrytis.

Storage of data

The raw data will be stored for a period of not less than 5 years, in the HRI archive at Stockbridge House and the ADAS archive at Arthur Rickwood, for the respective trials. Access to the data can only be made via the designated archivist.

Official recognition and quality assurance

Both trials were conducted in accordance with the guidelines for 'Official Recognition of Efficacy Testing Organisations in the United Kingdom' (Certificate numbers ORETO 020 (HRI) and ORETO 062 (ADAS)) as outlined by the Pesticide Safety Directorate (ref: PRD 2400/2996) and in accordance with ADAS and HRI's Standard Operating Procedures (SOPs). Specific quality assurance audits were not undertaken in these trials.

Fungicides for control of pythium root rot (*P. tracheiphilum*)

Source and culture of fungi

An isolate of *P. tracheiphilum* originally isolated from lettuce by Dr G M McPherson was kindly supplied by Dr G White, HRI Wellesbourne. A further isolate of *P. tracheiphilum*, pathogenic to chinese cabbage, was sourced from Dr J Hockenhull, Denmark. Cultures were grown on potato dextrose agar at 20ºC.

Inoculation of lettuce plants

Method 1 (AR)

A 3cm layer of compost was placed in the bottom of 13 cm plant pots, and either one plug (diameter 6 mm) bearing *P. tracheiphilum*, or 10 plugs, were placed on that layer. The plug(s) were covered with a further 4 cm layer of compost.

Block grown lettuce plants, cv. Vegas, at the 5 true-leaf stage were placed on the compost, with one plant per pot. Each pot was stood on a plastic saucer and watered individually. The compost was maintained moist at all times and wet for a period of three days one week after planting, to encourage infection by *Pythium*. Plants were grown in a frost-protected greenhouse.

Method 2 (SH)

Young lettuce plants, cv. Calgary, were raised in 4.3 cm peat blocks and inoculated with each of the two isolates of *P. tracheiphilum* by either stab inoculation into the stem base or by placing a 1 cm disc of agar containing the fungus beneath the propagation block. After 5 days the lettuce were planted out in the field in individual rows alongside uninoculated plants to await symptom development. The plants were covered for frost protection.

Trial design

Method 1 (AR)

There were 5 replicate pots for each isolate of *P. tracheiphilum* and for each control treatment (compost infested with PDA but no fungus; uninfested compost).

Method 2 (SH)

There were 10 replicate plants for each isolate of *P. tracheiphilum* and for the uninoculated controls.

Assessments

Method 1 (AR)

Plants were assessed for evidence of wilting at weekly intervals. At the final (destructive) assessment, each plant was assessed for wilting, root rot and butt rot.

Method 2 (SH)

Plants were assessed weekly for evidence of wilting. At the final (destructive) assessment, each plant was assessed for signs of butt rot and internal discolouration.

RESULTS

Fungicide products and programmes for control of botrytis and downy mildew *(B. lactucae*)

1. Field trial in Cambridgeshire

High winds and unusually wet weather in early September prevented spraying and delayed application of the third fungicide treatment. This weather also favoured lettuce growth, resulting in only enough time for three out the proposed four fungicide applications.

Botrytis and downy mildew were first confirmed in the trial area on 11 September, 17 days after the second application of fungicides. Botrytis affected 7.5% of untreated plants on 11 September, and was less (nil) where plants had been treated with Rovral (Table 1). Rovral significantly reduced botrytis severity. At harvest, although differences were small and not statistically significant, the least botrytis (disease index 15.3) was recorded on plants treated with Rovral, compared with 22.7 in untreated plots.

Downy mildew affected 6.3% of untreated plants on 11 September and this had increased to 41% by harvest. Severity of this disease at harvest was reduced by Amistar, Trustan and Invader (Table 2). Favour was ineffective, although testing of an isolate collected from the crop showed it to be metalaxyl sensitive.

Other diseases confirmed in the trial at a low incidence were powdery mildew (*Erysiphe cichoracearum* f. sp. *lactucae* and basal rot (*Rhizoctonia solani*). No wilting or butt rot were observed.

Differences in marketable head weight were not statistically significant and no difference between treatments was seen in head quality (Table 3).

Table 1. Effect of fungicide treatments on lettuce botrytis, Cambs - 1998

Treatment	Mean % plants affected		Mean disease index (0-100)	
	11 Sept	29 Sept	11 Sept	29 Sept
1. Untreated	7.5	57.3	3.8 (0.29)	22.7
2. Rovral Flo	0.0	41.7	0.0 (0.00)	15.3
3. Favour 600 SC	5.0	55.2	2.5 (0.18)	20.8
4. Scala	2.5	61.5	1.3 (0.14)	25.7
5. A-P5353	6.3	60.4	3.3 (0.28)	24.7
6. Folicur	2.5	60.4	1.3 (0.14)	25.3
7. Amistar	5.0	49.0	2.9 (0.29)	19.1
8. Invader	1.3	60.4	0.4 (0.06)	24.3
9. Trustan	15.0	52.1	7.9 (0.41)	22.6
10.Botrytis programme	5.0	53.1	2.1 (0.22)	19.4
11.Full programme	3.8	54.2	2.1 (0.18)	19.8
Significance (34 df)	NS	NS	- (*)	NS
SED between treatments	4.23	10.74	- (0.114)	4.64
vs control	3.66	9.30	- (0.099)	4.02

Transformed data shown in parenthesis are the square root of original severity data.

Table 2. Effect of fungicide treatments on lettuce downy mildew, Cambs - 1998

Treatment	Mean % plants affected		Mean disease index (0-100)
	11 Sept	29 Sept	29 Sept
1. Untreated	6.3	41.1	15.6
2. Rovral Flo	0.0	42.7	14.9
3. Favour 600 SC	1.3	56.3	22.9
4. Scala	0.0	54.2	22.6
5. A-P5353	0.0	45.8	18.1
6. Folicur	0.0	59.4	27.8
7. Amistar	0.0	18.8	6.6
8. Invader	0.0	28.1	10.1
9. Trustan	0.0	22.9	8.3
10.Botrytis programme	0.0	58.3	22.2
11.Full programme	1.3	42.7	14.9
Significance (34 df)	#	**	*
SED between treatments	#	11.10	5.84
vs control	#	9.61	5.06

- Data not fit for analysis due to high number of zero values.
* - Significant at P<0.05
NS - not significant

Table 3. Effect of fungicide treatments on mean trimmed head weight, Cambs - 1998

Treatment	Mean head weight (g)
1. Untreated	518
2. Rovral Flo	494
3. Favour 600 SC	528
4. Scala	476
5. A-P5353	516
6. Folicur	484
7. Amistar	454
8. Invader	524
9. Trustan	529
10.Botrytis programme	495
11.Full programme	479
Significance (34 df)	NS
SED between treatments	29.3
vs control	25.3

2. Field trial in Lancashire

Following establishment of the trial, downy mildew was relatively quick in establishing across the entire area of the trial with significant differences between treatments becoming apparent 3-4 weeks after planting. As the trial progressed there was continued build up of downy mildew. This provided a good base line from which to evaluate the performance of the standard product Favour 600 SC and to compare it with a range of experimental fungicides.

Interim assessments on the level of downy mildew showed that both Trustan and Amistar significantly reduced the level of mildew compared with the control (Table 4). Favour 600 SC and the experimental fungicide, A-P5353, appeared to reduce the level of mildew slightly, though not significantly. There was little or no difference between the other treatments and the untreated control. On the second assessment, some 10-14 days later, levels of downy mildew infection had increased considerably throughout the trial. However, at this assessment the plots treated as part of the integrated downy mildew programme (Treatment 10) had significantly lower levels of mildew (Table 4).

At harvest, an assessment of downy mildew on the undersides of the lower leaves gave a more accurate record of disease severity. The disease remained active through to harvest and provided an exceptionally stern test for the fungicides. Several of the fungicides successfully reduced downy mildew though none eradicated it totally. The results in Table 5 show that the most effective treatments were Invader, Trustan and Amistar. The integrated downy mildew programme (T10), (which also included applications of Favour) significantly reduced mildew levels although not to the same degree as Invader, Trustan and Amistar. However, the full integrated programme for botrytis and downy mildew (T11) did not significantly reduce downy mildew.

Favour 600 SC, the commercial standard fungicide, whilst significantly reducing the level of mildew at harvest ($P<0.05$) did not provide effective disease control as compared with some of the experimental products. This suggests that one or more metalaxyl-insensitive strains of *B. lactucae* predominated in the population at the field site.

At crop maturity, the plants were scored for the extent of bottom rot symptoms caused by *B. cinerea* (Table 6). While the levels of *Botrytis* were not particularly high, Amistar significantly reduced development of the disease. Rovral Flo, Scala, A-P5353 and Folicur all appeared to reduce the symptoms of botrytis, but not significantly so. At harvest, the levels of botrytis were high in the full integrated programme.

At harvest, Amistar and Invader treated plants had a significantly greater untrimmed and trimmed head weight relative to the control ($P>0.05$) (Table 7). In addition, treatment with Invader resulted in the smallest loss when removing the diseased lower foliage at trimming. The integrated downy mildew programme, alternating Favour and Invader, performed the best with the highest mean untrimmed head weight as well as the highest mean trimmed head weight. None of the other fungicide treatments resulted in significantly increased yields.

The numbers of plants that died or collapsed due to infection by *Sclerotinia* or butt rot was recorded at the time of harvest (Table 8). Plant death due to attack by *Sclerotinia* appeared at a low level over the whole field but there were no marked differences between treatments. It is possible that due to the intensive nature of lettuce production in the Lancashire area, there is a relatively high inoculum in the soil for this disease. Symptoms of butt rot were evident in the majority of treatments across the trial site and plant samples taken to the laboratory confirmed the presence of *Pythium*.

There were no symptoms of crop damage from any of the experimental fungicide treatments used in this trial at the time of harvest. However, after the first fungicide spray application on 30 July there was some leaf tip browning on lettuce plants treated with Rovral Flo. These symptoms did not persist after further applications of Rovral Flo as the trial progressed.

Table 4. Mean disease scores for lettuce downy mildew on 20 August and on 3 September 1998 at the field trial site in Lancashire

Treatment		Mean Disease Index for Downy Mildew (0-100) + Interim assessments	
		20 August 1998	3 September 1998
T1	Untreated (water control)	22.47	60.62
T2	Rovral Flo	22.27	51.98
T3	Favour 600SC	19.37	55.28
T4	Scala	21.88	54.85
T5	A-P5353	19.37	56.92
T6	Folicur	21.88	63.10
T7	Amistar	16.10	58.97
T8	Invader	20.62	56.92
T9	Trustan	10.33	54.45
T10	Downy mildew programme	23.10	45.38
T11	Full programme	23.92	56.1
Uninoculated control v Fungicide treatment SED (34 df)		3.382	3.214
Compare 2 fungicide treatments SED (34 df)		3.904	3.709

+ Mean disease index is calculated from assessing 20 individual heads in each of four replicate plots.

Table 5. Assessment of downy mildew at harvest on 21 September 1998 at the Lancashire field trial

Treatment		Disease Index for Downy Mildew at Harvest (0-100)+ 21 September 1998
T1	Untreated (water control)	65.37
T2	Rovral Flo	61.88
T3	Favour 600SC	49.50
T4	Scala	56.92
T5	A-P5353	57.75
T6	Folicur	63.13
T7	Amistar	25.18
T8	Invader	9.50
T9	Trustan	21.45
T10	Downy mildew programme	37.55
T11	Full programme	63.13
Uninoculated control v Fungicide treatment SED (34 df)		6.778
Compare 2 fungicide treatments SED (34 df)		7.828

+ Mean disease index is calculated from assessing 20 individual heads in each of four replicate plots.

Table 6. Assessment of Botrytis at harvest on 21 September 1998 in the Lancashire field trial

Treatment		Disease Index for Botrytis at Harvest (0-100)[+] 21 September 1998
T1	Untreated (water control)	18.55
T2	Rovral Flo	12.38
T3	Favour 600SC	24.06
T4	Scala	13.07
T5	A-P5353	13.76
T6	Folicur	16.50
T7	Amistar	7.55
T8	Invader	26.80
T9	Trustan	23.36
T10	Downy mildew programme	15.81
T11	Full programme	22.01
Uninoculated control v Fungicide treatment SED (34 df)		5.425
Compare 2 fungicide treatments SED (34 df)		6.263

[+] Mean disease index is calculated from assessing 12 individual heads in each of four replicate plots.

Table 7. Untrimmed and trimmed head weight of lettuce at harvest on 21 September 1998 at the Lancashire field site

Treatment		Mean Untrimmed+ Head Weight/Plant (g)	Mean Trimmed+ Head Weight/Plant (g)
T1	Untreated (water control)	944.5	708.6
T2	Rovral Flo	920.5	722.5
T3	Favour 600SC	990.5	763.3
T4	Scala	981.2	744.8
T5	A-P5353	983.0	772.5
T6	Folicur	987.2	785.3
T7	Amistar	1041.5	783.0
T8	Invader	1039.2	828.8
T9	Trustan	984.7	789.3
T10	Downy mildew programme	1072.7	835.3
T11	Full programme	937.7	738.5
Uninoculated control v Fungicide treatment			
SED (34 df)		38.86	39.39
Compare 2 fungicide treatments			
SED (34 df)		44.88	45.48

Table 8. Percentage of lettuce plants affected by *Sclerotinia* spp. and butt rot at harvest on 21 September, Lancashire 1998

	Treatment	% of plants with *Sclerotinia*[+]	% of plants with butt rot[+]
T1	Untreated (water control)	8.13	1.89
T2	Rovral Flo	8.75	0.00
T3	Favour 600SC	6.25	2.50
T4	Scala	7.50	0.00
T5	A-P5353	6.25	6.25
T6	Folicur	6.25	2.50
T7	Amistar	5.00	2.50
T8	Invader	6.25	2.50
T9	Trustan	10.00	3.75
T10	Downy mildew programme	2.50	5.00
T11	Full programme	10.00	1.25

[+] 20 plants assessed per plot for symptoms of *Sclerotinia* and Butt Rot

Fungicides for control of pythium (*P. tracheiphilum*)

Inoculation of pot-grown lettuce plants

In the experiment at ADAS Arthur Rickwood, production of lettuce plants in compost infested with the UK isolate of *P. tracheiphilum* appeared to result in a slight increase in root rot, but did not result in an obvious development of wilting or butt rot (Table 9).

Table 9. Effect of infesting compost with *P. tracheiphilum* on wilting, root rot and butt rot in lettuce - 1998

Treatment[+]	Wilt index (0-3)	Root rot index (0-3)	Butt rot index (0-3)
Control	1.4	1.2	1.0
Control + agar	1.2	1.4	1.2
Pythium 1 - low inoculum	1.4	1.8	1.0
Pythium 1 - high inoculum	1.2	1.6	1.2
Pythium 2 - low inoculum	1.6	1.6.	1.4
Pythium 2 - high inoculum	1.0	1.2	0.6
P value (5 df)	0.781	0.627	0.190
S value[a]	2.47	3.48	7.46

[+] Pythium 1 - UK isolate; Pythium 2 - Danish isolate
[a] Friedmann's test.

Inoculation of field grown lettuce plants

In the work at HRI Stockbridge House, plants were harvested after 8 weeks and examined for bottom rots and signs of tissue discolouration. None of the plants examined displayed any sign of bottom rot or internal tissue discoloration. Attempts to re-isolate *P. tracheiphilum* from stem tissue all proved to be negative.

DISCUSSION

Botrytis

In the laboratory screening, Rovral gave complete inhibition of mycelial growth at 2 mg/litre, indicating that the set of *B. cinerea* isolates used for testing were sensitive to iprodione. Octave, which has an off-label recommendation for control of ring spot on lettuce and is known from previous experimental work to have activity against botrytis, also performed well in the laboratory test. The new fungicides, Unix (cyprodinil), which is recommended for control of botrytis on grapevine in France, and Scala (pyrimethanil), recommended for control of botrytis on blackcurrants and strawberries in the UK, gave only 50-67% inhibition at 2 mg/litre in the standard *in vitro* assay used in this study. It has recently been reported that a different *in vitro* method to the standard one used here is needed accurately to assess the sensitivity of *B. cinerea* to anilinopyrimidine fungicides such as cyprodinil and pyrimethanil. Similarly, although the two strobilurin fungicides gave only 48-49% inhibition of mycelial growth in the agar plate tests, previous field trials on other crops have demonstrated good activity by these fungicides against *B. cinerea* which is not well reflected in *in vitro* tests; for strobilurin fungicides, *in vivo* assays are reported to be the most accurate screening method.

Four DMI fungicides (Alto 100 SC, Folicur, Opus and Plover) strongly or completely inhibited mycelial growth at 2 mg/litre and a fifth (Systhane) gave partial suppression (56%) at this concentration. DMI fungicides are not generally regarded as good botrytis fungicides when used *in vivo*.

In the field trial at ADAS Arthur Rickwood in 1997, botrytis did not develop until late in the crop life, despite the presence of necrotic leaf tissue which is a common site for infection to start. This was probably because of the hot, dry weather experienced during August and early September. At harvest, botrytis was affecting parts of one or two lower leaves on most plants. Although differences in the botrytis disease index were not statistically significant, it was noticeable that Rovral Flo, Octave and Folicur, which all gave complete inhibition of mycelial growth in the laboratory tests, all had low disease indices (46.3, 48.1, 42.0) compared with the untreated (62.3) in the field trial.

Downy mildew severity at harvest was significantly reduced by the resistance elicitor (CGA 245704) and not by any other treatment. This product has previously been shown to elicit control of powdery mildew diseases in cereals. The failure of azoxystrobin and kresoxim-methyl to control downy mildew was surprising as these fungicides are reported to be active against downy mildew fungi. It is probable that the spray interval (14 days) was too long in a crop where the disease developed rapidly.

Although mean trimmed head weights were not significantly different, three treatments (Folicur, azoxystrobin and kresoxim-methyl) appeared to result in an increased head weight, possibly associated with control of botrytis and/or downy mildew. The resistance elicitor, which has been reported to cause phytotoxicity in some crops, resulted in the lowest head weight. This may have been due to a phytotoxic effect, although no obvious crop damage was observed following treatment with this product.

In the Cambridgeshire field trial in 1998, Rovral Flo appeared to give the best protection against infection by botrytis. Although at harvest infection was not reduced significantly, levels in the Rovral treatment were noticeably lower than in the untreated plots. This result complements laboratory studies conducted where Rovral gave complete inhibition of mycelial growth.

In the Lancashire field trial in 1998, the level of botrytis was relatively low. Only Amistar performed well with the other chemicals reducing the disease slightly. The dicarboximide fungicide, Rovral Flo, gave only a moderate suppression of the disease and this suggests that the population of *B. cinerea* may be somewhat tolerant to the fungicide. This again points to the need for alternative products with differing modes of action. In this respect, the results with Scala, A-P5353 and Folicur were somewhat disappointing. The better control with Amistar is considered to be as a result of an indirect effect. The downy mildew, which cases leaf damage allowing *B. cinerea* in secondarily, was well controlled by the fungicide and therefore plants were less predisposed to bottom-rots. The integrated programmes were not very effective in reducing the levels of downy mildew or *Botrytis* and in particular the 'full programme' was ineffective This suggests the spray interval is too long when botrytis and downy mildew treatments are alternated every 14 days, resulting in a specific botrytis or downy mildew treatment only every 28 days. Fungicide programmes based on products or mixtures with more broad - spectrum activity need to be considered.

Downy mildew

The *in vivo* preliminary 'bioassay' provided an effective means of selecting fungicides for their efficacy against this obligate parasite. Also, because young lettuce seedlings were used it was a useful method to determine whether any of the applied chemicals were phytotoxic at the dose rates used. Fortunately, no damage was observed.

In the initial screen Favour 600 SC was only partially effective and this suggested natural infection of metalaxyl-resistant variants as the original inoculum used (isolate 10/96) was metalaxyl-sensitive. Several of the 'novel chemistry' fungicides i.e. those with different modes of action to metalaxyl, provided a good suppression of the disease in the initial screen and therefore appeared to offer promise for the control of downy mildew where metalaxyl-resistance is present in the *Bremia* population. Interestingly, the dithiocarbamate fungicide, mancozeb, particularly where it was applied as a HV spray, was particularly effective. As a protectant fungicide however it is unlikely to afford effective protection where the disease is already established. Yet, as a 'multi-site' partner in mixture with other 'single-site' systemic fungicides (e.g. Trustan, Invader, Tattoo) it could prove effective in reducing the risk of resistance development.

Fungicides from several groups were selected for full field evaluation in autumn 1997. Products included multi-site protectant fungicides (e.g. mancozeb), mixtures of protectant, translaminar and systemic fungicides (e.g. Trustan) and novel fungicides with completely different modes of action (e.g. Amistar). Downy mildew developed to a moderate extent in the trial and significant differences in terms of both disease suppression and yield were recorded. Whilst infection levels in 1997 were insufficient to fully test the performance of fungicides, several products currently not available to growers of outdoor lettuce were identified which offer promise for improved disease control, particularly where metalaxyl-resistant strains are prevalent. These include Trustan, Invader, and Amistar.

In the Cambridgeshire field trial in 1998, results confirmed those obtained in the initial screening, with Amistar (disease index 18.8), Trustan (22.9) and Invader (28.1) all significantly reducing the severity of downy mildew compared with the untreated control (41.1).

In the Lancashire field trial in 1998, levels of downy mildew were high and provided an exceptionally stern test for the fungicides. Significant differences in both disease control and yield were recorded. Invader performed well throughout the trial in reducing levels of mildew when used either in alternation with Favour 600 SC in an integrated downy mildew programme or on its own. The incidence and severity of downy mildew on plants treated with metalaxyl strongly suggested that a metalaxyl-resistant strain of *B. lactucae* had occurred. This was subsequently confirmed. In effect, the only benefit of this product is the trial was to control the various metalaxyl-sensitive strains, which would have occurred on the cultivar Roxette. This new strain (1998A) was subsequently identified on lettuce plants in Lancashire, Norfolk, Yorkshire and Fife.

Pythium

Unfortunately, symptoms of butt rot were not evident on plants artificially inoculated with either of the two isolates of *Pythium tracheiphilum* used in this study, at either research centre. A *Pythium* sp. conforming to *P. tracheiphilum*, was however, consistently isolated from butt-rot affected plants in the Lancashire field site. Clearly, there is a need for further investigation of this disease in outdoor (and protected) lettuce.

CONCLUSIONS

1997

1. Five fungicides (Rovral, Octave, Folicur, Patrol and Plover) incorporated into agar at 2 mg/litre completely inhibited mycelial growth of *B. cinerea* recently isolated from lettuce.

2. Several novel fungicides (Trustan, Invader, Tattoo, and Amistar) with promising activity against downy mildew were identified in a preliminary *in vivo* bioassay.

3. Development of botrytis in an August-planted crop of cv. Saladin at ADAS Arthur Rickwood was slight, probably because of warm, dry weather.

4. Botrytis disease indices lower than that on untreated plants were recorded following application of Rovral WP, Octave, Folicur and Corbel.

5. An experimental product (resistance elicitor) significantly reduced downy mildew severity but also appeared to result in a reduced head weight.

6. Establishment of downy mildew in an August-planted crop of cv. Saladin at HRI Stockbridge House was good though subsequent disease progression was slow due to warm dry weather.

7. Several fungicides were effective in significantly reducing downy mildew. These were Trustan, Filex, Amistar, Invader, Mancozeb and the two integrated programmes.

8. Significant increases in head weight were recorded where downy mildew was well controlled in the trial at HRI, Stockbridge House. 38% yield increase was recorded where Trustan had been applied.

1998

1. Rovral significantly reduced a low incidence of botrytis in a field crop of cv. Saladin in Cambridgeshire.

2. Three fungicides (Amistar, Trustan and Invader) appeared to reduce the severity of downy mildew at harvest in this crop. Favour was ineffective.

3. There was a rapid establishment of downy mildew in cv. Roxette at the Lancashire field site, which reached a high level at the time of harvest providing a stern test for the experimental fungicides.

4. Three novel fungicides (Amistar, Trustan and Invader) and an integrated programme were effective at reducing downy mildew.

5. Significant increases in head weight (17% with Invader, 18% with the integrated mildew programme) were recorded where downy mildew was controlled.

6. Favour 600 SC was largely ineffective against downy mildew due to the presence of metalaxyl-resistant strain(s) of *Bremia lactucae* in the population.

7. Low - moderate levels of Botrytis were recorded. Only Amistar gave a marked reduction in the disease, and this was probably an indirect effect resulting from control of downy mildew.

8. A low incidence of *Sclerotinia* was recorded and there was limited evidence that Amistar reduced the disease. This supports results from other HDC funded projects (e.g. PC 131- Disease control in Protected Celery.)

9. No evidence of phytotoxicity was recorded following application of any of the experimental fungicides.

10. A high incidence of butt rot was experienced across the Lancashire field site in all of the treatments resulting in plant collapse. A *Pythium* sp. conforming to *P. tracheiphilum* was consistently isolated for the stem tissue.

11. At both research sites, isolates of *P. tracheiphilum* failed to cause wilting or butt rot when lettuce plants were challenged with the fungus.

ACKNOWLEDGEMENTS

Grateful thanks are given to Mr Roy Roberts, Len Wright Marketing Ltd, for acting as HDC Project Co-ordinator, and to both him and Mr Ian Hall, G's Fresh Salads, for provision of trial sites. This work was carried out with skilled assistance of Dr Andy Jackson, Miss F Pomares and Ms C Lambourne, HRI Stockbridge House; and of Mr Giles Budge, Mrs Jackie Town and Mrs Jo Fitzpatrick, ADAS Arthur Rickwood, and Mr J Lynn, Biometrics Department, HRI Wellesbourne and Mr D Wilson, Statistician, ADAS Cardiff.

REFERENCES

Blok I & van der Plaats-Niterink AJ (1978). *Pythium uncinulatum* sp. nov. and *P. tracheiphilum* pathogenic to lettuce. *Netherlands Journal of Plant Pathology* **84**, 135-147.

Reelder RD & Charbonnea F (1987). Incidence and severity of diseases caused by *Botrytis cinerea*, *Pythium tracheiphilum* and *Sclerotinia* spp. on lettuce in Quebec, 1985-1986. *Canadian Plant Disease Survey* **67**, 45-46.

Zinkernagel VV & Krober H (1978). A root rot and vascular disease of lettuce caused by *Pythium tracheiphilum* Matta. *Nachrichtenbl Deut. Pfbanzenschutzd*. **30**, 33-36.

ABBREVIATIONS

Figures 1 - 3

Unt	Untreated
Rov	Rovral Flo
Fav	Favour
Sca	Scale
5353	Experimental
Fol	Folicur
Ami	Amistar
Inv	Invader
Tru	Trustan
R/S/R	Rovral/Scala/Rovral
R/F/S	Rovral/Favour/Scala

Figures 4 - 6

Unt	Untreated
Rov	Rovral Flo
Fav	Favour
Sca	Scale
5353	Experimental
Fol	Folicur
Ami	Amistar
Inv	Invader
Tru	Trustan
F/I/F/I	Favour/Invader/Favour/Invader
R/F/S/I	Rovral/Favour/Scala/Invader

Fig 1. Control of lettuce botrytis - Cambs, 1998

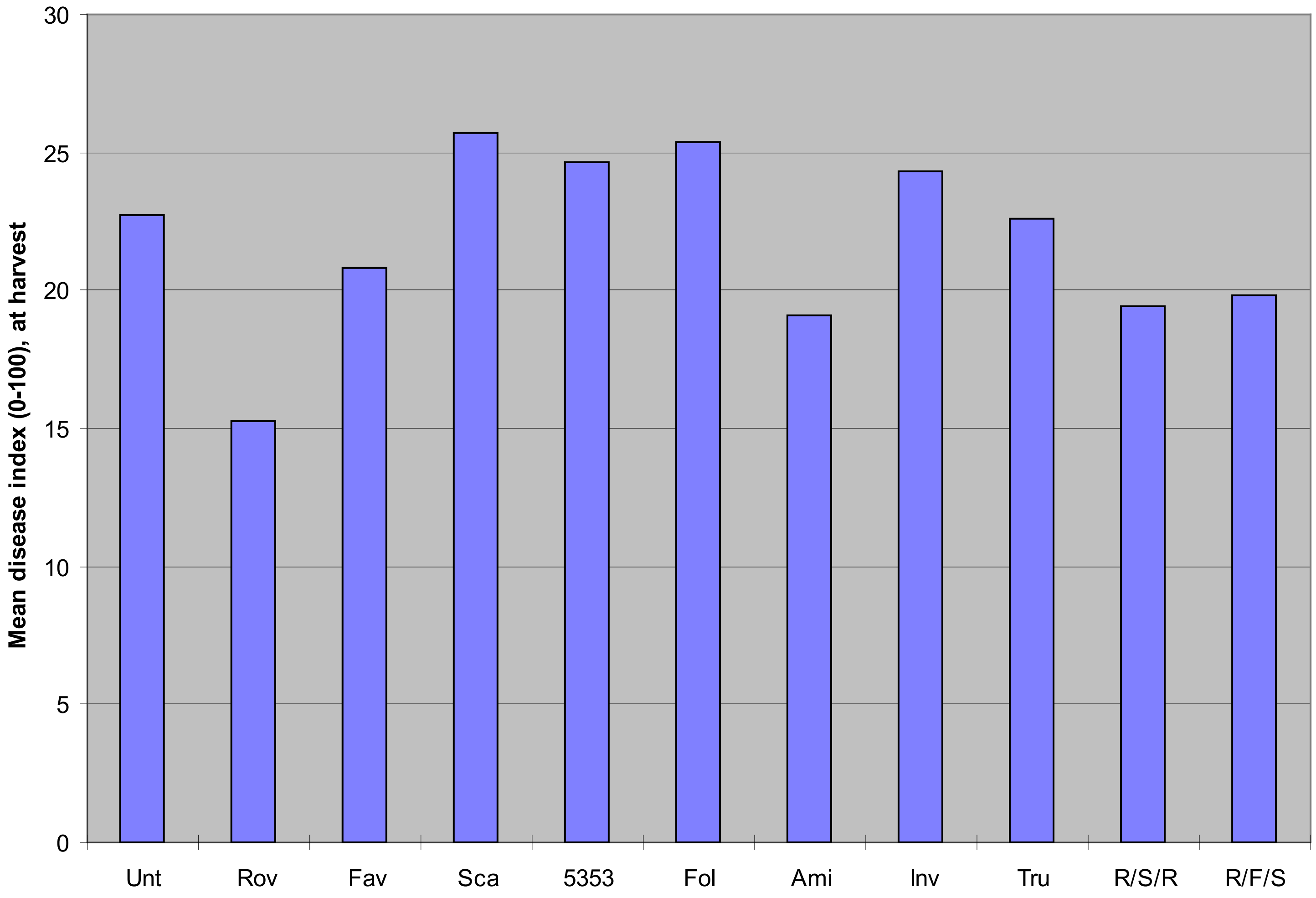

Fig 2. Control of lettuce downy mildew - Cambs, 1998

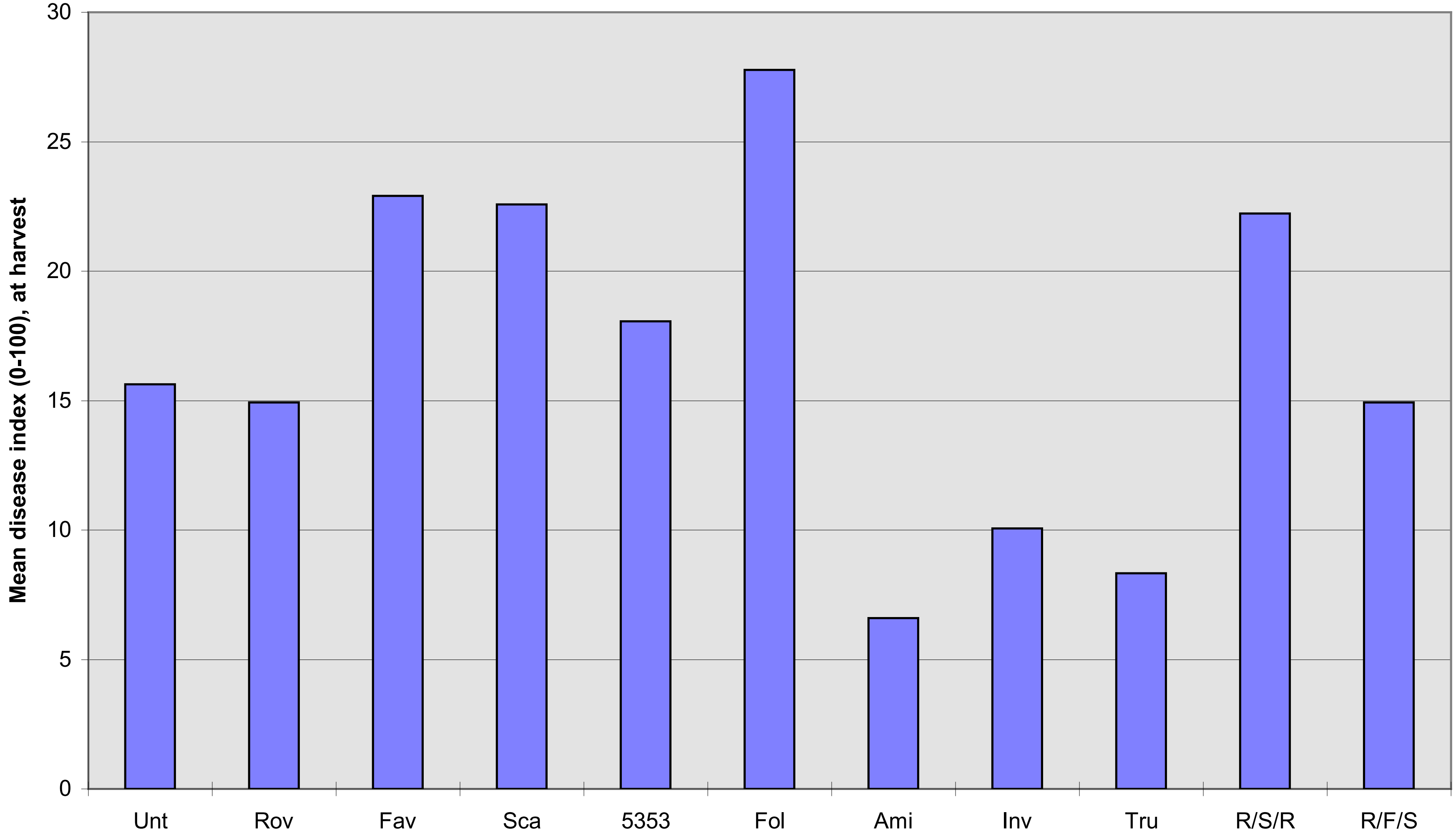

Fig 3. Effect of fungicide treatments on yield of marketable lettuce - Cambs, 1998

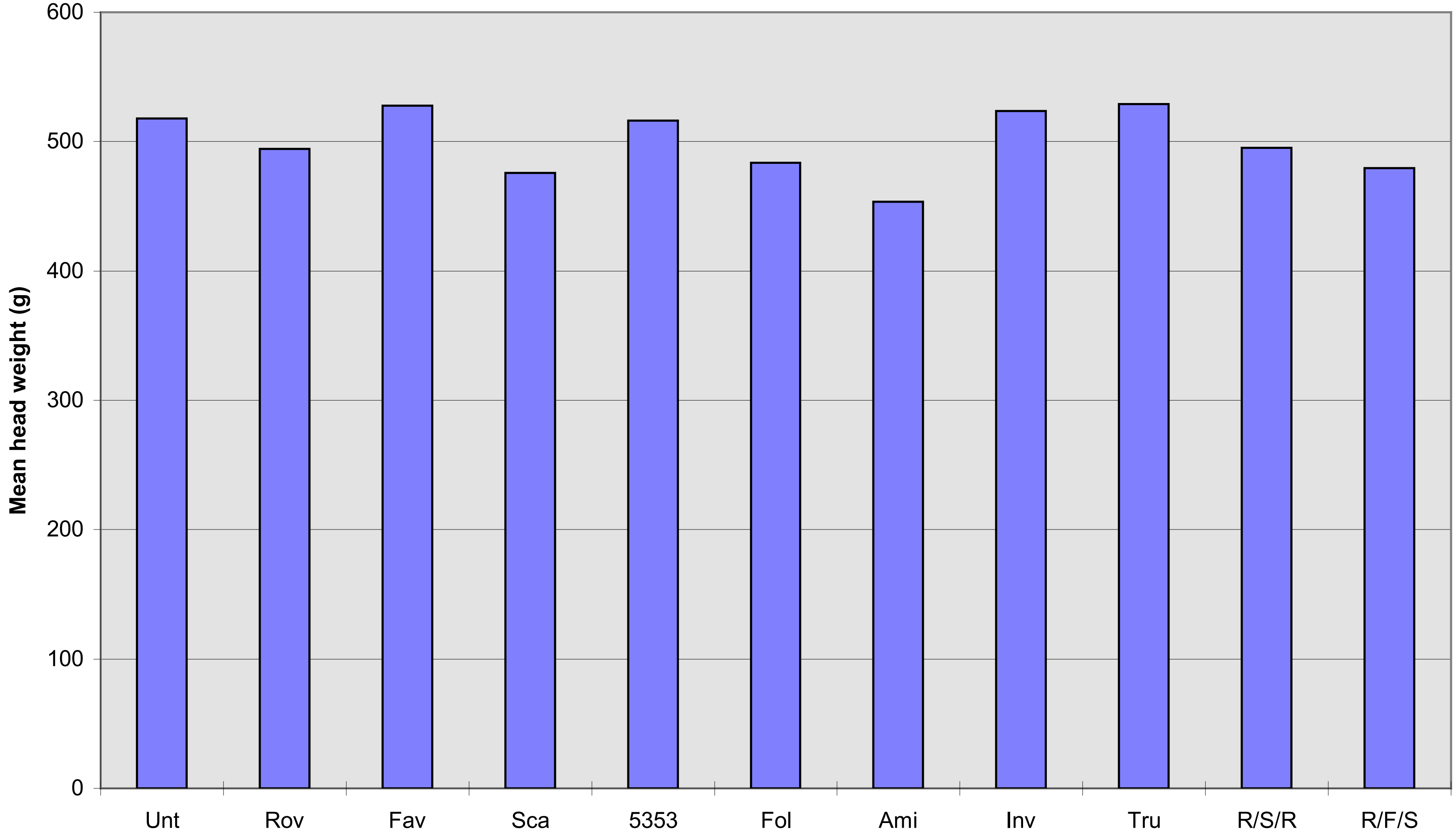

Fig 4. Control of lettuce botrytis - Lancs 1998

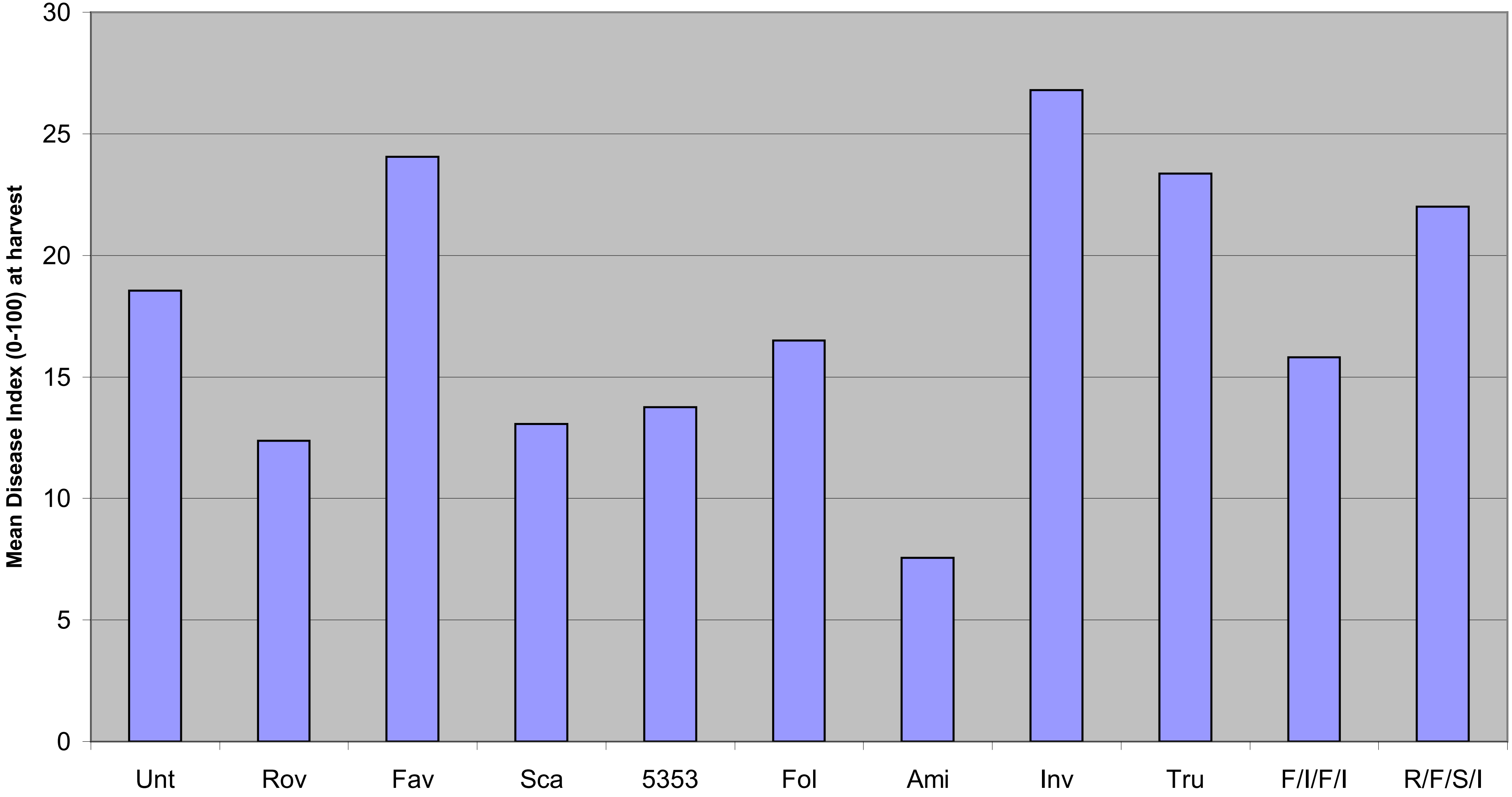

Fig 5. Control of lettuce downy mildew - Lancs 1998

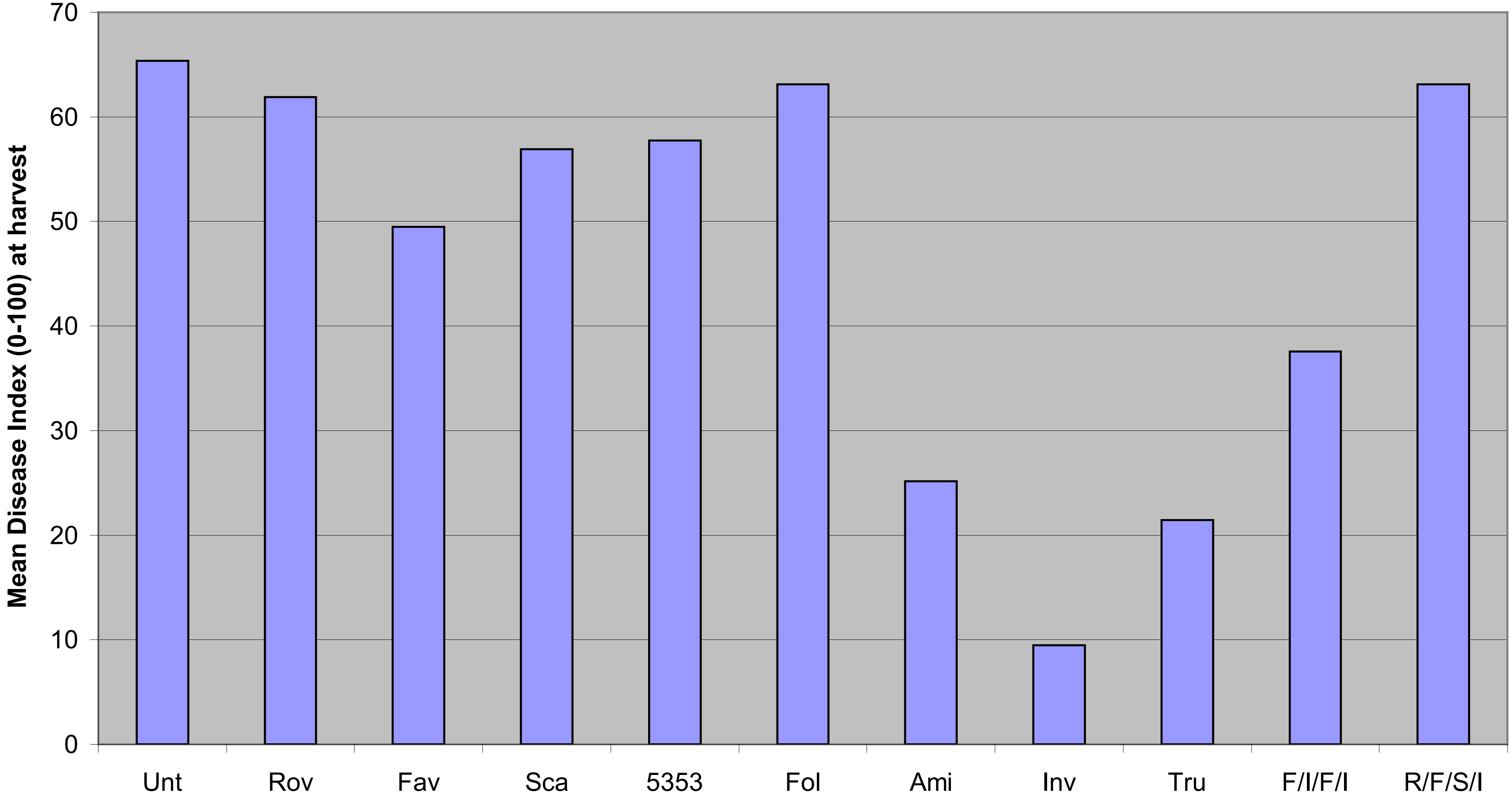

Fig 6. Effect of fungicide treatments on yield of marketable lettuce - Lancs 1998