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Blackberry: Control of downy mildew (*Peronospora rubi*) 1995-1997

(SF 39)

Angular, purple-coloured leaf spots, often bounded by the veins, are one of the most common symptoms of blackberry downy mildew (central leaf)

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PRACTICAL SECTION FOR GROWERS

Objectives and background

The objective of this project was to provide a strategy for providing effective and reliable control of downy mildew during propagation of blackberry plants.

In recent years outbreaks of downy mildew (*Peronospora rubi*) have occurred on blackberry and blackberry-red raspberry hybrids in the UK both on propagation nurseries and in fruiting plantations (McKeown, 1988; Wallis *et al.*, 1989). The disease is usually recognised by angular purple-red lesions on leaves, although primocanes, calyces, pedicels and fruit may also be affected and on highly susceptible varieties the fungus spreads systemically through most of the plant. On red raspberry the pathogen is restricted mainly to the leaves. In experimental work it was found that oospores (resting spores) of *P. rubi* developed abundantly in leaves of *Rubus* spp. inoculated *in vitro* (Williamson *et al.*, 1995). It is a potentially serious threat to the UK rubus industry because affected fruit may rapidly shrivel and harden or split. Several fruiting blackberry crops in Suffolk were severely affected by downy mildew in 1993 and in one, yield loss was estimated at 25%.

Summary of results

1995

Eleven fungicide treatments were evaluated in a micropropagated crop of cv. Loch Ness grown in a polythene tunnel with overhead irrigation. Natural infection with downy mildew occurred in the crop on 22 September, seven weeks after potting, and then increased rapidly over the next three months. By 23 November, 79 % of untreated plants were affected by downy mildew and symptoms were severe in many of them; by 20 December, 6 % of untreated plants had died.

All treatments reduced the incidence and severity of downy mildew at early assessments and six treatments gave good control through to 20 December. These were fortnightly sprays of Bravo, Favour, Fubol, Ripost Pepite and Shirlan and monthly drenches of Aliette. Four treatments (Aliette drench, Fubol, Favour and Ripost Pepite sprays) were particularly effective, reducing the incidence of plants with downy mildew from 79 % to 12, 14, 17 and 22 % respectively and the mean leaf area affected from 28 % to less than 2 %. Cuprokylt and two Aliette treatments (compost incorporation and root dip) failed to control downy mildew as the disease pressure increased.

When assessed in November 1995, plant growth was reduced by Aliette compost incorporation but not by other treatments. Cuprokylt resulted in leaf spotting after application of several sprays. Plant growth appeared to be improved by Favour, Filex, Ripost Pepite and Shirlan.

In a second experiment, the effect of different irrigation regimes on development of downy mildew was compared. The incidence of downy mildew was considerably less on plants grown with sub-irrigation (6%) than on plants watered from overhead (97%).

1996

Work in the second year continued the investigation into effective means of controlling downy mildew in micropropagated plants of cv. Loch Ness, with emphasis placed on developing a fungicide programme which minimised the risk of selecting fungicide-resistant strains. This involved alternation of different fungicides at 10-14 day intervals on young plants grown in a polythene tunnel with overhead irrigation. Downy mildew was not confirmed in this first trial. Nevertheless, all fungicide treatments improved plant growth as measured by leaf number and area of green leaf. An Aliette drench followed by alternating sprays of Ripost Pepite and Bravo was the most effective programme in improving plant growth.

In a second experiment, the effect of sub- and overhead irrigation on the development of downy mildew, in combination with a fungicide spray programme, was investigated. The fungicide programme consisted of an Aliette drench followed by Ripost Pepite, Favour and Bravo sprays in alternation every 10-14 days. Treatments were applied to young plants stood on sand beds outdoors.

Natural infection with downy mildew was first observed on 17 July and developed rapidly in subsequent weeks to cause extensive leaf damage. Irrigation regime had a marked effect on the incidence of downy mildew where no fungicides were used. By 2 August 40% of overhead-irrigated plants were affected, compared with 19.4% of sub-irrigated plants. This difference between irrigation regimes became less as the trial progressed and disease pressure increased. By 18 September, all plants were affected in each irrigation regime where no fungicides were applied for control of downy mildew. The severity of damage by downy mildew was also affected by irrigation regime. By 30 August, 16.8% of leaf area was affected on sub-irrigated plants compared with 35.8% on overhead irrigated plants. A difference between irrigation regimes was maintained until 14 October.

Application of the fungicide programme significantly reduced the incidence of plants with downy mildew. By 2 August, in overhead-irrigated plots, 40% of plants were affected by downy mildew where no fungicides had been applied, compared with 22% of plants where fungicides had been applied. The corresponding figures in sub-irrigated plots were 19.4% and 8.9%.

The efficacy of the fungicide spray programme was demonstrated more clearly by the disease severity data. Two weeks after downy mildew was first observed on overhead-irrigated plants, 8% of leaf area was affected by downy mildew compared with just 0.5% where plants were treated with fungicides. This difference became greater as the trial progressed, and by 14 October 67.5% leaf area was affected on unsprayed plants compared with 2.9% on sprayed plants. A similar difference between unsprayed and sprayed plants was evident in sub-irrigated plots.

No evidence was found to support the hypothesis that latent infection by downy mildew may be present in micropropagated plants arriving from overseas. Tayberry and tummelberry plants were potted and grown for 8 months in an isolated greenhouse, without fungicide treatment, and no symptoms or sporing of downy mildew were observed.

Action points for growers

1. The following fungicides have been shown to provide some control of blackberry downy mildew on young plants: Aliette, Bravo, Cuprokylt, Favour 600, Filex, Fubol 75, Ripost Pepite and Shirlan. High volume sprays of Favour, Fubol and Ripost Pepite and monthly drenches of Aliette, at the rates used, were particularly effective (Figs 1-3).

2. Use of products from different fungicide groups in a spray programme will reduce the risk of selection of fungicide-resistant strains of *P. sparsa*. The fungicide groups of products used in this work are:

Fungicide group	Products
Phenylamide-based mixtures	Favour 600*, Fubol 75*, Ripost Pepite*
Thiocarbamate	Filex
Phthalonitrile	Bravo
Copper	Cuprokylt
Diarylamine	Shirlan
Other	Aliette

   * These products are all mixtures of two or more fungicides, with each component active against downy mildew.

3. Cuprokylt and two of the Aliette treatments (root dip and compost incorporation) were partially effective early in the season but all failed to give disease control as disease pressure increased.

4. Cuprokylt caused leaf spotting and Aliette (compost incorporation), at the rate used, reduced plant growth.

5. All of the products listed above are permitted for use on blackberry plants during propagation, under the long term extension of use arrangements for nursery fruit crops (any fruit harvested within one year of treatment must be destroyed; no treatments may be applied if fruits are present). Cuprokylt and Bravo have label recommendations for use on fruiting crops.

6. Recent reports have indicated that for some people Shirlan is a potential skin sensitiser; this product is therefore not suitable for use where plants are moved and handled, such as on a propagation nursery.

7. Development of blackberry downy mildew is strongly promoted by leaf wetness. In the absence of fungicide treatment, disease incidence and severity can be reduced by growing plants with sub-irrigation rather than overhead-irrigation.

8. A programme consisting of an Aliette drench followed by Ripost Pepite, Favour and Bravo sprays in alternation every 10-14 days provided good control of downy mildew in a high disease-risk situation where the susceptible variety cv. Loch Ness was grown with overhead irrigation.

Practical and anticipated financial benefits

This work has clearly shown that blackberry downy mildew is strongly influenced by leaf wetness. Adoption of a sub-irrigation system will reduce disease risk and the need for intensive fungicide treatment. Benefits will include savings in the cost of fungicides and their application, a reduced risk of fungicide resistance occurring in *P. rubi* and increased opportunity to produce plants free of downy mildew.

This work has also identified fungicide products capable of providing effective control of downy mildew when conditions are favourable for disease development and demonstrated the efficacy of a programme of alternating products in a high disease-risk situation. Information on fungicide efficacy and fungicide groups is provided to enable growers to devise other effective programmes.

SCIENCE SECTION

INTRODUCTION

After a period of decline in the early 1980s, the area of blackberries in England and Wales is now steadily rising and in 1996/97 it was around 150 ha valued at £3.15 m. With the introduction of spine-free varieties (e.g. Loch Ness and Waldo), other new varieties with a high yield, large, attractive berries, extended harvest period or improved shelf-life, increasing production under protection, and increased demand from supermarkets and wholesalers, it appears likely that the area will continue to increase over the next few years. Unfortunately, some of the new varieties being planted at present (e.g. Loch Ness, Kotata) appear very susceptible to downy mildew, particularly in the propagation stage. The causal fungus is *Peronospora rubi*, believed to be conspecific with *Peronospora sparsa*, the cause of rose downy mildew (Breese *et al.*, 1994).

In the USA and New Zealand, systemic fungicides such as metalaxyl have provided good control of the disease (Tate & Van der Mespel, 1983). However, downy mildew fungi on some crops (e.g. lettuce) have rapidly developed resistance to metalaxyl (Crute, 1994). Recent experiments on control of rose downy mildew (O'Neill, 1994) identified a range of fungicides with good activity against *P. sparsa*. The objective of the work described here was to evaluate fungicides for control of downy mildew in young blackberry plants.

MATERIAL AND METHODS

Crop details

Micropropagated blackberry plants, cv. Loch Ness, were grown in an unheated polythene tunnel with overhead irrigation, (Experiments 1 and 3) or on sandbeds outside (Experiment 4), or both outside and in a polythene tunnel (Experiment 2), on a nursery in Norfolk. The plants originated from Romania. In 1995 plants were potted in 7 cm pots on 4 August one day after arriving on the nursery; plants were re-potted on 26 September into 2 litre pots. In 1996 plants in 2 litre pots were used. In 1996, 15 microplanted plants each of tayberry and tummelberry were potted and grown in isolation in a glasshouse at ADAS Arthur Rickwood; no fungicides were applied to these plants.

Treatments

Experiment 1. Comparison of fungicide products (1995)

1. Water (control)
2. Aliette WP (80% fosetyl aluminium) at 5g/litre
3. Bravo 500 (50% chlorothalonil) at 2.2 ml/litre
4. Cuprokylt (50% copper oxychloride) at 5 g/litre
5. Favour 600 SC (10% thiram + 50% metalaxyl) at 3 ml/litre
6. Filex (72% propamocarb hydrochloride) at 1.5 ml/litre
7. Fubol 75 WP (67.5 % mancozeb + 7.5 % metalaxyl) at 2 g/litre
8. Ripost Pepite (3.2% cymoxanil + 56% mancozeb + 8% oxadixyl) at 2.5 g/litre
9. Shirlan (50% fluazinam) at 1 ml/litre
10. Aliette - pre-planting root dip (3.75 g/litre) + sprays (5 g/litre)

11. Aliette - compost incorporation (0.9 g/litre of compost)
12. Aliette - monthly drench (1 g/litre)

Spray treatments were applied as high volume sprays to the point of run-off (150 ml/m^2) at 14 day intervals from 22 August to 10 November (8 sprays in total). Drench treatments were applied monthly at 50 ml/plant (4 in total). The root dip (treatment 10) was followed by sprays at 14 day intervals after potting. For treatment 11, Aliette was incorporated both in the initial compost and at re-potting (26 September).

Experiment 2. Comparison of irrigation regimes (1995)

1. Plants grown outside with overhead irrigation
2. Plants grown in a polythene tunnel with overhead irrigation
3. Plants grown in a polythene tunnel on a sand bed

No fungicides were applied for control of downy mildew.

Experiment 3. Evaluation of fungicide programmes (1996)

1. Untreated (no sprays)
2. Aliette drench monthly (1 g/litre)
3. Ripost Pepite (2.5 g/l) and Bravo (2.2 ml/l) sprays alternating every 10 to 14 days
4. Favour 600 SC (3 ml/l) and Bravo sprays alternating every 10 to 14 days
5. Aliette drench (x1), then Ripost and Bravo sprays alternating every 10 to 14 days
6. Aliette drench (x1), then Favour and Bravo sprays alternating every 10 to 14 days
7. Aliette drench (x1), then Ripost, Favour and Bravo sprays alternating every 10-14 days
8. Aliette drench (x1), then no sprays until the disease is first seen. Then immediately spray Ripost and Favour alternating every 10-14 days.
9. No treatment until downy mildew is first seen. Then immediately spray Ripost and Favour alternating every 10-14 days.

Rates for treatments 5-8 were as specified for each product and the relevant application method in treatments 2-4. Sprays were applied at high volume to the point of run-off (150 ml/m^2); drenches were applied at 50 ml/plant. Where spray treatments followed an Aliette drench, the first spray was applied 28 days after the Aliette drench (except treatment 8). Ten blackberry plants severely affected by downy mildew (infector plants) were placed along pathways between replicate blocks on 14 October 1996.

Experiment 4. Effectiveness of a fungicide programme under two irrigation regimes (1996)

	Irrigation	Fungicide
1.	Overhead sprinkler	Nil
2.	Sand bed	Nil
3.	Overhead sprinker	Programme
4.	Sand bed	Programme

The fungicide programme consisted of an Aliette drench (1 g/litre, 50 ml/plant) followed by Ripost Pepite (2.5 g/litre), Favour (3 ml/litre) and Bravo (2.2 ml/litre) sprays alternating every 10-14 days .

Disease assessments

In 1995, plants were assessed for incidence of plants affected by downy mildew at 7 to 14 day intervals to 23 November, and then at 28 day intervals. Disease severity was assessed as % leaf area affected on 5 October, 13 October, 27 October, 10 November and 23 November. The causal fungus, *Peronospora rubi*, was confirmed by microscopic examination of a sample of leaves showing symptoms typical of downy mildew.

In 1996/1997 plants were examined for disease every 14 days from 2 August through to 10 December and then at monthy intervals to 23 January (Experiment 3). In Experiment 4, plants were assessed for disease incidence 28 days after the first treatment, and then at 14 day intervals. Disease severity was assessed as % leaf area affected on 16 August, 30 August, 18 September and 14 October. Micropropagated plants grown on at ADAS Arthur Rickwood were examined for symptoms of downy mildew every 2 weeks from July 1996 to March 1997.

Crop growth

In 1995, crop growth was assessed as a vigour index (0-5) on 23 September and 5 October, and as % area of pot surface covered by plant growth on four subsequent occasions.

In 1996/1997, crop growth in Experiment 3 was assessed by recording the number of green leaves per stem and the % plot area covered by green leaves on two occasions (22 November and 23 January). Crop growth in Experiment 4 was also asssessed as a vigour index (0-3) on 2, 16 and 30 August.

Crop diary

The dates of fungicide treatment are listed below:

1995		1996	
Experiment 1		Experiment 3	Experiment 4
Sprays	**Drenches**	**Treatments**	**Treatments**
4 Aug	4 Aug	12 Aug	5 July
18 Sep	1 Sep	22 Aug	26 July
1 Sep	29 Sep	2 Sept	14 Aug
14 Oct	27 Oct	18 Sept	30 Aug
29 Sep		30 Sept	10 Sept
13 Oct		14 Oct	18 Sept
27 Oct		24 Oct	30 Sept
10 Nov		7 Nov	14 Oct
		22 Nov	
		10 Dec	

Experimental design and analysis

Experiment 1 (1995)
The experiment was set up as a randomised block design with four blocks. There were four replicates of each treatment except for the untreated control, where there were eight replicates. There were 20 plants per plot, placed pot tight, and a gap of one metre was left between adjacent plots.

Experiment 2 (1995)
Groups of 50 plants were grown pot-tight and no fungicides were applied for control of downy mildew.

Experiment 3 (1996)
The experiment was set up as a randomised block design with four blocks. There was fourfold replication of each treatment. Each plot consisted of 25 plants placed pot tight in a 5x5 arrangement.

Experiment 4 (1996)
Treatments 1 and 3 were arranged in one area (with overhead irrigation) and treatments 2 and 4 in an adjacent area (with sub-irrigation). There was sixfold replication of each treatment. Treatments 1 and 3, and 2 and 4, were randomised within blocks. Each plot consisted of 40 plants.

Results from Experiments 1 and 3 were analysed by analysis of variance, after appropriate transformation of data where necessary. Results from Experiments 2 and 4 are presented as treatment comparisons.

RESULTS

Experiment 1. Comparison of fungicide products (1995)

Disease development

Downy mildew was first confirmed on 22 September 1995, 7 weeks after the experiment commenced. The disease then increased rapidly and by 23 November 79 % of untreated plants were affected. All treatments gave some reduction in the incidence and severity of downy mildew up to 13 October (Figs 1 & 2; Table 1) but only six treatments gave disease control through to 20 December, six weeks after the final spray. These were fortnightly sprays of Bravo, Favour 600, Fubol 75, Ripost Pepite and Shirlan and monthly drenches of Aliette. Four treatments (Aliette drench, Fubol 75, Favour 600 and Ripost Pepite) were particularly effective, reducing the incidence of plants with downy mildew from 79 % to 12, 14, 17 and 22 % respectively and the mean leaf area affected from 28 % to less than 2 % (Fig 3 and Table 1).

Cuprokylt and two of the Aliette treatments (compost incorporation and root dip) failed to control downy mildew as the disease pressure increased. At the final assessment on 20 December, severe downy mildew had resulted in plant death in untreated plants (6 %), Aliette sprays (2 %), Aliette compost incorporation (5 %) and Cuprokylt (12 %) (Table 2).

Disease progress in treatments 2 (Aliette sprays) and 10 (root dip + Aliette sprays) was very similar (Fig 2), indicating that an initial root dip in Aliette gave no additional control to that achieved by a series of sprays. The Aliette spray and drench treatments both resulted in an application dose of approximately 50 mg/plant/month (Table 3) but the drench treatment was considerably the more effective (Fig 2). Incorporation of Aliette in compost (approx. 300 ml in a 7 cm pot resulting in a dose of 270 mg/plant) gave control intermediate between that of the spray and drench treatments; however, the high rate was phytotoxic and reduced plant growth. The efficacy of Aliette when used as a compost incorporant declined sharply from 27 October approximately one month after treatment at re-potting (Fig 2).

Crop growth

When assessed in November 1995, plant growth was reduced by Aliette compost incorporation and not by other treatments. Cuprokylt resulted in leaf spotting after application of several sprays. Plant vigour appeared to be improved by Favour, Filex, Ripost Pepite and Shirlan (Fig 3 and Table 4).

Experiment 2. Comparison of irrigation regimes (1995)

Plants grown on a sand bed in a polythene tunnel developed a very low incidence of downy mildew (6.3 %) compared to plants grown outside with overhead irrigation (100 %), or in a polythene tunnel with overhead irrigation (97 %) (Fig 4 and Table 5).

Experiment 3. Evaluation of fungicide programmes (1996-1997)

Leaf blotches typical of downy mildew were observed on 30 August, although *P. rubi* was not confirmed. The disease failed to develop further despite the use of overhead irrigation and the introduction of additional plants affected by downy mildew into the trial area. Nevertheless, fungicide treatments significantly improved plant growth (Table 6). When assessed on 22 November, all plants treated with fungicides had a greater number of green leaves than untreated plants; Aliette drench followed by Ripost Pepite and Bravo sprays was most effective. When assessed on 23 January, all treatments had increased the % plot area covered by green leaves and again Aliette drench followed by Ripost Pepite and Bravo sprays was the most effective, increasing the plot area covered by green leaf from 44.5 to 81.3% (Fig 6).

Experiment 4. Effectiveness of a fungicide programme under two irrigation regimes (1996)

Downy mildew was first observed on 17 July, two weeks after establishing the trial. The disease then developed rapidly to cause extensive leaf damage by late August. Both the method of irrigation and the fungicide programme influenced the rate of disease development, with fungicide treatment having the greater effect.

In the absence of fungicides, the incidence of affected plants on 2 August was greater with overhead irrigation (40%) than with sub-irrigation (19.4%) (Table 7). On 18 September, the severity of downy mildew was greater on plants irrigated from overhead (41.2%) compared with plants irrigated from below (18.5%) (Table 8). However, by 14 October all plants not treated with fungicide were affected by downy mildew, and there was no difference in disease severity between the two irrigation regimes, with plants in both regimes severely affected (Table 8).

The fungicide programme markedly reduced development of downy mildew under both irrigation regimes. It delayed the rapid increase in number of affected plants by approximately 2 weeks (Fig. 7) and, more importantly, the leaf area affected by downy mildew was maintained at less than 5% through to the end of the experiment (14 October) (Fig. 8). Over 65% of leaf area was affected by downy mildew on plants not treated with the programme of fungicides (Table 8). The beneficial effect of fungicide treatment was also evident in the plant vigour assessment (Table 9).

Occurrence of latent downy mildew in micropropagated plants

No symptoms or sporing of downy mildew developed on micropropagated plants of tayberry and tummelberry grown for 8 months in isolation from other *Rubus* spp.

DISCUSSION

1995

Although none of the fungicide treatments in Experiment 1 gave complete control of blackberry downy mildew, high volume sprays of Bravo, Favour, Fubol, Ripost Pepite and Shirlan applied every 14 days provided some control in a highly susceptible variety grown under conditions favourable to development of the disease. The results with Favour, Ripost and Shirlan are in agreement with studies on control of *P. sparsa* on rose (O'Neill, 1994). Shirlan is unsuitable for use where crops are likely to be handled because of reports that some people may develop an allergic contact dermatitis from the active ingredient fluazinam (Ginkel & Sabapathy, 1995).

Interestingly, high volume sprays of Aliette gave relatively poor control of blackberry downy mildew and yet this fungicide was effective against rose downy mildew. The application rate on roses (5 g/litre) was the same as that used as a spray treatment (5 g/litre)in this work on blackberries. Aliette did control blackberry downy mildew effectively when applied as a monthly drench on micropropagated plants, and for a limited period when used as a compost incorporant.

Of the nine fungicides evaluated, Bravo 500 and Cuprokylt currently have approval for use on cane fruit. In this experiment Bravo gave better control than Cuprokylt and also had no obvious phytotoxic symptoms, a problem that became evident with increasing number of applications of latter fungicide.

Experiment 2, comparing irrigation regimes, demonstrated very clearly that blackberry downy mildew is strongly promoted by leaf wetness, as has been found with other downy mildew diseases (Morgan, 1984). This probably reflects the need for a prolonged period of leaf wetness (approx. 6-9 hours) required for downy mildew dispersal spores (conidia) to germinate and infect when they land on leaves.

1996

Although downy mildew was not confirmed in Experiment 3, it is interesting that all fungicide treatments improved plant growth. Possibly this may be a direct effect of fungicides on plant growth, an effect which has been reported with some fungicides on other crops. Alternatively, it is possible that plants were infected systemically by downy mildew, resulting in poor plant growth (but no obvious leaf lesions), and the fungicide treatments controlled this infection. It is reported that young blackberry plants may carry downy mildew without showing the usual angular lesions on leaves (Wallis *et al.*, 1989). Further work is needed to clarify the reason for improved growth from fungicide treatment in the apparent absence of downy mildew.

Experiment 4 confirmed that development of blackberry downy mildew is favoured by leaf wetness. In the absence of any fungicide treatment, irrigation during the summer from a sandbed rather than overhead sprinkler reduced disease severity by approximately 50%, through to 18 September. The subsequent increase in downy mildew was probably associated with rain in September and October. There were 4 days and 13 days with rainfall greater than 1.0 mm in September and October respectively. It should be possible to achieve greater and more persistent control of downy mildew by the use of sub-irrigation, rather than overhead irrigation, for blackberry crops grown under protection. The fungicide programme proved very effective for control of downy mildew under both methods of irrigation.

CONCLUSIONS

1995

1. Micropropagated plants of cv. Loch Ness grown in an unheated polythene tunnel with overhead irrigation became infected with downy mildew seven weeks after potting.

2. The disease increased rapidly on untreated plants and 2 months after it first occurred 79 % of plants were affected, some severely, and 6 % had died.

3. All fungicide treatments reduced the incidence and severity of downy mildew at early assessments and six gave good control through to the end of the experiment. These were These were fortnightly sprays of Bravo, Favour, Fubol, Ripost Pepite and Shirlan and monthly drenches of Aliette.

4. Four treatments (Aliette drench, Fubol, Favour and Ripost Pepite) were particularly effective, reducing the incidence of plants with downy mildew from 79 % to 12, 14, 17 and 22 % respectively and the mean leaf area affected from 28 % to less than 2 %.

5. Cuprokylt and two of the Aliette treatments (compost incorporation and root dip) failed to control downy mildew as the disease pressure increased.

6. Plant growth was reduced by Aliette compost incorporation and not by other treatments. Cuprokylt resulted in leaf spotting after application of several sprays.

7. Plants grown on a sand bed in a polythene tunnel developed a very low incidence of downy mildew (6.3 %) compared to plants grown outside with overhead irrigation (100 %), or in a polythene tunnel with overhead irrigation (97 %).

1996

1. Seven fungicide programmes improved growth of container-grown protected blackberry plants in a crop where downy mildewws not confirmed. A programme of one Aliette drench followed by alternating sprays of Ripost Pepite and Bravo was most effective.

2. Irrigation of plants from a sandbed rather than by overhead sprinker reduced the incidence and severity of downy mildew. The effect on disease severity was greater than that on disease incidence.

3. A fungicide programme consisting of one Aliette drench, followed by sprays of Ripost Pepite, Favour and Bravo in alternation at 10-14 day intervals, gave very good control of downy mildew on plants grown with overhead irrigation.

4. No evidence was found of latent infection in micropropagated plants arriving from overseas. No downy mildew developed on tayberry and tummelberry plants grown for 8 months in an isolated glasshouse.

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Table 1. Effect of fungicides on incidence and severity of blackberry plants affected by downy mildew - Experiment 1, 1995

Treatment	Mean % plants affected			Mean % leaf area affected
	27 Sept	13 Oct	27 Oct	20 Dec
1. Water	35.1 (1.41)	60.1 (1.74)	61.2 (1.77)	27.8 (1.39)
2. Aliette	19.9 (1.01)	34.9 (1.42)	40.1 (1.56)	9.3 (0.96)
3. Bravo	6.8 (0.88)	18.3 (1.23)	30.9 (1.40)	3.4 (0.62)
4. Cuprokylt	19.8 (1.29)	42.9 (1.57)	59.7 (1.73)	50.0 (1.59)
5. Favour 600	5.8 (0.83)	15.0 (1.15)	15.0 (1.15)	1.7 (0.32)
6. Filex	11.6 (0.91)	35.9 (1.49)	44.0 (1.61)	5.6 (0.75)
7. Fubol	1.3 (0.20)	12.4 (0.88)	10.5 (0.84)	2.4 (0.50)
8. Ripost Pepite	9.0 (0.83)	13.0 (1.12)	17.1 (1.20)	1.0 (0.30)
9. Shirlan	4.3 (0.62)	8.2 (0.95)	13.7 (1.06)	1.7 (0.38)
10. Aliette-dip	21.0 (1.21)	30.6 (1.46)	40.7 (1.58)	21.0 (1.13)
11. Aliette-compost	3.9 (0.31)	13.4 (0.64)	27.8 (1.29)	40.0 (1.53)
12. Aliette-drench	3.7 (0.46)	6.4 (0.70)	5.8 (0.33)	1.9 (0.45)
Significance (33 df)	(**)	(***)	(***)	(***)
SED control vs treatment	(0.283)	(0.220)	(0.202)	(0.176)
between treatments	(0.326)	(0.254)	(0.233)	(0.203)

Angular transformed values are shown in brackets
** significant difference at P<0.01
*** significant difference at P<0.001

Table 2. Effect of fungicides on the incidence of dead plants - Experiment 1, 1995

Treatment	Mean % dead plants	
	3 Nov	20 Dec
1. Water	0	5.6
2. Aliette	2.5	2.5
3. Bravo	0	0
4. Cuprokylt	3.9	11.6
5. Favour 600	0	0
6. Filex	0	0
7. Fubol 75	0	0
8. Ripost Pepite	0	0
9. Shirlan	0	0
10. Aliette-dip	0	0
11. Aliette-compost	0	5.3
12. Aliette drench	0	0

Table 3. Comparison of Aliette application rates and control of downy mildew - Experiment 1, 1995

Treatment	Rate (g/litre)	Application volume (ml)	Dose/plant (mg)	% plants affected 27 Oct
Untreated	-	-	0	61.2
Aliette spray	5	5	25	40.1
Aliette (dip) + sprays	(3.75) + 5	5	25	40.7
Aliette in compost	0.9	300	270	27.8
Aliette drench	1.0	50	50	5.0

Table 4. Effects of fungicides on growth of blackberry plants, cv. Loch Ness - Experiment 1, 1995

Treatment	% vigour (0-5)		Pot cover (%)			
	23 Sept	5 Oct	13 Oct		27 Oct	
1. Water	2.5	2.6	55.6	(1.75)	61.9	(1.79)
2. Aliette	2.0	2.5	60.0	(1.78)	65.0	(1.82)
3. Bravo	3.0	3.5	66.2	(1.83)	70.0	(1.85)
4. Cuprokylt	2.8	2.8	57.5	(1.77)	58.8	(1.77)
5. Favour 600	3.5	4.0	71.2	(1.86)	73.8	(1.87)
6. Filex	3.0	3.5	70.0	(1.85)	75.0	(1.88)
7. Fubol 75	3.0	3.0	61.2	(1.79)	70.0	(1.85)
8. Ripost Pepite	3.3	3.5	70.0	(1.85)	75.0	(1.88)
9. Shirlan	3.8	3.8	76.2	(1.89)	76.3	(1.89)
10. Aliette-dip	3.8	3.8	67.5	(1.83)	72.5	(1.87)
11. Aliette-compost	1.3	1.8	46.2	(1.65)	55.0	(1.74)
12. Aliette-drench	3.3	2.8	66.2	(1.83)	68.8	(1.84)
Significance (33 df)	-	-		(**)		(***)
SED control vs treatments	-	-		(0.432)		(0.285)
between treatments				(0.499)		(0.329)

Transformed values (angular transformation) are shown in brackets
** significant difference at P<0.01
*** significant difference at P<0.001

Table 5. Effect of protection and irrigation on incidence of blackberry pplants (cv. Loch Ness) affected by downy mildew - Experiment 2, 1995.

Treatment		Mean % plants affected						
Location	Irrigation	15 Sept	22 Sept	29 Sept	5 Oct	3 Nov	23 Nov	20 Dec
1. Outside	Overhead	0	14.3	23.8	47.6	95.0	100	100
2. Tunnel	Overhead	0	3.9	35.1	47.4	73.9	79.8	97.1
3. Tunnel	Sub-irrigation	0	0	0	0	6.3	6.3	6.3

Table 6. Effect of fungicide treatments on blackberry plant growth - Experiment 3, 1996

Treatment	No. green leaves / stem (22 November)	% plot area covered by green leaf (23 January)
1. Untreated	2.1	44.5
2. Aliette drench monthly	3.0	67.6
3. Ripost Pepite and Bravo	3.3	76.3
4. Favour 600 SC and Bravo	2.9	66.3
5. Aliette drench, then Ripost and Bravo	3.4	81.3
6. Aliette drench, then Favour and Bravo	2.9	66.8
7. Aliette drench, then Ripost, Favour and Bravo	3.3	78.8
8. Aliette drench, then no sprays until mildew found	2.7	58.0
9. Ripost and Favour when mildew found	2.3	51.8
Significance (df 24)	***	***
SED	0.15	3.87
SEM	0.10	2.73

*** Significant difference at P<0.001

Table 7. Effect of irrigation and fungicide sprays on incidence of blackberry plants affected by downy mildew - Experiment 4, 1996

Treatment		Mean % plants affected				
Fungicides	Irrigation	2 Aug	16 Aug	30 Aug	18 Sept	14 Oct
1. No	Overhead	40.0	99.4	100	100	-
2. No	Sub-irrigation	19.4	84.4	99.4	100	-
3. Yes	Overhead	22.2	24.4	69.4	72.8	-
4. Yes	Sub-irrigation	8.9	18.3	91.1	95	-

Table 8. Effect of irrigation and fungicide sprays on severity of blackberry plants downy mildew - Experiment 4, 1996.

Treatment		Mean % leaf area affected				
Fungicides	Irrigation	2 Aug	16 Aug	30 Aug	18 Sept	14 Oct
1. No	Overhead	-	8.0	35.8	41.2	67.5
2. No	Sub-irrigation	-	6.2	16.8	18.5	68.3
3. Yes	Overhead	-	0.5	3.5	4.7	2.9
4. Yes	Sub-irrigation	-	0.8	4.0	4.8	2.8

Table 9. Effect of irrigation and fungicide sprays on blackberry plant vigour - Experiment 4, 1996

Treatment		Vigour index (0-3)				
Fungicides	Irrigation	2 Aug	16 Aug	30 Aug	18 Sept	14 Oct
1. No	Overhead	1.7	1.5	1.0	-	-
2. No	Sub-irrigation	2.3	2.2	1.7	-	-
3. Yes	Overhead	1.8	2.8	2.5	-	-
4. Yes	Sub-irrigation	2.7	3.0	3.0	-	-

Fig. 1 Effect of fungicide sprays on blackberry downy mildew - Norfolk 1995

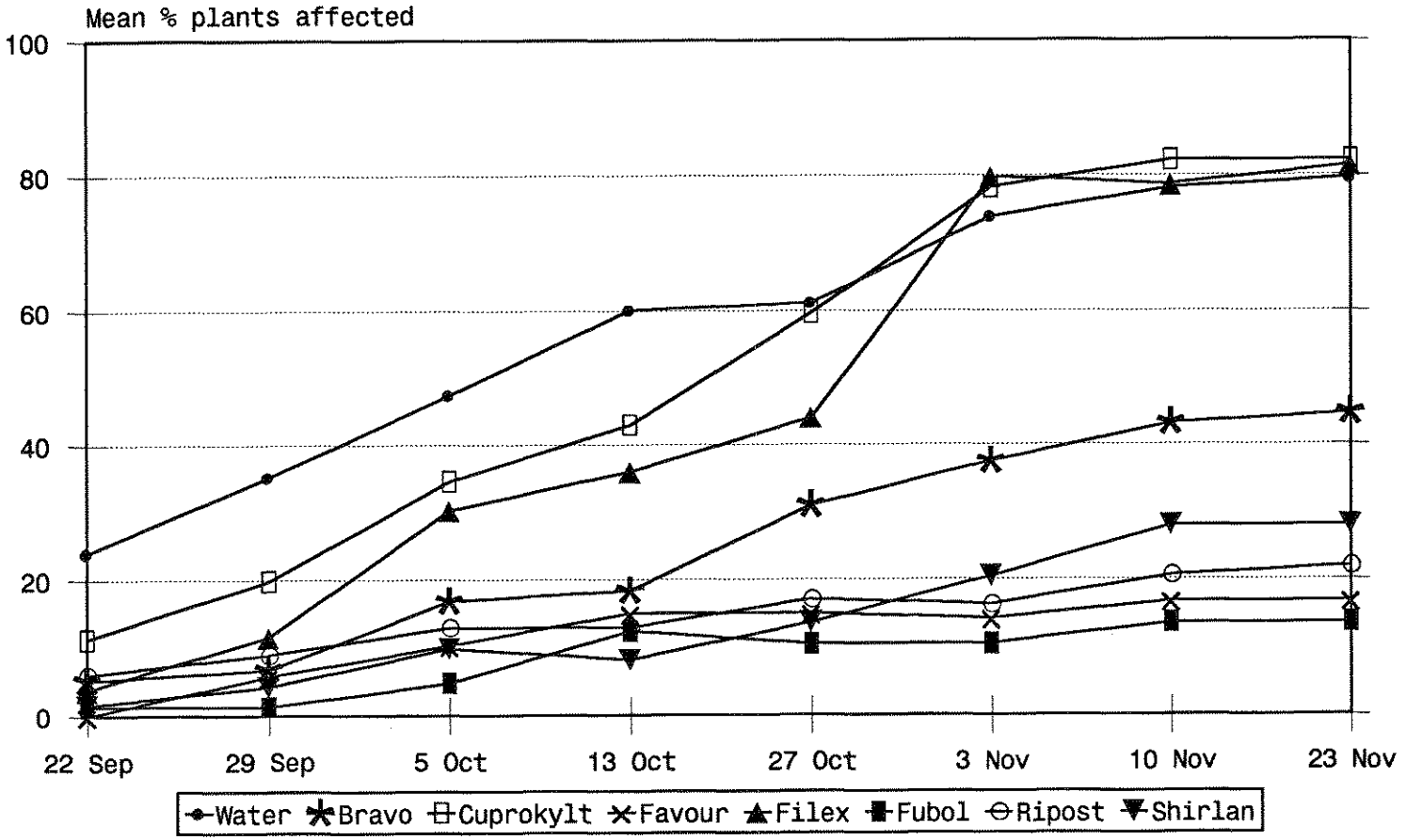


Fig 2. Effect of Aliette treatments on blackberry downy mildew - Norfolk 1995

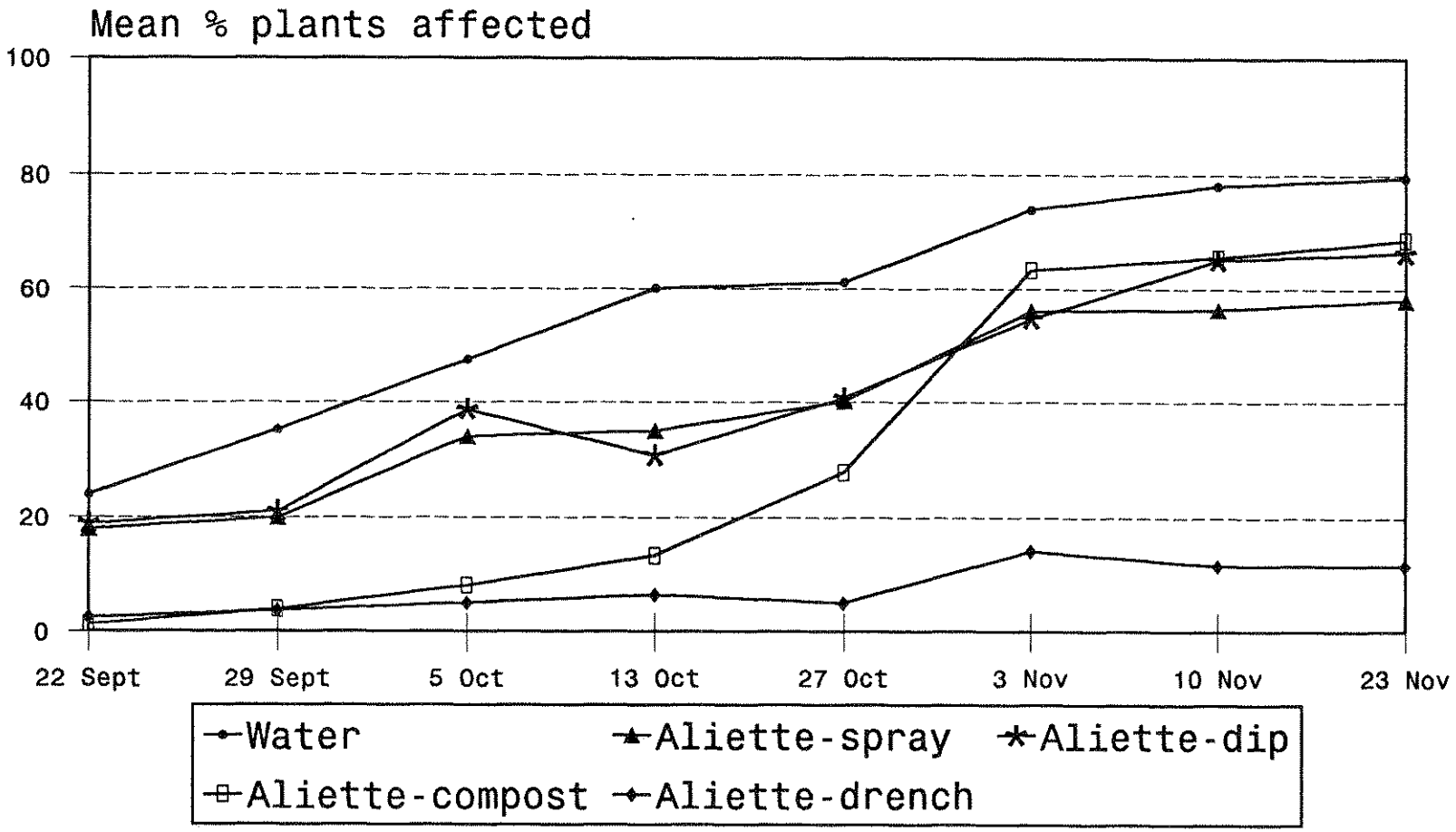


Fig 3. Effect of fungicides on severity of blackberry downy mildew - Norfolk 1995

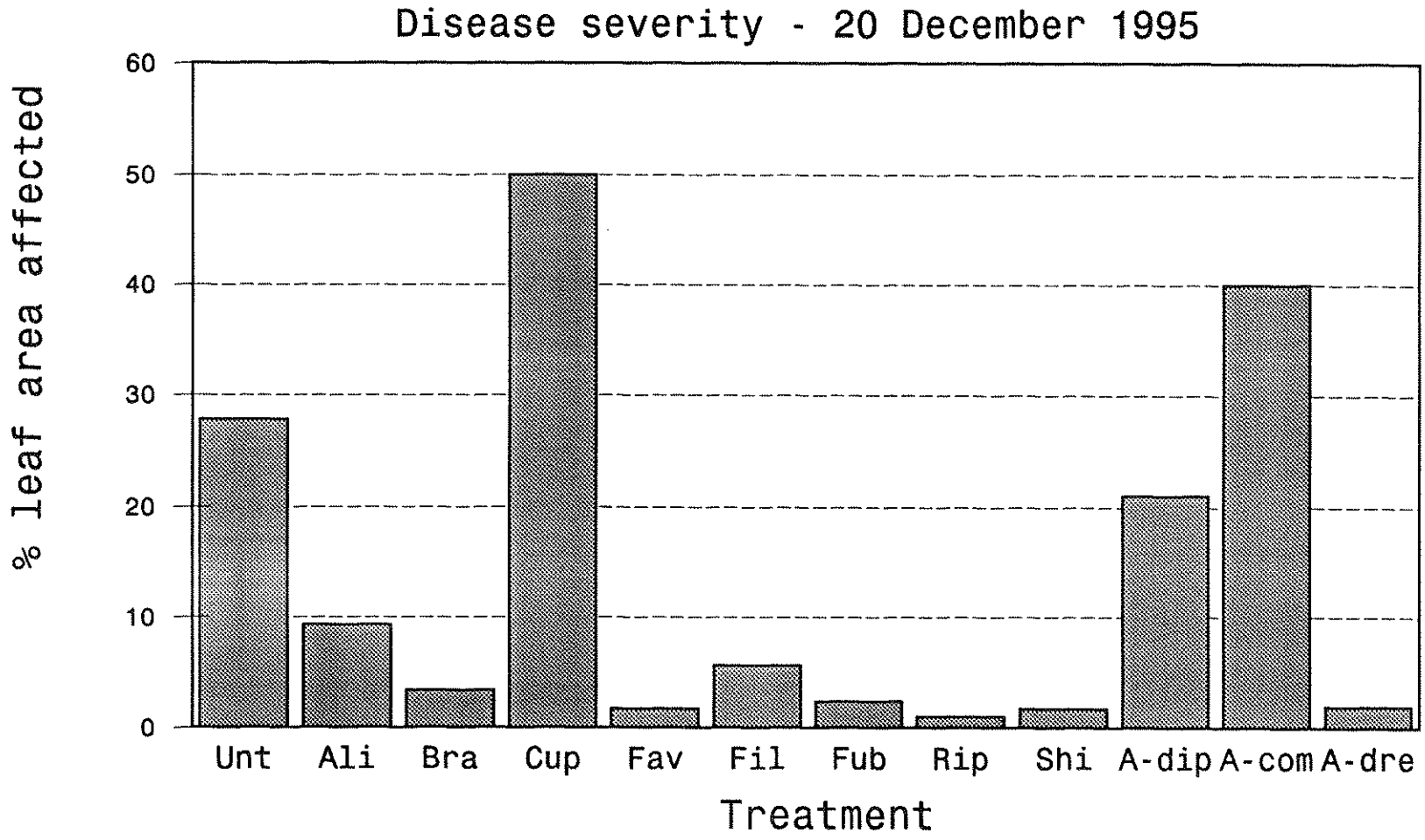


Fig 4. Effect of fungicides on growth of young blackberry plants, cv. Loch Ness

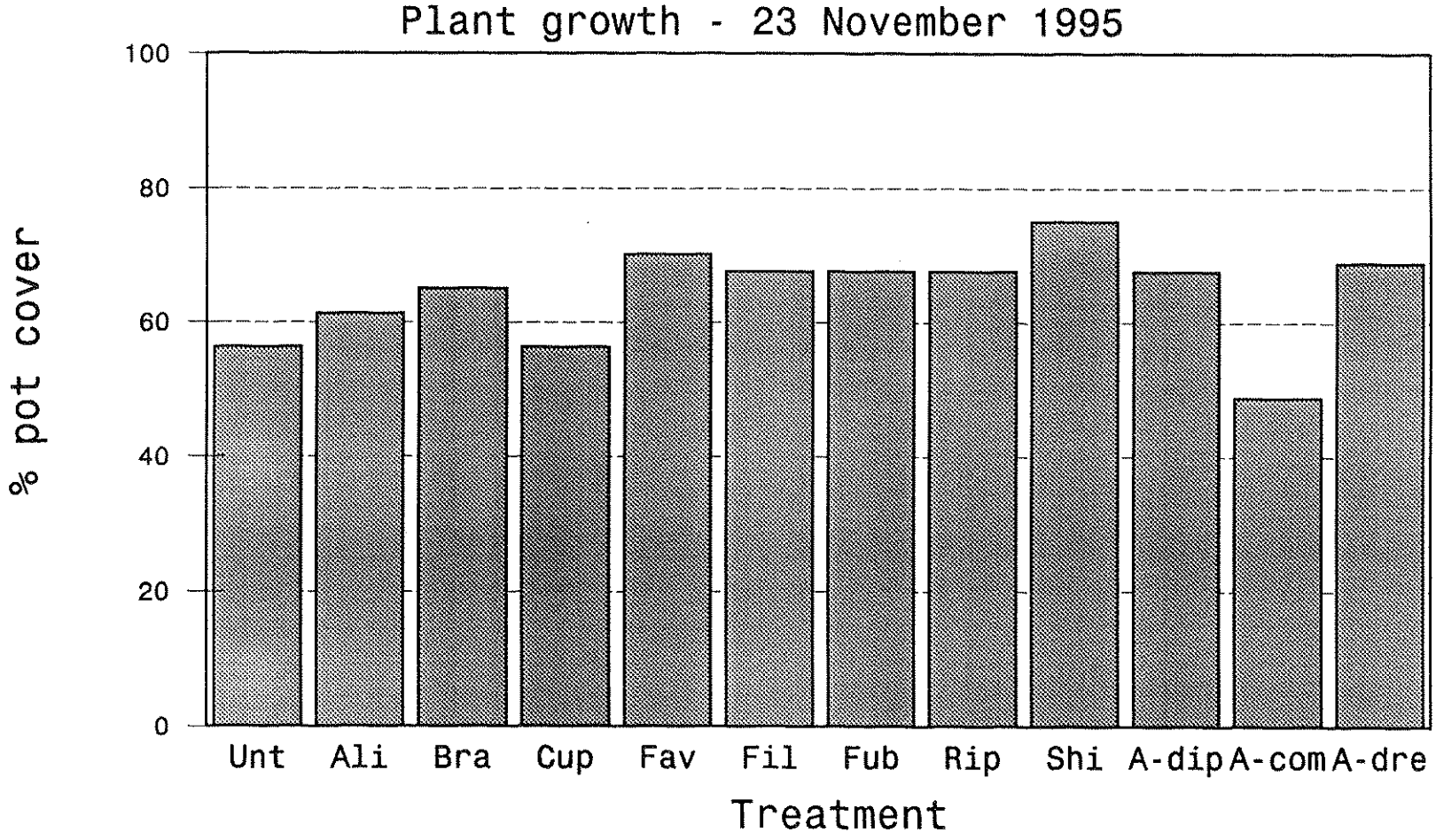


Fig 5. Effect of irrigation regimes on development of blackberry downy mildew

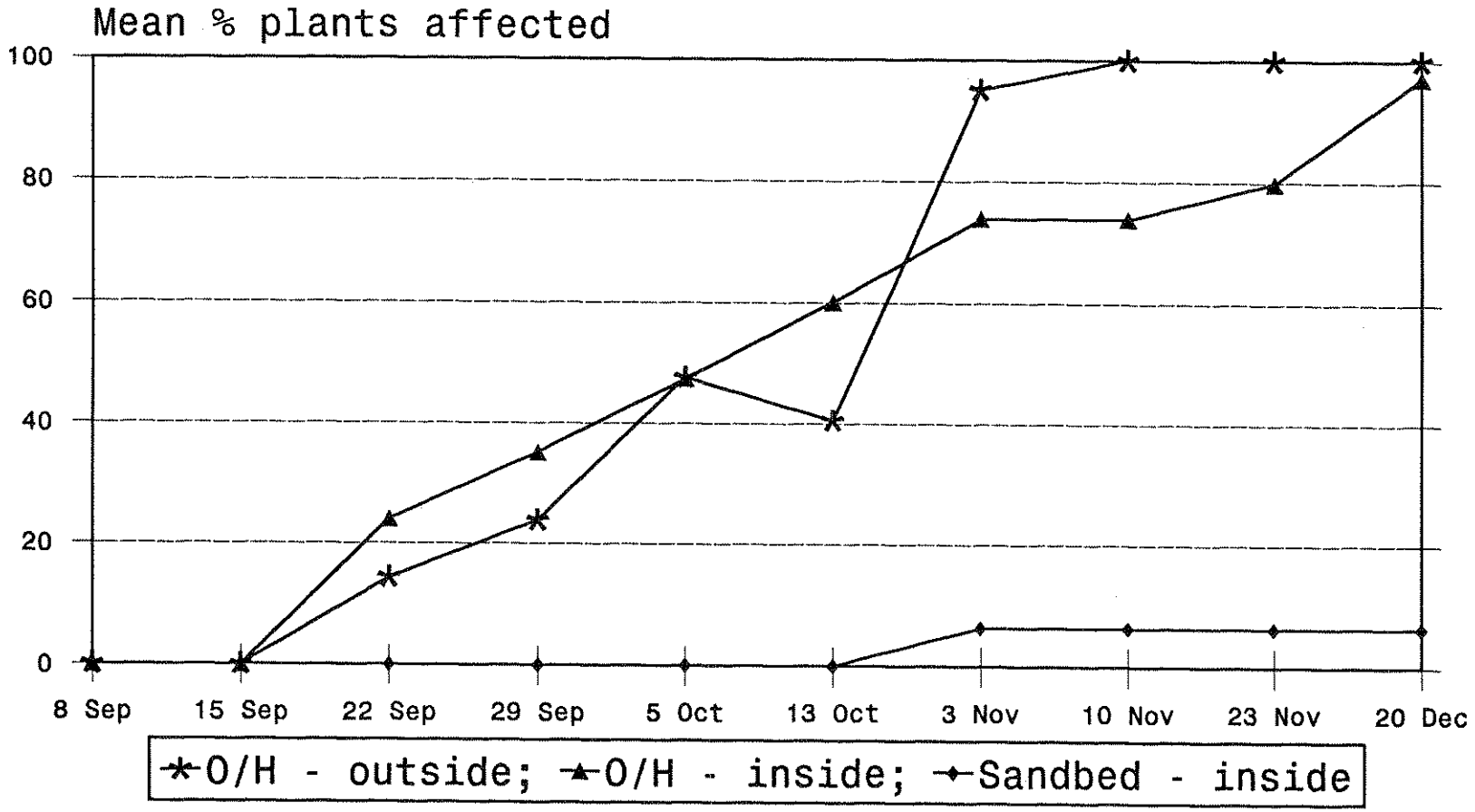


Fig 6. Effect of fungicide programmes on plant growth - Norfolk 1996

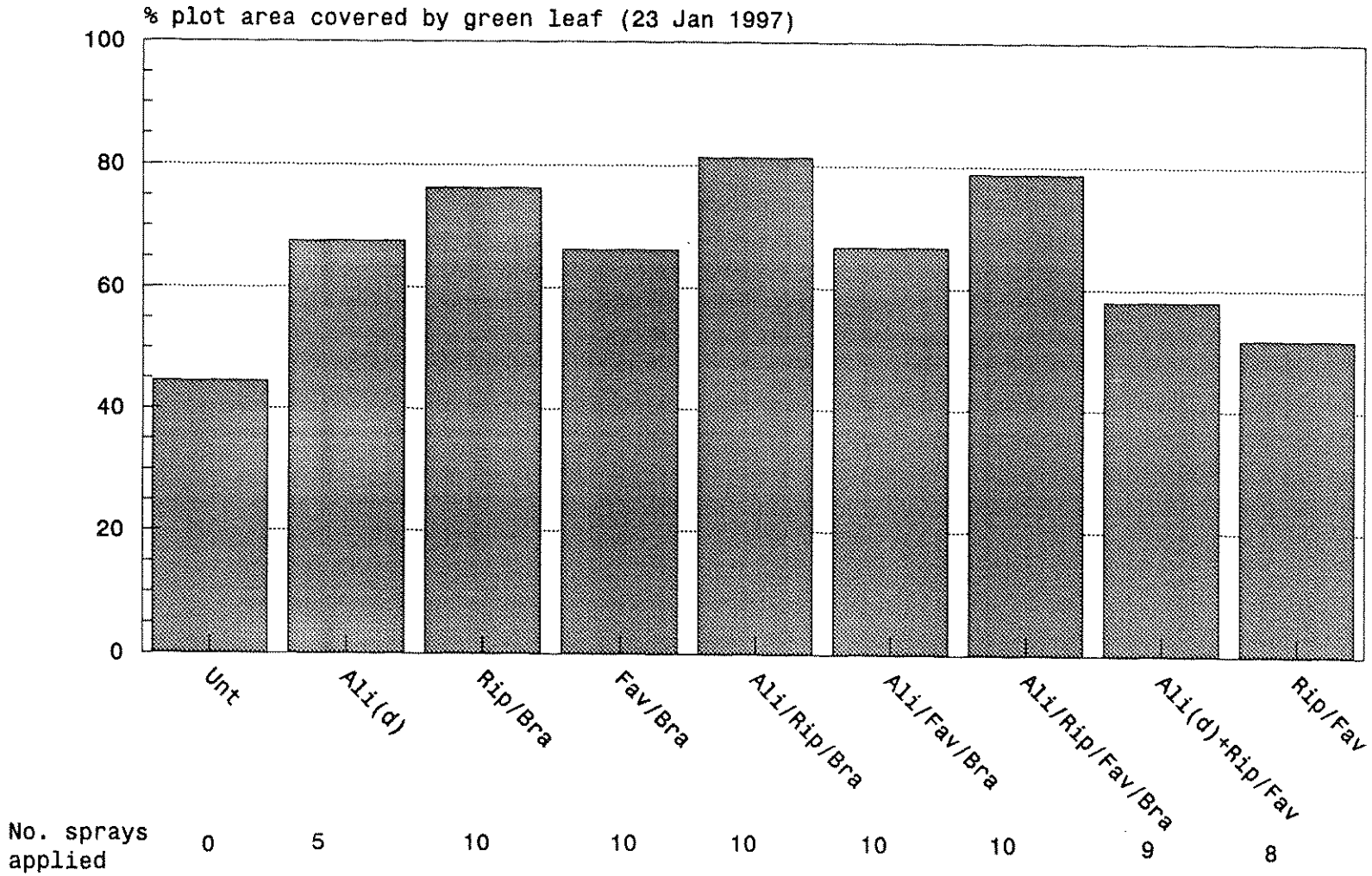


Fig 7. Effect of irrigation and fungicide sprays on incidence of blackberry plants affected by downy mildew - 1996

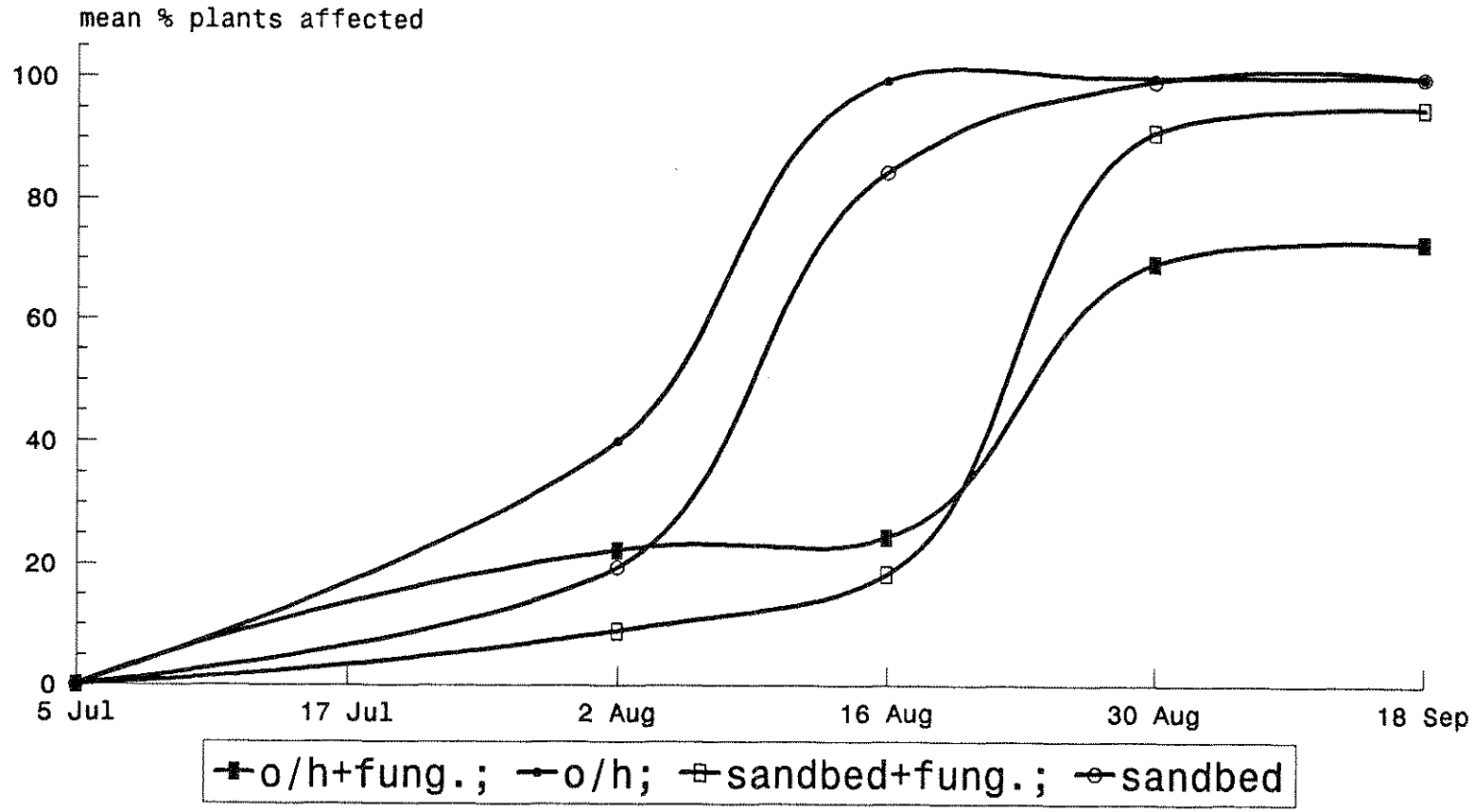
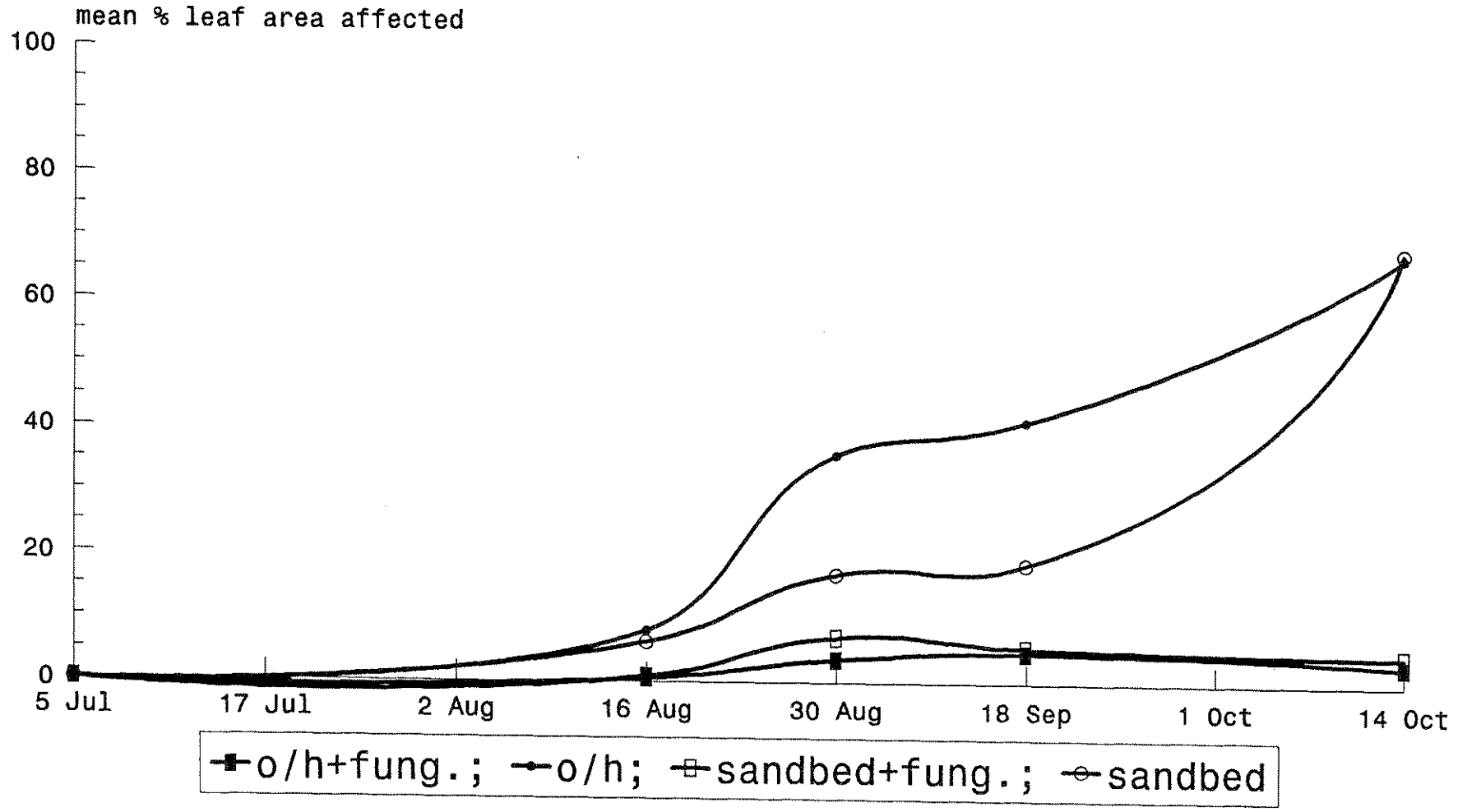


Fig 8. Effect of irrigation and fungicide sprays on severity of blackberry downy mildew - 1996



varieties, (Kotata, Silvan, Fantasia) with an extended harvest period, high yield, large berry size and good shelf-life for supermarkets.

4. Extension of the season by production under protection.

Unfortunately, the major new variety being planted at present (Loch Ness) appears very susceptible to downy mildew and the number of outbreaks of the disease in blackberry plantations is steadily increasing.

The potential financial benefit to the industry is difficult to quantify as the effect of the disease on yield has not been investigated. However, it seems likely that an outbreak in a plantation will affect both immediate production (losses die to 'dryberry') and may reduce the next season's production (infection of primocanes). An estimated yield loss of 25% occurred in one crop affected by downy mildew in 1993. If there was an average yield loss of 5%, this would represent a product value of £285,000.

As plantation outbreaks appear to develop from propagation material rather than from hedgerow sources, any success in improving the health of young plants would benefit the whole industry. It would also increase confidence in new varieties such as Loch Ness with their production and marketing advantages over Bedford Giant and other older varieties.

5. SCIENTIFIC/TECHNICAL TARGET OF THE WORK

1. To evaluate fungicides for control of downy mildew in young plants and to devise a fungicide programme which provides effective and durable control.

2. To investigate methods of manipulating production systems for young plants (eg irrigation, spacing) to reduce the risk of downy mildew occurring.

5. CLOSELY RELATED WORK COMPLETED OR IN PROGRESS

The second year of an HDC-funded project investigating control of downy mildew on container-grown roses is in progress (HNS 53) and is led by the proposer. This project has already identified three fungicide which provided good control of downy mildew on rose, cv Silver Jubilee and has demonstrated that the disease is extremely difficult to control in roses once it is well established in plants.

Earlier work investigating the biology and host-specificity of downy mildew on blackberry and hybrid berries was undertaken at SCRI (*Rep.*SCRI, 1988, 113-115; *Acta Hort.* **262** 227-230; *Ann. App. Biol* **125**, 73-85) and at ADAS Cambridge (*Plant Pathology* **37**, 281-284). Dr B. Williamson at SCRI has submitted a proposal to DAFS for PCR work aimed at developing a sensitive method for detecting downy mildew in young rubus plants. A commercial application of such testing would be to ensure that micropropagated plants are free from downy mildew. However, initial freedom from downy mildew is no guarantee that plants will remain free from the disease during propagation.

Contract between ADAS (hereinafter called the "Contractor") and the Horticultural Development Council (hereinafter called the "Council") for a research/development project.

1. TITLE OF PROJECT

Contract No: SF39
Contract date: 13.2.95

Blackberry: Evaluation of fungicides and manipulation of young plant growing conditions for control of downy mildew.

2. BACKGROUND AND COMMERCIAL OBJECTIVES

Serious outbreaks of downy mildew have occurred on blackberry and blackberry/raspberry hybrids in recent years both on propagation nurseries and in fruiting plantations. The disease affects leaves, petioles, primocanes and fruit and, in highly susceptible varieties, the fungus spreads systemically through most of the plant. Infection of leaves causes purple blotches and premature leaf fall resulting in poor growth. Infection of the fruit causes the berry to dry and split ('dryberry'). Plants appear to be particularly susceptible to the disease during propagation; there continues to be a high incidence of the disease in young plants of Loch Ness and Kotata, two commercially important blackberry varieties, despite the adoption of intensive fungicide programmes.

The disease also occurs on wild blackberry where it is mainly restricted to the leaves, and on wild and cultivated roses. Cross-inoculation experiments with downy mildew from rose (*Peronsopora sparsa*) and downy mildew from rubus (*Peronospora rubi*) indicates that the fungus from one host can infect the other, and the two fungi are probably one and the same.

The **commercial objectives** of the work proposed here are:

1. To devise a strategy for providing effective and reliable control of rubus downy mildew during propagation.

2. To minimise the effect of the disease on crop production in fruiting plantations.

3. POTENTIAL FINANCIAL BENEFIT TO THE INDUSTRY

After a period of decline in the early 1980's the area of blackberries has now stabilised and the area in England and Wales in 1993/94 is estimated to be around 283 ha with a gross production of 2,280 tonnes (8 t/ha) valued at £5.7m (£2,500/tonne). it appears likely that the area will increase steadily over the next few years because of:

1. Increased demand and prices from supermarkets and wholesalers.

2. Improved processing prices.

3. Introduction of new spine-free varieties (Loch Ness and Waldo) and other new

6. DESCRIPTION OF WORK

1995

Experiment 1 : Evaluation of fungicides for control of downy mildew on young micropropagated blackberry plants, cv Loch Ness, under protection.

To undertake a fully replicated trial evaluating fungicides applied as root dips, compost incorporants, drenches or sprays for control of downy mildew on young, micropropagated plants of blackberry, cv Loch Ness. Fungicides found to be effective in control of the disease on roses would be included. (Appendix 1) Young micropropagated plants would also be grown on in an isolated glasshouse and examined to determine if symptomless systemic infection is present in the young plant material.

Treatments

1.	Untreated	(double replication) - spray with water
2.	Aliette	(fosetyl-aluminium) at 500g product/100 litres
3.	Bravo 500*	(chorothalonil) at 250ml product/100 litres
4.	Cuprokylt*	(copper oxychloride) at 500g product/100 litres
5.	Favour 600 SC	(thiram + metalaxyl) at 300ml product/100 litres
6.	Filex	(propamocarb HCl) at 150ml product/100 litres
7.	Fubol 75+	(mancozeb + metalaxyl) at ~~20g~~ 200g product/100 litres
8.	Ripost Pepite+	(cymoxanil + mancozeb + oxadxyl) at 250g product/100 litres
9.	Shirlan+	(fluazinam) at 100ml product/100 litres

* Approval for use on cane fruit.
\+ Experimental permit required for use under protection.

Treatments would be applied as high volume sprays to the point of run-off (probably 200-500 l/ha) at 14 day intervals from **immediately** after potting, to a maximum of sprays. Natural infection, by downy mildew is anticipated. Introduction of 'infector plants' into the trial area will be considered if downy mildew is present on the nursery not affecting untreated plants by end June.

Assessments

1. Number of plants affected by downy mildew.

10. Aliette root dip (3.75g/l for 15 mins); then Aliette spray (5g/l) every 14 days.
11. Aliette compost incorporation (0.9 g/litre of compost). No further fungicides.
12. Aliette drench (1g/litre) at potting, and every 28 days thereafter.

2. Leaf area (%) visibly affected by downy mildew (purple blotches).

3. Crop damage (0-5 index); describe symptoms, measure height if reduced.

Plants will be assessed as soon as the disease is obvious (> 10% leaf area affected) on untreated plants and one week after the final spray.

Design

Randomised blocks with fourfold replication and 20 plants/plot (800 plants required). Plants would be watered from overhead; no irrigation within 12 hours of spraying.

Anticipated timing

May	-	pot plants, establish trial, apply first sprays
June - Aug	-	sprays and assessments
September	-	final assessment

Experiment 2: Investigation of irrigation and plant spacing on development of downy mildew in young blackberry plants, cv Loch Ness

Treatments

	Irrigation	Spacing
1.	Overhead sprinklers	Pot tight
2.	Overhead sprinkler	Pot tight in rows 20 cm apart in each direction
3.	Overhead sprinklers	20 cm gap between pots in each direction
4.	Drip lines	Pot tight
5.	Drip lines	Pot tight in rows 20 cm apart
6.	Drip lines	20 cm gap between pots in each direction

No fungicides applied for control of downy mildew. Natural infection by downy mildew is anticipated.

Assessments

1. Number of plants affected by downy mildew.

2. Leaf area (%) visibly affected by downy mildew.

Design

Four replicate blocks with 20 plants/pot (480 plants required). Full randomisation of spacing treatments; irrigation treatments would be grouped in one-half of each block (selected at random).

1996

1. To devise and evaluate fungicide programmes for control of downy mildew on young, micropagated plants of cv Loch Ness based on effective products and treatment methods identified in year one.

2. To repeat and extend the work on manipulation of cultural factors which affect development of downy mildew on young plants of cv Loch Ness.

nb Precise details of the treatments will be determined in consultation with the Project Co-ordinator at the start of each year.

7. START DATE, DURATION AND REPORTING

Start date 01.05.95; duration 2 years.
The project may be extended for a third year if it is decided that further work needs to be carried out to examine disease control in fruiting plantations.

An interim report would be produced by April 1996 and a final report by April 1997. Short additional reports may also be required for publication in Project News and/or the trade press. A grower walk will be arranged if appropriate. The results will also be presented at an appropriate HDC/HRI/ADAS fruit conference or show (further promotion, if required, will be subject to an extra charge).

8. STAFF RESPONSIBILITIES

Project leader: Dr T M O'Neill, ADAS Cambridge

Key staff: D Pye, ADAS Cambridge

9. LOCATION

Blackberry propagation nursery, Norfolk and ADAS Arthur Rickwood, Cambs.

Contract No: SF39

TERMS AND CONDITIONS

The Council's standard terms and conditions of contract shall apply.

Signed for the Contractor(s)

Signature...Martin Heath.....

Position. ADAS...ACCOUNT...MANAGER..FOR HDC

Date.....12/5/95.....

Signed for the Contractor(s)

Signature.....

Position.....

Date.....

Signed for the Council

Signature.....

Position.....CHIEF EXECUTIVE

Date.....14·2·95

Appendix 1

The following fungicides have all proved successful in controlling rose downy mildew in experiments and are worthy of evaluation for control of on blackberry downy mildew.

1.	Aliette	(fosetyl aluminium)
2.	Fubol 75	(mancozeb + metlaxyl)
3.	Shirlan	(fluazinam)
4.	Ripost Pepite	(cymoxanil + mancozeb + oxadixyl)
5.	Filex	(propamocarb)
6.	Favour	(metalaxyl + thiram)

As they already have clearance on cane fruit, the trials should also include:-

7.	Cuprokylt L	(copper oxychloride)
8.	Bravo 500	(chlorothalonil)