COVERSHEET

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Contents

Relevance to growers and practical application

Application

The four primary objectives of this study were:

1. To compare the efficacy of the new DF formulation of Bavistin in relation to the existing product Bavistin WP.

2. To identify alternative products, with activity against the vector, *O. brassicae* to minimise infection.

3. To evaluate the most promising treatments in commercial scale trials on growers holdings.

4. To evaluate a range of disinfectants with a view to identifying those with activity against the resting spores of *O. brassicae* with a short contact time and to determine the risk from phytotoxicity.

Suppression of big-vein symptoms obtained with Bavistin DF was equal to that obtained with Bavistin WP in most trials. Aliette used in accordance with label recommendations gave good control of big-vein in protected lettuce in one experiment. Hymush identified as effective in pot studies at HRI Wellesbourne provided good control of big-vein in one outdoor trial at HRI Stockbridge House. Of the 32 disinfectants tested, a number were very effective in killing resting spores of *Olpidium brassicae*. However, in the presence of soil, at the rates tested, only Iodel FD, Jet 5 and sodium hypochlorite killed all *O. brassicae* resting spores. A number of the products tested that did not kill resting spores are currently being used by some propagators to wash trays.

Summary

1. Laboratory-based experiments were carried out at HRI Wellesbourne on as many fungicides, wetting agents and other chemicals as possible to identify the most promising products for subsequent evaluation in field experiments at HRI Stockbridge House. Products that could be incorporated into peat blocks and that would protect the lettuce transplants from infection by the fungal vector and hence the virus were sought. Such products would have to have activity against the motile zoospores of the fungal vector which transmit the virus to healthy plants. Earlier experiments that identified Bavistin WP as a control agent for big-vein demonstrated that it inactivated zoospores, consequently twenty five additional products were tested for their ability to inactivate zoospores.

   - Although neither Bavistin WP or Bavistin DF showed much activity, at the concentrations tested Agral, Iodel FD, Aliette, Aliette Extra, Agribrom, Tachegaren, fluazinam, Fubol, Zinc Chloride, Panacide M, Patrol and Dithane rapidly inactivated zoospores.

   The twenty products that showed most activity against the zoospores were then tested in pot experiments simulating field conditions to evaluate fully their efficacy in controlling LBVV symptom expression. Products were either mixed as powders into the blocking compost prior to blocking or drenched onto blocks with lettuce plants in them. The ability of the products to inhibit or delay symptom expression was then assessed.

- The products that showed most promise (Aliette Extra, and Tecto) contained thiabendazole.

- The wetter sodium dodecyl sulphate and Agribrom also showed promise.

Some of the products identified in these experiments were subsequently evaluated under commercial conditions in the field and in a polytunnel at HRI Stockbridge House. The most promising were also further evaluated in more detail at HRI Wellesbourne. Hymush was also included in these experiments as it contains thiabendazole and used to have an off-label recommendation (now lapsed) for use on lettuce.

- Bavistin WP gave the best control followed by fluazinam.

- Although Hymush and Tecto gave some control they were slightly phytotoxic.

Fluazinam (50% wettable powder formulation) is a new fungicide from Ishihara Sangyo Kaisha and is licensed to ICI Agrochemicals for the UK market. It has also been shown to give excellent control of another virus disease transmitted by a fungus (Rhizomania of sugar beet) and warrants further evaluation for its ability to control big-vein in the field.

2. Six fully replicated trials in both outdoor crisp and protected 'flat' lettuce conducted during 1991-1993 evaluated a range of fungicides, wetting agents and disinfectants for the control of the chytrid fungus *O. brassicae*, the vector of big-vein virus.

During the period of the investigation 11 different products were evaluated at a range of different timings and rates of application. In the early trials at HRI, Stockbridge House inoculum of *O. brassicae* carrying the big-vein virus, was introduced artificially via the propagation blocks with soil and root debris from a known contaminated site. Later trials, including those on growers holdings, relied on natural infestation in order to simulate commercial situations. The most significant findings from this study were:

- Bavistin DF provided a suppression of big-vein equivalent to that from Bavistin WP in most trials.

- The higher rate of Bavistin DF (0.04 g/block) did not appear to provide more effective control of big-vein than the lower rate applied (0.02 g/block).

- Slight phytotoxicity occurred with Bavistin DF in the protected lettuce trials in 1992 and in 1993 and this therefore raises some doubt about the future use of this formulation on the crop.

- Aliette, applied as a block incorporation treatment according to label recommendations, gave outstanding control of big-vein virus in protected lettuce in 1991. Other trials in the series also showed Aliette to be moderately effective though the same level of control achieved in this early trial was not repeated.

- Aliette applied according to the Specific Off-Label Approval was less effective than the block incorporation treatment at 900 g product/m^3.

- Hymush (thiabendazole) identified as effective in pot studies at HRI Wellesbourne, was included in the studies from 1992 and provided very good control of big-vein in outdoor lettuce in that year.

- Hymush was phytotoxic to lettuce at the rates tested in 1993 and the yield was significantly reduced.

Aliette is currently recommended for use in integrated control strategies against lettuce downy mildew. However, the Specific Off-Label Approval (No. 0201/94) is preferred to the On-Label block incorporation treatment as it provides an opportunity for later application. In view of the results obtained here growers will need to consider carefully what the relative disease risk is. If big-vein is problematic then perhaps Aliette applied for big-vein as a block incorporation treatment should be considered. (NB. It is only recommended during the period October - April in each year). It will also provide 6-8 weeks protection from downy mildew. Downy mildew control later in the crop can be based on Filex (propamocarb hydrochloride), a product which in this trial series showed no activitity against *O. brassicae*, in conjunction with other products such as metalaxyl and mancozeb. It should be noted that Aliette must not be used both as a block incorporation treatment and as foliar sprays according to the SOLA in the same crop as this will lead to unacceptably high residues in the harvested produce. Neither Bavistin DF or Hymush should currently be used as there are no On or Off-Label Approval for these products.

3. A test for determining the ability of disinfectants to kill the resting spores of *O. brassicae* had to be designed and tested before any disinfectants could be evaluated. The test developed at HRI Wellesbourne involved a contact time of 20 minutes. An untreated control and Iodel FD treatments were included in all tests. Treated spores were added to lettuce seedlings and infection monitored. As well as the products that worked it is important to list all those that did not work, as some of these are currently being used by propagators.

- Of the 32 products tested in the absence of soil only Iodel FD, Jet 5, Sodium hypochlorite, Iodosan B, and Medentech A, B, and D killed all resting spores.

- In the presence of soil, at the concentrations tested, only Jet 5, Iodel FD and Sodium hypochlorite killed all resting spores.

- The minimum effective doses for these three products were: Iodel FD, 8.3%; Jet 5, 2%; sodium hypochlorite, $\leq$ 26%.

Experimental Section

Introduction

Big-vein disease is now known to be caused by a virus, referred to in scientific circles as lettuce big-vein virus (LBVV). Infection by this virus induces a range of symptoms including leaf bubbling, crinkling and distortion, vein banding and when severe it can prevent hearting. The disease is familiar to both protected and outdoor lettuce producers in the UK and is particularly prevalent in Spring and Autumn when light levels are lower, soil moisture levels are high, and the long growing periods allow symptoms to develop. At such times it is not unusual to find crops with more than 10-20% plants infected and in extreme cases severely affected crops have been ploughed in. The symptoms are not always recognised, particularly on butterhead cultivars, and large proportions of affected plants are sometime marketed. It may only be a matter of time before buyers begin to recognise symptoms and reject affected consignments. Crisp head lettuce types are more severely affected by big-vein and such types account for over 60% of field produced lettuce. At present, the disease is most troublesome in field crops but the current tendency to reduce the frequency of soil sterilisation in protected cropping regimes is already leading to an increase in the disease.

The virus is transmitted by the soil-borne, root infecting fungus, *Olpidium brassicae*. The resting spore stage of this fungus harbours the virus, is long lived, resistant to desiccation and can remain dormant in the soil for many years harbouring the virus. This means that eradication of the disease once it is established in field soils is virtually impossible. Disease control is currently based on control of the fungal vector.

It has been suggested that much of the original spread of the disease occurred following a move to centralised propagation. As symptoms take at least 4 weeks to develop and under some conditions (high light levels and rapid plant growth) symptoms do not develop in infected plants, contaminated and/or infected seedlings showing no symptoms can all too easily be sold by propagators and unwittingly transplanted into previously disease-free soils. Fortunately the risk of big-vein spread in this way is now recognised and the major propagators in the UK have implemented comprehensive hygiene procedures including the installation of tray washers to minimise the risk of infection of transplants from fungal spores in soil left adhering to trays following their return from growers. Until this study, little or nothing was known about the efficacy of most of the disinfectants that propagators are using in attempts to kill the fungal resting spores.

Research at Wellesbourne in the 1980s demonstrated that certain components of the fungicide Bavistin WP were effective in suppressing big-vein symptoms. This led to a label recommendation by the manufacturers (BASF). Bavistin incorporation into peat blocks (0.02g Bavistin WP per 4.3cm peat block; 252g/m^3) has been widely used by UK lettuce growers for big-vein control. BASF have indicated their intention to replace Bavistin WP with an alternative dry flowable formulation - Bavistin DF. This product contains an equivalent rate of carbendazim and whilst the product has the same wetting agents (thought to be the component that has activity against *O. brassicae*) they are present in different proportions. More importantly Bavistin DF no longer carries a label recommendation for big-vein control. This decision by BASF left growers without an effective method for the control of this increasingly important disease problem.

The use of Iodel FS (1% v/v) for the disinfection of propagation areas, machinery etc., was promoted in the 1980s. However, its efficacy was questioned and numerous other disinfectants of unknown efficacy are currently in use.

Materials and Methods

Activity of various chemicals, surfactants and fungicides against zoospores

Laboratory-based experiments were carried out at HRI Wellesbourne on as many fungicides, wetting agents and other chemicals as possible to identify the most promising products for subsequent evaluation in field experiments at HRI Stockbridge House. Products that could be incorporated into peat blocks and that would protect the lettuce transplants from infection by the fungal vector and hence the virus were sought. Such products would have to have activity against the motile zoospores of the fungal vector which transmit the virus to healthy plants. Consequently twenty-five products were tested for their ability to inactivate zoospores; products and their rate of use are shown in table 8. After adding the products to zoospore suspensions the motility of the zoospores was assessed after 5, 30 and 60 minutes and their movement scored on a scale of 0-3 where 0 = dead, 1 = severely impaired movement, 2 = slightly impaired movement and 3 = normal movement (indistinguishable from control).

Activity of products in pot experiments

The twenty products that showed most activity against the zoospores were then tested in pot experiments simulating field conditions at HRI Wellesbourne to evaluate fully their efficacy in controlling LBVV symptom expression. Products were either mixed as powders into the blocking compost prior to blocking or drenched onto blocks with lettuce plants in them. The ability of the products to inhibit or delay symptom expression was then assessed. The twenty products and their rates of use are shown in table 9. Some of the products identified in these experiments were subsequently evaluated under commercial conditions in field and polytunnel experiments at HRI Stockbridge House. The most promising were also further evaluated at HRI Wellesbourne in further pot experiments (see table 10 for products and rates). Hymush was also included in these experiments as it contains thiabendazole at the same rate as Tecto but has the advantage of formerly having an off-label recommendation (now lapsed) for use on lettuce. In all pot experiments all plants were assessed twice a week and the time taken for big-vein symptoms to appear and the severity of symptoms were recorded. After the data had been collated the treatments were ranked according to their abilities to reduce symptom severity and the time taken for disease symptoms to appear. Finally they were ranked for efficacy based on a combination of these two rankings.

Field and polytunnel experiments

Sites

The trials were located at HRI Stockbridge House in 1991 and 1992. In each year the protected lettuce were located in a polythene tunnel, the outdoor lettuce trials were located in Fields L and E respectively. The trials in 1993 were located at growers holdings. The protected lettuce was located at Snaith Salads, West Bank, Carlton, Goole, North Humberside. The outdoor lettuce was located at Thornton, Melbourne, York.

Duration

The protected and outdoor lettuce trials were conducted during the autumn period in each year in order to target the high risk period for symptom expression with big-vein virus.

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Cultivars

The protected lettuce cultivar used in each year was the butterhead variety Titania, whereas that used for outdoor lettuce was the crisp variety Saladin.

Trial Design

Protected Lettuce: In each year a randomised block design with 4 replicates of each treatment was used. In 1991 and 1992 the plots consisted of 5 rows of 12 plants. 60 plants/plot. Plant spacing was 20 cm x 20 cm giving a plot size of 2.48 m^2. In the grower study in 1993 each plot consisted of 7 rows of 9 plants, 63 plants per plot. Plant spacing was 20 cm x 20 cm giving an equivalent plot size of 2.48 m^2.

Outdoor Lettuce: In each year a randomised block design with 4 replicates of each treatment was used. In 1991 and 1992 plots consisted of 4 rows of 15 plants, 60 plants per plot. Plant spacing was 30 cm x 37.5 cm, giving a plot size of 8.1 m^2. In the grower study in 1993 each plot consisted of 7 rows of 10 plants, 70 plants/plot. Plant spacing was 30 cm x 35 cm giving a plot size of 7.35 m^2.

In each trial on protected and outdoor lettuce the outer row of each plot formed a picture frame guard area. The central plants in each plot were used for assessments and yield determination at harvest.

Pathogen Inoculation

Protected Lettuce: In the first year (1991) soil and root debris was collected from a site known to be heavily contaminated with *O. brassicae* carrying the big-vein virus. This material was sieved and subsequently incorporated evenly into the blocking compost (T2-12 only) at a rate of 5 kg soil/root debris per 75 kg bag of blocking compost. 4.3 cm peat blocks were then prepared using this contaminated compost using a manual blocking machine. Blocks for T1 were prepared earlier using uncontaminated compost. In the second year infection by big-vein virus relied on utilisation of the same site with the addition of a further quantity of contaminated soil to ensure an even infection potential across the polythene tunnel. Uncontaminated blocking compost was used throughout. In 1993 the trial was located and a commercial nursery in order to utilise a naturally infested site and the crop was not artificially inoculated with the big-vein virus.

Outdoor Lettuce: In 1991 and 1992 soil and root debris, collected from a big-vein contaminated site (see above), was incorporated evenly into blocking compost (T2-12 only) at a rate of 5 kg soil/root debris per 75 kg blocking compost. 4.3 cm peat blocks were subsequently prepared using the contaminated compost using a manual blocking machine. Blocks for T1 were prepared earlier using uncontaminated compost. In 1993 the trial was located on a commercial nursery in order to utilise a naturally infested site and the crop was not artificially inoculated with the big-vein virus.

In order to avoid contamination of uninoculated control plots with *O. brassicae* and the big-vein virus these treatments were always blocked and sown first using sterilised equipment. Subsequently plants in this treatment were maintained in isolation to avoid cross-transfer of inoculum.

Treatments

1. Uninoculated, untreated control.

2. Inoculated, control.

3. Bavistin WP (50% carbendazim) applied as a block incorporation treatment at a rate of 0.02 g product/4.3 cm block (252 g Bavistin WP/m^3 blocking compost).

4. Bavistin DF (50% carbendazim) applied as a block incorporation treatment at a rate of 0.02 g product/4.3 cm block (252 g Bavistin DF/m^3 of blocking compost).

5. Bavistin DF (50% carbendazim) applied as a block incorporation treatment at a rate of 0.04 g product/4.3 cm block (504 g Bavistin DF/m^3 of blocking compost).

6. Bavistin DF (50% carbendazim) applied as a block incorporation treatment - as in Treatment 5 above, followed by a drench application immediately post-planting at a rate of 0.2 g product/1 litre water/m^2.

7. Aliette (80% fosetyl-aluminium) applied as a block incorporation treatment at a rate of 900 g product/m^3 blocking compost according to label recommendations.

8. Aliette (80% fosetyl-aluminium) applied as a block incorporation treatment at a rate of 450 g product/m^3 blocking compost.

9. Aliette (80% fosetyl-aluminium) applied according to the Specific Off-Label Approval (No. 0556/91) at 10 g product/1 litre water/m^2 at the 2-3 leaf stage, irrigated immediately to wash the treatment from the foliage and repeated 7 and 21 days post-planting at 3 g product/1 litre water/10 m^2 with irrigation 1 hour later at 1 litre water/10 m^2 to remove the fungicide from the foliage.

10. Aliette (80% fosetyl-aluminium) applied according to the Specific Off-Label Approval (No. 0556/91) except that the treatment in propagation to be applied immediately post-seeding 10 g product/1 litre water/m^2 instead of the 2-3 leaf stage and immediately post-planting and 21 days later at 3 g product/1 litre water/10 m^2 with irrigation 1 hour after each post-planting treatment with 1 litre water/10 m^2 to remove the fungicide from the foliage.

11. Filex (72% propamocarb hydrochloride) applied as a drench to the propagation blocks immediately before seeding at 7.5 ml product/3 litres water/m^2 and repeated immediately post-planting at a rate of 1 ml product/1 litre water/m^2.

12. Iodel (an iodophor) applied as a drench to the propagation blocks immediately before seeding at 2 litres product/m^2 of a 1.0% solution and repeated immediately post-planting.

13. Agral (90% alkyl phenol ethylene oxide) applied as a drench to the propagation blocks immediately before seeding at 2 litres product/m^2 of a 0.5% solution and repeated immediately post-planting.

14. Agribrom (1-bromo-3-chloro- 5,5-dimethyl-2,4-imidazolidimedione) applied as a drench to the propagation blocks immediately before seeding at 2 litres product/m^2 of a 0.5% solution and repeated immediately post-planting.

15. Tachegaren (70% hymexazole) applied as a block incorporation treatment at a rate of 0.02 g product/4.3 cm block (252 g product/m^3 blocking compost) followed by a drench application immediately post-planting at a rate of 0.2 g product/1 litre water/m^2.

16. Sodium lauryl sulphate applied as a drench to the blocking compost immediately after seeding at a rate of 0.5 g product/1 litre water/m^2 and again immediately post-planting.

17. Aliette (80% fosetyl-al) + Hymush (60% thiabendazole) applied as a block incorporation treatment applied at 900 g product and 107 g product/m^3 blocking compost respectively.

18. Hymush (60% thiabendazole) applied as a block incorporation treatment at a rate of 107 g product/m^3 compost and repeated as a drench immediately post-planting at 0.2 g product/1 litre water/m^2 .

19. Hymush (60% thiabendazole) applied as a block incorporation treatment at a rate of 107 g product/m^3 blocking compost.

20. Hymush (60% thiabendazole) applied as a drench at a rate of 1 g product/1 litre water/m^2 at the 2-3 leaf stage in propagation and repeated at 14 day intervals post-planting with a total of 4 applications at 1 g product/1 litre water.

21. Proxitane 0510 (5% peroxy-acetic acid) applied as a drench at the 2-3 leaf stage at a rate of 2.0 ml product/1 litre water/m^2 followed by HV sprays to run-off at 14 day intervals post-planting with a total of 4 applications at 5 ml product/ 1 litre water/m^2.

Table 1: Treatments used on protected and outdoor lettuce in each year of the trials programme.

		1991		1992		1993	
Treatments		Protected Lettuce	Outdoor Lettuce	Protected Lettuce	Outdoor Lettuce	Protected[#] Lettuce	Outdoor[#] Lettuce
1.	Uninoculated, untreated control	✓	✓	-	✓	-	-
2.	Inoculated, untreated control	✓	✓	✓[+]	✓	✓[+]	✓[+]
3.	Bavistin WP block incorporation (0.02 g/block)	✓	✓	✓	✓	✓	✓
4.	Bavistin DF block incorporation (0.02 g/block)	✓	✓	✓	✓	✓	✓
5.	Bavistin DF block incorporation (0.04 g/block)	✓	✓	✓	✓	✓	✓
6.	Bavistin DF BI and drench post-planting *	✓	✓	✓	✓	✓	✓
7.	Aliette block incorporation (900 g/m^3 compost)	✓	✓	✓	✓	✓	✓
8.	Aliette block incorporation (450 g/m^3 compost)	-	-	✓	-	✓	✓
9.	Aliette SOLA (No. 0556/91)	-	-	✓	✓	✓	✓
10.	Aliette modified SOLA	-	-	✓	✓	-	-
11.	Filex drench pre-seeding and post-planting	✓	✓	✓	✓	-	-
12.	Iodel drench pre-seeding and post-planting	✓	✓	-	-	-	-
13.	Agral drench pre-seeding and post-planting	✓	✓	-	-	-	-
14.	Agribrom drench pre-seeding and post-planting	✓	✓	-	-	-	-
15.	Tachegaren BI and drench post-planting	✓	✓	-	-	-	-
16.	Sodium lauryl sulphate drench (x2)	-	-	✓	✓	-	-
17.	Aliette and Hymush block incorporation	-	-	-	-	✓	✓
18.	Hymush BI and drench post-planting	-	-	✓	✓	-	-
19.	Hymush block incorporation	-	-	-	-	✓	✓
20.	Hymush drench pre- and post-planting	-	-	-	-	✓	✓
21.	Per-acetic acid pre- and post-planting	-	-	-	-	✓	✓

* In 1993 this treatment was modified and the post-planting application rate was increased from 0.2 g product to 1.0 product/m^2.

[+] Whilst this site was not artificially inoculated, inoculum of big-vein was present in the soil (see under Inoculation in Materials and Methods).

[#] Commercial grower sites.

BI Block incorporation treatment.

Fungicide Application

Block incorporation treatments were applied by mixing the correct quantity of fungicide/chemical in 5 litres of water and the resulting solution was used to wet the compost prior to blocking. Drench applications were made either by hand-held sprayer or watering can with fine rose attachment, depending on the water volume applied. HV spray/drench applications at the 2-3 leaf stage were made using a hand operated sprayer. All applications post-planting were carried out using an Oxford Precision Knapsack sprayer (E-bar Engineering) with boom attachment.

Crop Husbandry and Cultural Details

All crops were grown to a good commercial standard and were maintained in a healthy state, with the exception of the pathogen under study, according to normal horticultural practice in order to produce adequate, commercially representative yields.

Protected Lettuce: Triple super phosphate (23 kg), potassium sulphate (22 kg), kieserite (14.5 kg), and ammonium nitrate (11.5 kg) was applied to the protected lettuce trial site in 1991 on 20 August. In autumn 1992 the same site was treated with ammonium nitrate (11.5 kg) on 13 August. At the commercial site in 1993 fertiliser was applied as required for good commercial practice at the discretion of the grower. .

For details of pesticides used see Appendix II. Fungicides for downy mildew control were avoided where possible due to the potential interference with *Olpidium* development.

Outdoor Lettuce: Ground limestone was applied to the outdoor lettuce trial site (Field L) on 22 July at a rate of 1.5 kg/ha and base fertiliser was applied on 27 July at a rate of 17:17:17 (600 kg/ha), In 1992, the site (Field E) received base fertiliser at a rate of 17:17:17 (735 kg/ha) in conjunction with super triple phosphate (272 kg/ha) on 23 July. At the commercial site in 1993 fertiliser was applied as required for good agricultural practice at the discretion of the grower. For details of pesticides used see Appendix II. Fungicides for downy mildew control were avoided were possible due to potential interference with *Olpidium* development.

Crop Diary

Protected Lettuce: The seed were sown on 8, 10, and 12 August respectively in 1991, 1992 and 1993. After the pre and post-seeding treatments were applied the blocks were transferred to a cold room operating at 1-2°C for 24 hours to aid germination and then moved to a propagation house (M21) on raised open-mesh benching. Germination counts were made as required where adverse treatment effects became apparent. Fungicide/chemical treatments were applied according to the schedules in Tables 2-4. The lettuce were subsequently planted out on 2, 3 and 3 September in 1991, 1992, and 1993 respectively.

Disease assessments for big-vein were made on 23 September and 10 October in 1991 and on 19 October and 27 October in 1992. In 1993 no detailed assessments for big-vein could be carried out as the trial was abandoned prematurely due to extreme disease pressure on the adjacent commercial crop from downy mildew. Untrimmed and trimmed yields were taken on 10 October and 27 October in 1991 and 1992 respectively.

Outdoor Lettuce: The seed were sown on 27, 14, and 22 July in 1991, 1992, and 1993 respectively. After the pre and post-seeding treatments were applied the blocks were transferred to a cold room operating at 1-2°C for 24 hours to aid germination and then moved to a propagation house (M21) on raised open-mesh benching. Germination counts were made as required where adverse treatment effects became apparent. Fungicide/chemical treatments were applied according to the schedules in Tables 5-7. The lettuce were subsequently planted out on 28, 6, and 13 August in 1991, 1992, and 1993 respectively.

Disease assessments for big-vein were made on 3 October and 6 November in 1991, 24 September and 16 October in 1992, and 7 October and 20 October in 1993. Untrimmed and trimmed yields were taken on 6 November, 16 October and 20 October in 1991, 1992 and 1993 respectively.

Table 2: Diary of application of fungicide treatments on protected lettuce (August - September 1991).

Treatment	Propagation Phase: Block incorporation treatments (8 Aug)	Propagation Phase: Pre-seeding drench treatments (8 Aug)	Cropping Phase: Post-planting treatments (2 Sept)
Uninoculated control	-	-	-
Inoculated control	-	-	-
Bavistin WP (0.02 g)	*	-	-
Bavistin DF (0.02 g)	*	-	-
Bavistin DF (0.04 g)	*	-	-
Bavistin DF (0.04 g) + drench	*	-	*
Iodel	-	*	*
Agral	-	*	*
Aliette BI (900 g/m^3)	*	-	-
Filex	-	*	*
Agribrom	-	*	*$^{\Delta}$
Tachegaren	*	-	*

$^{\Delta}$ As difficulty was encountered dissolving this product it was incorporated into the top few centimetres of soil as a granule by raking in immediately prior to planting out.

* Treatment applied.

Table 3: Diary of application of fungicide treatments on protected lettuce (August - September 1992).

	Propagation Phase				Cropping Phase	
Treatment	Block incorporation (10 Aug)	Post-seeding drench treatment (10 Aug)	2-3 leaf drench treatment (28 Aug)	Immediately post-planting (3 Sept)	7 days post-planting (10 Sept)	21 days post-planting (24 Sept)
Untreated control[⊗]	-	-	-	-	-	-
Bavistin WP (0.02 g)	*	-	-	-	-	-
Bavistin DF (0.02 g)	*	-	-	-	-	-
Bavistin DF (0.04 g)	*	-	-	-	-	-
Bavistin DF (0.04 g) + dr.	*	-	-	*	-	-
Hymush	*	-	-	*	-	-
Aliette BI (450 g)	*	-	-	-	-	-
Aliette BI (900 g)	*	-	-	-	-	-
Aliette (modified SOLA)	-	*	-	*	-	*
Aliette (SOLA)	-	-	*	-	*	*
Filex	-	*+	-	*	-	-
Sodium Lauryl Sulphate	-	*	-	*	-	-

⊗ The 1991 site was utilised again for this trial and therefore the site was already contaminated with big-vein virus. However, to ensure an even infection additional soil and root debris was incorporated.

\+ Treatment applied immediately before seeding.

* Treatment applied.

Table 4: Diary of application of fungicide treatments on protected lettuce (August - October 1993).

Treatment	Propagation Phase		Cropping Phase				
	Block incorporation (12 Aug)	2-3 leaf drench treatment (30 Aug)	Immediately post-planting (3 Sept)	1 week post-planting (10 Sept)	2 weeks post-planting (17 Sept)	3 weeks post-planting (24 Sept)	4 weeks post-planting (1 Oct)
Untreated control[⊗]	-	-	-	-			
Bavistin WP (0.02 g)	*	-	-	-			
Bavistin DF (0.02 g)	*	-	-	-			
Bavistin DF (0.04 g)	*	-	-	-			
Bavistin DF (0.04 g) + drench	*		*	(trial terminated prematurely on 17 September			
Hymush (BI)	*	-	-	due to severe infection with *Bremia lactucae*.			
Hymush drenches	-	*	-	Post-planting treatment programmes not completed.			
Aliette BI (450 g)	*	-	-	-			
Aliette BI (900 g)	*	-	-	-			
Aliette (SOLA)	-	*	-	*			
Aliette BI + Hymush BI	*	-	-	-			
Per-acetic acid	-	*	-				

⊗ Artificial inoculation not carried out as a naturally infested grower site was used.

BI Block incorporation

* Treatment applied.

Table 5: Diary of application of fungicide treatments on outdoor lettuce (July - August 1991).

Treatment	Propagation Phase: Block incorporation treatments (24 July)	Propagation Phase: Pre-seeding drench treatment (24 July)	Cropping Phase: Post-planting treatments (22 August)
Uninoculated control	-	-	-
Inoculated control	-	-	-
Bavistin WP (0.02 g)	*	-	-
Bavistin DF (0.02 g)	*	-	-
Bavistin DF (0.04 g)	*	-	-
Bavistin DF (0.04 g) + drench	*	-	*
Iodel	-	*	*
Agral	-	*	*
Aliette BI (900 g/m^3)	*	-	-
Filex	-	*	*
Agribrom	-	*	*$^{\Delta}$
Tachegaren	*	-	*

$^{\Delta}$ As difficulty was encountered dissolving this product it was incorporated into the top few centimetres of soil as a granule by raking in immediately post-planting.

* Treatment applied.

Table 6: Diary of application of fungicide treatments on outdoor lettuce (July - August 1992).

	Propagation Phase			Cropping Phase		
Treatment	Block incorporation (14 July)	Post-seeding drench treatment (14 July)	2-3 leaf drench treatment (30 July)	Immediately post-planting (7 August)	7 days post-planting (14 August)	21 days post-planting (28 August)
Uninoculated control	-	-	-	-	-	-
Inoculated control	-	-	-	-	-	-
Bavistin WP (0.02 g)	*	-	-	-	-	-
Bavistin DF (0.02 g)	*	-	-	-	-	-
Bavistin DF (0.04 g)	*	-	-	-	-	-
Bavistin DF (0.04 g) + drench	*	-	-	*	-	-
Hymush BI + drench	*	-	-	*	-	-
Aliette BI (900 g/m^3)	*	-	-	-	-	-
Aliette (modified SOLA)	-	*	-	*	-	*
Aliette (SOLA)	-	-	*	-	*	*
Filex	-	*+	-	*	-	-
Sodium Lauryl Sulphate	-	*	-	*	-	-

+ Treatment applied immediately before seeding.

* Treatment applied.

Table 7: Diary of application of fungicide treatments on outdoor lettuce (July - October 1993).

Treatment	Propagation Phase: Block incorporation (22 July)	Propagation Phase: 2-3 leaf drench treatment (5 Aug)	Cropping Phase: Immediately post-planting (13 Aug)	Cropping Phase: 1 week post-planting (20 Aug)	Cropping Phase: 3 weeks post-planting (6 Sept)	Cropping Phase: 5 weeks post-planting (17 Sept)	Cropping Phase: 7 weeks post-planting (29 Sept)
Untreated control[⊗]							
Bavistin WP (0.02 g)	*	-	-	-	-	-	-
Bavistin DF (0.02 g)	*	-	-	-	-	-	-
Bavistin DF (0.04 g)	*	-	-	-	-	-	-
Bavistin DF (0.04 g) + dr.	*	-	*	-	-	-	-
Hymush BI	*	-	-	-	-	-	-
Hymush drenches	-	*	-	*	*	*	*
Aliette BI (450 g)	*	-	-	-	-	-	-
Aliette BI (900 g)	*	-	-	-	-	-	-
Aliette (SOLA)	-	*	-	*	*	-	-
Aliette BI & Hymush BI	*	-	-	-	-	-	-
Per-acetic acid	-	*	-	*	*	*	*

BI Block incorporation

⊗ Artificial inoculation not carried out as naturally infested grower site used.

* Treatment applied.

Disease Assessments

In each year an interim assessment of big-vein was conducted when/if the disease became apparent. This was followed by a more detailed assessment at crop maturity. Assessments were based on various parameters depending on symptom expression but included percentage plants with visible symptoms and severity of big-vein using a 0-3 scale of severity where:

0 = No visible sign of big-vein.

1 = Slight big-vein symptoms. Evidence of vein clearing but heart development normal.

2 = Moderate big-vein symptom; vein-clearing frequent,often pronounced, heart development poor.

3 = Big-vein symptoms severe. Plant stunted with little heart development, leaf bubbling at centre.

A disease index was calculated using the formula:

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

The range of the index was, therefore 0 (no disease) to 100 (most severe disease).

Assessments were based on the central 10-20 plants/plot leaving the outer plants as a picture-frame guard area.

Yield Assessments

At harvest 10-20 plants were cut from the centre of each plot and bulk weighed to give a mean untrimmed lettuce head weight. Each lettuce was then trimmed to a commercial standard, removing any discoloured outer leaves to provide a clean frame. Any lettuce with a significantly reduced heart were discarded at this point and regarded as unmarketable. The remaining lettuce were then re-weighed to provide a mean trimmed head weight. The difference between the untrimmed and trimmed yield was therefore regarded as the weight loss from infection by big-vein and other secondary fungi causing bottom-rots eg. *Botrytis cinerea*, *Rhizoctonia solani*.

Statistical Analysis

The data from each trial was subjected to an analysis of variance and significance determined at the 5% level of probability (P = 0.05). Where necessary data was transformed using a logit (back) transformation or using $\log_{10}$. Where data has been transformed the raw data is provided in Appendix I.

Storage of Data

The raw data from this trials series will be stored for a period not less than 5 years in the HRI archive at Stockbridge House. Access to the raw data files can only be made via the designated archivist.

Laboratory-based experiments to determine the ability of disinfectants to kill resting spores of *Olpidium brassicae*

A test for determining the ability of disinfectants to kill the resting spores of *O. brassicae* had to be designed and tested before any disinfectants could be evaluated. The test developed at Wellesbourne involved a contact time of 20 minutes. An untreated control and Iodel FD treatments were included in all tests. Treated spores were added to lettuce seedlings and infection monitored. All the products tested and the rates at which they were used are listed in table 25.

Results

Activity of various chemicals, surfactants and fungicides

Earlier experiments that identified Bavistin WP as a control agent for big-vein demonstrated that it inactivated zoospores. In these experiments although neither Bavistin WP or Bavistin DF showed much activity at the concentrations tested, Agral, Iodel, Aliette, Aliette Extra, Agribrom, Tachegaren, fluazinam, Fubol, zinc chloride, Panacide M, Patrol and Dithane rapidly inactivated zoospores (Table 8).

Activity of products in pot experiments

The twenty products that showed most activity against the zoospores and that were further evaluated in pot experiments are listed in table 9. The products that showed most promise (Aliette Extra and Tecto) contained thiabendazole; the wetter sodium dodecyl sulphate and Agribrom also showed promise (Table 9).

Table 8. Effect of various products on the motility of *O. brassicae* zoospores

Test Solution	Concentration	Zoospore Mobility at time intervals of		
		5 mins	30 mins	60 mins
Control	-	3	3	3-2
Aliette	0.9 g/L	0	0	0
Aliette Extra	0.9 g/L	0	0	0
Agribrom	0.5%	0	0	0
Fluazinam	0.4%	0	0	0
Fubol	0.02%	0	0	0
Dithane 945	2.2 g/L	0	0	0
Iodel	1%	0	0	0
Panacide M	2%	0	0	0
Patrol	0.37%	0	0	0
Tachegaren	0.252 g/L	0	0	0
Zinc Chloride	23.64 mg/L	0	0	0
Agral	20 mg/L	0	0	0
Agral	5 mg/L	3-2	2	1
Tecto	1.66 g/L	1-0	0	0
Ridomil	800 mg/L	2	0	0
Sodium dodecyl sulphate	10 mg/L	2	1	0
Sodium dodecyl sulphate	5μg/L	2	2-1	2-1
Filex	2.5 ml/L	3-2	1	0
Benomyl	0.1 g/L	3-2	2	1-0
Zinc Sulphate	50 mg/L	-	2	2-1
Lime pH 9	-	3	2	2-1
Lime pH 7.6	-	3	2	2-1
Zinc Oxide	14.13 mg/L	3-2	3-2	2-1
$CaCO_3$	1%	3	3-2	3-2
Fungaflor	0.125 ml/L	3-2	3-2	3-2
Bavistin WP	2.52 g/L	3-2	3-2	2-1
Bavistin WP	0.252 g/L	3	3-2	2
Bavistin WP	0.126 g/L	3	3-2	2
*Bavistin WP	2.52 g/L	3-2	2	1
*Bavistin WP	0.252 g/L	3-2	3-2	2-1
*Bavistin WP	0.126 g/L	3-2	3-2	2
Bavistin DF	2.52 g/L	3-2	2-1	1-0
Bavistin DF	0.252 g/L	3	3-2	1
Bavistin DF	0.126 g/L	3	3-2	2
*Bavistin DF	2.52 g/L	3-2	3-2	2-1
*Bavistin DF	0.252 g/L	3-2	3-2	2
*Bavistin DF	0.126 g/L	3	3-2	2

* Dialysed Bavistin solutions

Table 9. Products tested for their efficacy in controlling LBVV symptoms.

Treatment	Active Ingredient	Rate	Ranking for efficacy based on % of plants with symptoms after 80 days + symptom severity
Drenches			
Tecto †	Thiabendazole	1.66 g/L	2
Sodium dodecyl sulphate	Wetter	5mg/L	3
Agribrom	Halogenated compound containing bromine and chlorine	0.5%	4
Ridomil 25 WP	Metalaxyl	800mg/L	5
Benlate	Benomyl	0.1g/L	6=
Panacide M	Dichlorophen	2.0%	6=
Zinc chloride	-	23.64mg/L	8
Fluazinam	3-chloro-N-(3-chloro-2,6-dinitro-4-trifluoromethyl)-phenyl-5-trifluoromethyl-2-pyridinamine	4g/L	11
Patrol †	Fenpropidin	0.19-0.37%	12
Fubol 58 WP	Metalaxyl + Mancozeb	0.02-0.04%	14=
Agral	Wetter	0.5%	17
Filex	Propamocarb hydrochloride	2.5ml/L	19
Dithane 945	Mancozeb	2.19g/L	20
Iodel FD	Iodine + phosphoric and sulphuric acids	1.0%	21
Block Incorporated			
Aliette Extra	Captan + fosetyl-Al + thiabendazole	900g/m^3	1
Tachegaren †	Hymexazol	252g/m^3	9
Bavistin WP	Carbendazim	252g/m^3	10
Lime	-	350kg/m^3	13
Bavistin DF	Carbendazim	252g/m^3	14=
Aliette	Fosetyl - Al	900g/m^3	18
Untreated control	-	-	16

† Phytotoxic to lettuce plants

In the next set of experiments where the most promising products were examined in more detail, Bavistin WP gave the best control followed by fluazinam (Table 10). Although Hymush and Tecto gave some control they were slightly phytotoxic.

Table 10. Products tested for their efficacy in controlling LBVV symptoms in pot experiments.

Treatment	Active Ingredient	Rate	Ranking for efficacy based on symptom severity + % of plants with symptoms after 80 days.
Drenches			
Hymush †	Thiabendazole	1.66g/L	3=
Tecto †	Thiabendazole	1.66g/L	3=
Sodium dodecyl sulphate	Wetter	5 mg/L	5
Fluazinam	3-chloro-N-(3-chloro-2, 6-dinitro-4-trifluoromethyl)-phenyl-5-trifluoromethyl-2-pyridinamine	4g/L	2
Zinc chloride	-	0.05g/L	8
Block incorporated			
Bavistin WP	Carbendazim	252g/m^3	1
Aliette Extra*	Captan+fosetyl-Al+thiabendazole	900g/m^3	7
Untreated control	-	-	6

* Reduced germination of lettuce seeds
† Slightly phytotoxic in some experiments

Field and polytunnel experiments
1991

Artificial inoculation, using soil/root debris from a known big-vein contaminated site incorporated into the blocking compost, was very successful in reproducing characteristic symptoms of big-vein virus in both protected 'flat' and outdoor crisp lettuce. It should be noted, however, that symptoms are very much weather related and whilst every effort was made to ensure favourable conditions by conducting trials in the Autumn, it could not be guaranteed.

In the protected lettuce trial in 1991, symptoms consistent with those of big-vein occurred ca. 6 weeks after artificial contamination of the propagation blocks when almost all the plants in the inoculated control exhibited big-vein symptoms (Tables 11 and 11a), though interestingly 40% of plants were also recorded as infected in the uninoculated control plants during this interim assessment. At this stage the only treatment that significantly reduced the incidence of big-vein as compared to the inoculated control was Aliette applied as block incorporation treatment according to manufacturers label recommendations.

At crop termination on 10 October when symptoms were much clearer infection levels in the inoculated control were moderately high at 53% (Table 12). The Aliette block incorporation treatment provided outstanding control, the earlier recorded symptoms in the interim assessment no longer in evidence and a 0% plant infection recorded.

Bavistin WP applied according to the earlier (now lapsed) label recommendation provided some suppression though not significantly so (P = 0.05), whereas Bavistin DF (the new formulation) did provide a significant suppression as compared to the inoculated control. The higher rate of Bavistin DF in this trial provided a further marginal reduction in infection though for some unexplained reason a high level of infection was recorded where an additional drench treatment was applied post-planting. None of the other treatments provided any control of big-vein virus and indeed some treatments appeared to exacerbate the disease. A satisfactory explanation for this apparent increase in disease incidence is not available.

When the crop was harvested yield determinations were made on both untrimmed lettuce and lettuce trimmed to a commercial standard (Table 13). Interestingly, the presence of big-vein virus reduced both the untrimmed and trimmed yield significantly as compared with the uninoculated control (15-16% yield loss) and this was considered to be due largely to the poor hearting in infected plants. The only treatment to significantly increase the untrimmed yield was Aliette applied according to the manufacturers recommendation as a block incorporation. The mean head weight of lettuce from both the Agribrom and the Tachegaren treated plots was significantly reduced suggesting phytotoxicity had occurred, even though this was not apparent visually in the crop.

Infection levels in the outdoor crop in an interim assessment was lower with only 27% plants affected 9-10 weeks after artificial inoculation (Table 14). Interestingly, this extended period between inoculation and symptom expression outdoors may have been due to the increased light levels and lower temperatures outdoors as compared with those under protection in a polythene tunnel, though this was not measured. Symptoms of big-vein infection could be found in all treatments with the exception of the uninoculated control. However Bavistin WP and Bavistin DF (all 3 treatments) reduced infection significantly. Aliette block incorporation reduced infection from 27 to 16% plant infection and this was significant at the 6% level of probability (P = 0.06). None of the other treatments were effective.

By harvest in early November 69% of plants exhibited symptoms in the inoculated control (Table 15) and surprisingly all treatments with the exception of the uninoculated control showed moderate infection levels. The most effective treatment was Bavistin DF (0.04 g/block) which significantly reduced infection levels by 44%. Aliette, by comparison, was disappointing reducing infection at harvest by only 27%. Only untrimmed head weights were recorded in this trial (Table 16 and 16a) and surprisingly, unlike the 'flat' lettuce trial yield was unaffected by the big-vein infection.

1992

The protected lettuce trial was repeated on the same site following the addition of further big-vein contaminated material, and as such it was not possible to have an uninoculated treatment for comparative purposes.

Whilst infection levels in 1991 had been high and additional infested material added, infection levels remained relatively low in 1992. In an interim assessment conducted on 19 September only 14% plants exhibited big-vein (Tables 17 and 17a) though by harvest 64% plants showed some symptoms of infection (Tables 18 and 18a). Most treatments with the exception of sodium lauryl sulphate and Aliette applied according to the modified Specific Off-Label Approval, reduced infection levels in the interim assessment, though not significantly so. Aliette block incorporation gave the lowest infection level of 1.3% plants infected compared to 13.8% for the untreated control. Symptoms were very difficult to assess in this trial at harvest and whilst several treatments appeared to reduce infection significant differences were not recorded. Interestingly, large differences in bottom-rots caused primarily by *B. cinerea* and *R. solani* were noted in this trial (Tables 19 and 19a) and some treatments reduced this significantly.

Yields (untrimmed and trimmed) were recorded at harvest but none of the treatments significantly improved head weights as compared to the untreated control (Table 20). Thiabendazole (Hymush) produced the lowest yield whereas the Aliette SOLA treatment gave the highest yield and this difference was significant.

A virgin site was used for the outdoor crisp lettuce trial in 1992 and again contaminated material was incorporated into the peat blocks. Big-vein infection was first noticed on 24 September some 11 weeks after artificial inoculation and even then only 16% plants were infected (Tables 21 and 21a). Most treatments with the exception of sodium dodecyl sulphate and Aliette applied according to the modified SOLA reduced the level of symptom expression, most significantly so, and in the Bavistin DF (0.04 g/plant) and Hymush treatments big-vein symptoms were not recorded at all.

By harvest on 16 October 27% plants exhibited big-vein in the inoculated control and again most treatments had effectively suppressed the disease (Tables 22 and 22a). Bavistin WP provided a moderate but significant suppression though Bavistin DF at the same rate was slightly more effective. Aliette block incorporation provided an extremely good suppression though its performance was bettered by Hymush which provided complete freedom from big-vein in this trial (but see additional comments on phytotoxicity).

At harvest the yield was reduced following infection but not significantly so (Table 23). The yield in most treatments was unaffected though unfortunately Hymush appeared to depress yield again even in the absence of visual symptoms of phytotoxicity.

1993

No results are available for the protected lettuce trial conducted on a naturally infected grower site. Unfortunately, shortly after the trial was planted out a severe infection with downy mildew (*B. lactucae*), another oomycete, occurred and this jeopardised the adjacent commercial crop. As a standard *Bremia* control programme could not be applied due to potential interference with *O. brassicae* carrying big-vein virus a decision was taken to safeguard the commercial crop and the trial was terminated prematurely. This was particularly unfortunate as big-vein symptoms were just becoming apparent in adjacent bays of the glasshouse where infection levels of 20-30% were recorded.

The outdoor trial progressed extremely well on a site where lettuce had been grown consistently and where big-vein virus had been recorded at moderate-high levels, including in earlier crops that same year. Unfortunately, however, in the area the trial was laid down big-vein occurred at negligible levels only and whilst the trial was continued through to conclusion data on efficacy of the various treatments under commercial conditions was not secured.

Untrimmed and trimmed yield data was gathered and this clearly demonstrated a high risk of phytotoxicity from Hymush (Table 24). Both the untrimmed and trimmed yield was significantly depressed, particularly by the drench applications of thiabendazole but also by the block incorporation in conjunction with Aliette.

Table 11: Interim assessment of big-vein symptoms in protected lettuce - HRI Stockbridge House (Autumn 1991).

Treatments	Interim Assessment (23 September)*	
	% Plants with big-vein symptoms^Δ	Disease Index
Uninoculated control	40.0	9.52 (-2.21)
Inoculated control+	97.5	52.97 (0.12)
Bavistin WP (0.02 g)+	98.8	57.07 (0.28)
Bavistin DF (0.02 g)+	97.5	58.01 (0.32)
Bavistin DF (0.04 g)+	95.0	51.96 (0.08)
Bavistin DF (0.04 g) + Drench+	98.8	51.61 (0.06)
Iodel+	97.5	52.27 (0.13)
Agral+	100.0	59.74 (0.39)
Aliette BI (900 g/m^3)+	53.8	19.33 (-1.41)
Filex+	98.8	70.72 (0.87)
Agribrom+	100.0	75.52 (1.11)
Tachegaren+	100.0	44.94 (-0.20)
Comparing the inoculated control with the mean of the inoculated treatments		
SED (30 df)	-	- (0.296)
LSD (5%)	-	- (0.604)
Comparing differences between the inoculated treatments only		
SED (30 df)	-	- (0.401)
LSD (5%)	-	- (0.819)

* Back transformed data is presented with logit transformed data in parentheses.

Δ Formal ANOVA not conducted and significance assumed for uninoculated control treatment and Aliette block incorporation.

\+ Treatments artificially inoculated with big-vein virus.

Table 12: Assessment of big-vein symptoms in protected lettuce at crop termination - HRI Stockbridge House (Autumn 1991).

Treatments	Harvest Assessments (10 October)	
	% Plants with Big-Vein Symptoms	Disease Index
Uninoculated control	0.0	0.0
Inoculated control+	52.8	21.3
Bavistin WP (0.02 g)	34.5	16.5
Bavistin DF (0.02 g)	21.5	7.2
Bavistin DF (0.04 g)	19.5	6.9
Bavistin DF (0.04 g) + Drench+	46.2	21.4
Iodel+	59.8	26.7
Agral+	50.5	21.5
Aliette BI (900 g/m^3)+	0.0	0.0
Filex+	68.4	32.8
Agribrom+	74.1	36.0
Tachegaren+	74.3	42.9
Comparing the uninoculated control with the mean of the inoculated treatments		
SED (30 df)	10.67	6.30
LSD (5%)	21.78	12.86
Comparing differences between the inoculated treatments only		
SED (30 df)	14.45	8.53
LSD (5%)	29.50	17.41

Data not transformed, raw data presented.

+ Treatments artificially inoculated with big-vein.

Table 13: Untrimmed and trimmed head weight of protected lettuce at harvest - HRI Stockbridge House (1991).

Treatments	Harvest Assessments (10 October)	
	Mean untrimmed head weight per plant (g)	Mean trimmed head weight per plant (g)
Uninoculated control	295.0	277.5
Inoculated control+	251.3	232.5
Bavistin WP (0.02 g)+	246.3	220.0
Bavistin DF (0.02 g)+	243.8	218.7
Bavistin DF (0.04 g)+	258.7	236.2
Bavistin DF (0.04 g) + Drench+	245.0	222.5
Iodel+	236.3	222.5
Agral+	240.0	223.7
Aliette+	297.5	271.2
Filex BI (900 g/m3)+	226.3	212.5
Agribrom+	213.8	197.5
Tachegaren+	177.5	156.2
Comparing the uninoculated control with the mean of the inoculated treatments		
SED (30 df)	11.64	11.41
LSD (5%)	23.76	23.29
Comparing differences between inoculated treatments		
SED (30 df)	15.76	15.45
LSD (5%)	32.18	31.54

Data not transformed, raw data presented.

\+ Treatments artificially inoculated with the big-vein virus.

Table 14: Interim assessment of big-vein symptoms in outdoor lettuce - HRI Stockbridge House (Autumn 1991).

Treatment	Interim Assessment (3 October)
	% Plants with big-vein virus
Uninoculated control	0.0
Inoculated control+	27.0
Bavistin WP (0.02 g)+	9.8
Bavistin DF (0.02 g)+	8.7
Bavistin DF (0.04 g)+	6.8
Bavistin DF (0.04 g) + Drench+	9.6
Iodel+	36.9
Agral+	32.8
Aliette+	15.9
Filex+	40.9
Agribrom+	43.2
Tachegaren+	30.1
Comparing differences between the inoculated treatments only	
SED (30 df)	5.61
LSD (5%)	11.45

Statistical analysis excludes Treatment 1 (uninoculated control).

Data not transformed, raw data presented.

\+ Treatments artificially inoculated with the big-vein virus.

Table 15: **Assessment of big-vein symptoms in outdoor lettuce at crop termination - HRI Stockbridge House (Autumn 1991).**

Treatments	Harvest Assessments (6.11.91)	
	% Plants with big-vein symptoms	Disease Index
Uninoculated control	0.0	0.0
Inoculated control+	68.8	37.9
Bavistin WP (0.02 g)+	46.2	25.0
Bavistin DF (0.02 g)+	54.7	28.7
Bavistin DF (0.04 g)+	38.7	22.5
Bavistin DF (0.04 g) + Drench+	42.5	23.7
Iodel+	71.7	45.1
Agral+	67.5	42.0
Aliette BI (900 g/m^3)+	50.0	26.7
Filex+	86.3	51.2
Agribrom+	88.8	55.0
Tachegaren+	76.9	50.2
Comparing differences between the inoculated treatments only		
SED (29 df)	10.43	6.81
LSD (5%)	21.32	13.92

Analysis excludes Treatment 1 (uninoculated control).

Data not transformed, raw data presented.

+ Treatments artificially inoculated with the big-vein virus.

Table 16: Untrimmed head weight of outdoor lettuce at crop termination - HRI Stockbridge House (1991).

Treatments	Harvest Assessments (6 November)* Mean untrimmed head weight/plant
Uninoculated control	2.50
Inoculated control+	2.36
Bavistin WP (0.02 g)+	2.45
Bavistin DF (0.02 g)+	2.34
Bavistin DF (0.04 g)+	2.41
Bavistin DF (0.04 g) + Drench+	2.39
Iodel+	2.37
Agral+	2.24
Aliette BI (900 g/m^3)+	2.41
Filex+	2.26
Agribrom+	2.30
Tachegaren+	2.05
Comparing the uninoculated control with the mean of inoculated treatment:	
SED (32 df)	0.09
LSD (5%)	NS
Comparing differences between inoculated treatments	
SED (32 df)	0.12
LSD (5%)	NS

* Data transformed - log_{10}.

\+ Treatments artificially inoculated with the big-vein virus.

Table 17: Interim assessments of plant vigour and big-vein symptoms in protected lettuce - HRI Stockbridge House (Autumn 1992).

Treatments+	Interim Assessments	
	Mean plant vigour score△ (0-3) (1 October)	% Plants with big-vein symptoms (19 September)*
Untreated control	1.00	13.22 (-1.85)
Bavistin WP (0.02 g)	1.75	5.23 (-2.81)
Bavistin DF (0.02 g)	1.25	2.37 (-3.51)
Bavistin DF (0.04 g)	2.50	9.21 (-2.24)
Bavistin DF (0.04 g) + Drench	2.75	2.43 (-3.51)
Hymush	1.75	1.73 (-3.79)
Aliette BI (450 g)	0.50	4.29 (-3.00)
Aliette BI (900 g)	0.50	0.41 (-4.69)
Aliette (modified SOLA)	1.00	12.41 (-1.92)
Aliette (SOLA)	0.75	6.81 (-2.55)
Filex	0.75	4.24 (-3.01)
Sodium Dodecyl Sulphate	1.50	20.96 (-1.31)
Comparing the control with the mean of the other treatments		
SED (30 df)	0.299	(0.897)
LSD (5%)	NS	(NS)
Comparing differences between the applied treatments (untreated control excluded)		
SED (30 df)	0.4048	(1.214)
LSD (5%)	0.82	(NS)

△ Data not transformed, raw data presented.

* Back transformed data is presented with logit transformed data in parentheses.

\+ Site already contaminated with the big-vein virus, although additional contaminated material incorporated.

Table 18: Assessment of big vein symptoms in protected lettuce at crop termination - HRI Stockbridge House (Autumn 1992).

Treatments+	Harvest Assessments (20 October)*	
	% Plants with big-vein symptoms	Disease Index
Untreated control	63.78 (0.56)	36.21 (-0.56)
Bavistin WP (0.02 g)	62.13 (0.49)	37.15 (-0.52)
Bavistin DF (0.02 g)	48.73 (-0.05)	28.87 (-1.04)
Bavistin DF (0.04 g)	43.47 (0.26)	28.48 (-0.91)
Bavistin DF (0.04 g) + Drench	22.34 (-1.23)	14.45 (-1.75)
Hymush	24.34 (-1.12)	13.95 (-1.79)
Aliette BI (450 g)	43.22 (-0.27)	24.19 (-1.09)
Aliette BI (900 g)	56.27 (0.25)	23.78 (-1.15)
Aliette (modified SOLA)	50.75 (0.03)	25.10 (-1.08)
Aliette (SOLA)	46.97 (-0.12)	22.34 (-1.23)
Filex	47.22 (-0.11)	23.05 (-1.19)
Sodium Dodecyl Sulphate	67.21 (0.71)	37.15 (-0.52)
Comparing the untreated control with the mean of the other inoculated treatments		
SED (30 df)	(0.517)	(0.392)
LSD (5%)	(NS)	(NS)
Comparing differences between the applied treatments (untreated control excluded)		
SED (30 df)	(0.700)	(0.531)
LSD (5%)	(NS)	(NS)

* Back transformed data represented with logit transformed data in parentheses.

\+ Site already contaminated with the big-vein virus, although additional contaminated material incorporated.

Table 19: **Assessment of bottom rots in protected lettuce at crop termination - HRI Stockbridge House (Autumn 1992).**

Treatments[+]	Harvest Assessments (27 October)*	
	% Plants with bottom rot	Disease Index
Untreated control	25.87 (-1.04)	10.13 (-2.14)
Bavistin WP (0.02 g)	47.47 (-0.10)	20.96 (-1.31)
Bavistin DF (0.02 g)	58.25 (0.33)	24.3 (-1.11)
Bavistin DF (0.04 g)	43.22 (-0.27)	17.33 (-1.54)
Bavistin DF (0.04 g) + Drench	45.96 (-0.16)	10.07 (-1.49)
Hymush	18.69 (-1.45)	6.48 (-2.60)
Aliette BI (450 g)	30.16 (-0.83)	12.98 (-1.87)
Aliette BI (900 g)	39.30 (-0.43)	16.04 (-1.63)
Aliette (modified SOLA)	10.13 (-2.14)	4.47 (-2.96)
Aliette (SOLA)	12.07 (-1.95)	4.33 (-2.99)
Filex	18.38 (-1.47)	6.22 (-2.64)
Sodium Dodecyl Sulphate	23.34 (-1.23)	12.30 (-1.93)
Comparing the untreated control with the mean of the other inoculated treatments		
SED (30 df)	(0.507)	(0.416)
LSD (5%)	(NS)	(NS)
Comparing differences between the applied treatments (untreated control excluded)		
SED (30 df)	(0.686)	(0.564)
LSD (5%)	(1.40)	(1.15)

* Back transformed data represented with logit transformed data in parentheses.

\+ Site already contaminated with the big-vein virus, although additional contaminated material incorporated.

Table 20: Untrimmed and trimmed head weights of protected lettuce at harvest - HRI Stockbridge House (Autumn 1992).

Treatments+	Harvest Assessments (27 October)*	
	Mean untrimmed head weight /plant (g)	Mean trimmed head weight /plant (g)
Untreated control	244.0	198.8
Bavistin WP (0.02 g)	235.7	192.3
Bavistin DF (0.02 g)	238.0	200.0
Bavistin DF (0.04 g)	235.7	195.8
Bavistin DF (0.04 g) + Drench	235.7	199.3
Hymush	226.7	188.3
Aliette BI (450 g)	253.0	203.8
Aliette BI (900 g)	254.5	210.0
Aliette (modified SOLA)	249.2	203.5
Aliette (SOLA)	264.7	223.5
Filex	256.7	221.3
Sodium Dodecyl Sulphate	240.7	202.5
Comparing the control with the mean of the other inoculated treatments		
SED (30 df)	(7.05)	(7.57)
LSD (5%)	(NS)	(NS)
Comparing differences between the applied treatments (untreated control excluded)		
SED (30 df)	(9.54)	(10.25)
LSD (5%)	(19.48)	(20.93)

* Data not transformed, raw data presented.

\+ Site already contaminated with the big-vein virus, although additional contaminated material incorporated.

Table 21: Interim assessment of big-vein symptoms in outdoor lettuce - HRI Stockbridge House (Autumn 1992)

Treatments	Interim Assessments (24 September)*
	% Plants with big-vein symptoms
Uninoculated control	0.0 (-5.30)
Inoculated control+	11.02 (-2.05)
Bavistin WP (0.02 g)+	1.07 (-4.15)
Bavistin DF (0.02 g)+	0.83 (-4.32)
Bavistin DF (0.04 g)+	0.0 (-5.30)
Bavistin DF (0.04 g) + Drench+	2.13 (-3.62)
Hymush BI + Drench+	0.0 (-5.30)
Aliette BI (900 g/m^3)+	1.32 (-4.00)
Aliette (modified SOLA)+	18.82 (-1.49)
Aliette (SOLA)+	6.42 (-2.61)
Filex+	5.74 (-2.72)
Sodium Dodecyl Sulphate+	10.81 (-2.07)
Comparing the uninoculated control with the mean of the inoculated treatments	
SED (33 df)	(0.488)
LSD (5%)	(0.99)
Comparing differences between the inoculated treatments only	
SED (33 df)	(0.661)
LSD (5%)	(1.34)

* Back transformed data presented, logit transformed data in parentheses.

\+ Treatments artificially inoculated with the big-vein virus.

Table 22: Assessment of big-vein symptoms in outdoor lettuce at crop termination - HRI Stockbridge House (Autumn 1992).

Treatments	Harvest Assessments (16 October)*	
	% Plants with big-vein symptoms	Disease Index
Uninoculated control	0.0 (-5.30)	0.0 (-5.30)
Inoculated control+	23.60 (-1.16)	14.45 (-1.75)
Bavistin WP (0.02 g)+	2.13 (-3.62)	1.48 (-3.91)
Bavistin DF (0.02 g)+	0.53 (-4.57)	0.37 (4.74)
Bavistin DF (0.04 g)+	1.54 (-3.88)	0.76 (-4.37)
Bavistin DF (0.04 g) + Drench+	6.88 (-2.54)	3.38 (-3.22)
Hymush BI + Drench+	0.0 (-5.30)	0.0 (-5.30)
Aliette BI (900 g/m^3)+	3.45 (-3.20)	2.23 (-3.58)
Aliette (modified SOLA)+	26.26 (-1.02)	19.33 (-1.41)
Aliette (SOLA)+	12.64 (-1.90)	9.30 (-2.32)
Filex+	8.87 (-2.28)	5.56 (-2.75)
Sodium Dodecyl Sulphate+	16.60 (-1.59)	9.57 (-2.20)
Comparing the uninoculated control with the mean of the inoculated treatments		
SED (33 df)	(0.498)	(0.45)
LSD (5%)	(0.99)	(0.92)
Comparing differences between the inoculated treatments		
SED (33 df)	(0.675)	(0.611)
LSD (5%)	(1.37)	(1.24)

* Back transformed data represented with logit transformed data in parentheses.

\+ Treatments artificially inoculated with the big-vein virus.

Table 23: **Untrimmed and trimmed head weight of outdoor lettuce at harvest - HRI Stockbridge House (Autumn 1992).**

Treatments	Harvest Assessments (16 October)	
	Mean untrimmed head weight /plant (g)	Mean trimmed head weight /plant (g)
Uninoculated control	447.5	342.5
Inoculated control+	430.0	267.5
Bavistin WP (0.02 g)+	462.5	370.0
Bavistin DF (0.02 g)+	432.5	330.0
Bavistin DF (0.04 g)+	432.5	325.0
Bavistin DF (0.04 g) + Drench+	442.5	317.5
Hymush BI + Drench+	392.5	295.0
Aliette BI (900 g/m^3)+	445.0	322.5
Aliette (modified SOLA)+	445.0	247.5
Aliette (SOLA)+	457.0	300.0
Filex+	407.5	307.5
Sodium Dodecyl Sulphate+	442.5	302.5
Comparing the inoculated control with the mean of the inoculated treatments		
SED (30 df)	16.90	18.11
LSD (5%)	34.5	NS
Comparing differences between the inoculated treatments only		
SED (30 df)	22.89	24.52
LSD (5%)	NS	50.0

Data not transformed, raw data presented.

\+ Treatments artificially inoculated with big-vein virus.

Table 24: Untrimmed and trimmed head weight of outdoor lettuce at harvest - HRI Stockbridge House (Autumn 1993).

Treatments[+]	Harvest Assessments (20 October)	
	Mean untrimmed head weight /plant (g)	Mean trimmed head weight /plant (g)
Untreated control	656.5	347.7
Bavistin WP (0.02 g)	623.5	306.0
Bavistin DF (0.02 g)	630.3	328.0
Bavistin DF (0.04 g)	567.8	282.7
Bavistin DF (0.04 g)+ Drench	619.8	311.7
Hymush (BI)	529.8	230.0
Hymush drenches	305.3	115.7
Aliette BI (450 g)	634.8	327.5
Aliette BI (900 g)	648.8	335.2
Aliette (SOLA)	670.8	325.7
Aliette BI + Hymush BI	531.8	222.7
Per-acetic acid	648.3	328.0
Comparing the untreated control with the mean of the other inoculated treatments		
SED (33 df)	22.82	15.96
LSD (5%)	46.59	32.59
Comparing differences between the applied treatments (untreated control excluded)		
SED (33 df)	30.89	21.61
LSD (5%)	63.07	44.12

Data not transformed, raw data presented.

+ Artificial inoculation was not carried out as a naturally infested grower site used.

NB: High level of trimming required due to superficial frost damage.

Laboratory-based experiments to determine the ability of disinfectants to kill resting spores of *Olpidium brassicae*

All the 32 products that were tested for their ability to kill resting spores are listed in table 25.

Table 25. Various products tested for their ability to kill *Olpidium brassicae* resting spores ranked in order of efficacy.

Product	Product Type	Concentration of product (%w/v or v/v)	% Plants infected by *Olpidium brassicae*
Untreated control	-	-	100
Iodel FD	Disinfectant	0.8	0
Iodosan B	Sanitiser	0.1	0
Jet 5	Disinfectant	5.0	0
Medentech A	Disinfectant	0.1	0
Medentech A + Agral	Disinfectant + Wetter	0.1	0
Medentech B	Disinfectant	0.1	0
Medentech D	Disinfectant + Wetter	0.1	0
Sodium hypochlorite	Disinfectant	10.0	0
Divosan LF	Sanitiser	0.3	3
Antec Farm Fluid S*	Disinfectant	2.0	5
Agribrom	Fungicide, Bactericide,Algicide, Anti-viral	0.5	6
Jeyes Fluid	Disinfectant	3.5	54
Panacide M	Disinfectant	1.0	61
Virkon S	Disinfectant/ Detergent	1.0	64
Menno Ter Forte	Disinfectant	0.8	69
Nalco 1115	Bactericide	0.2	72
Hycolin	Disinfectant	2.0	88
Panaclean, 736	Disinfectant	0.1	90
Bacta San	Bactericidal detergent	0.2	94
Opticide H	Disinfectant	1.0	94
Ter-Spezial	Disinfectant	1.0	94
Traymatic	Detergent	30.0	94
Armillatox	Fungicide	1.0	100
Cationic Pine Disinfectant	Disinfectant	3.3	100
Chitin	-	0.05	100
Gen 1	Detergent	0.3	100
Micro	Detergent	2.0	100
Myacide AS	Bactericide	0.1	100
Myacide SP	Bactericide, Fungicide	0.5	100
Ocean Supermix	Organic fertilizer	2.7	100
Prempol X	Detergent	0.6	100
QED Plus 18	Dishwasher liquid	0.3	100

*Residue was phytotoxic

The only products that killed all *O. brassicae* resting spores at the concentrations used were: Iodel FD, Jet 5, sodium hypochlorite, Iodosan B and Medentech, A, B and D. These and any other promising products were then tested further, to determine their ability to kill resting spores mixed with soil, to compare their cost effectiveness and determine their minimum effective concentrations. Some of these products gave no control in the presence of soil, and at the concentration used only Jet 5 killed all resting spores (Table 26).

Table 26. The efficacy of the most effective products in killing *Olpidium brassicae* resting spores in soil.

Product	Concentration of product (% w/v or v/v)	% plants infected by *Olpidium brassicae*
Untreated control	-	100
Iodel FD	0.8	31
Iodel FD	1.6	13
Sodium hypochlorite	10.0	25
Medentech A	0.1	100
Iodosan B	0.1	100
Divosan LF	0.3	42
Jet 5	5.0	0

The best three products from this test (Jet 5, Iodel FD and sodium hypochlorite) were then tested on an equal cost basis (Table 27).

On a cost basis Jet 5 was more effective than Iodel FD and sodium hypochlorite was more effective than Jet 5. However, dairy grade sodium hypochlorite contains trace levels of chlorate and can be extremely toxic to lettuce; these products should not be used on concrete surfaces which will subsequently come into contact with plants. Jet 5 breaks down to 'natural' products i.e. oxygen, water and acetic acid (vinegar).

Table 27. The efficacy of different concentrations of Jet 5, Iodel FD and sodium hypochlorite in killing *Olpidium brassicae* resting spores in soil.

Product	Concentration (% v/v)	Relative cost increases	% plants infected by *Olpidium brassicae*
Jet 5	1.5	*	81
Sodium hypochlorite	26	*	0
Jet 5	2	**	0
Sodium hypochlorite	34	**	0
Jet 5	2.5	***	0
Iodel FD	4.15	***	25
Sodium hypochlorite	43	***	0
Jet 5	5	****	0
Iodel FD	8.3	****	0
Sodium hypochlorite	86	****	0

Discussion

Of the products that were tested in laboratory-based pot experiments prior to field testing, the new fungicide fluazinam (50% wettable powder formulation) from Ishihara Sangyo Kaisha and licensed to ICI Agrochemicals for the UK market looked promising. It has also been reported to give excellent control of another virus disease transmitted by a fungus (Rhizomania of sugar beet) in field trials and warrants further evaluation for its ability to control big-vein in the field.

Whilst, the field and polytunnel trial series has confirmed that Bavistin WP can provide a moderate suppression of big-vein, particularly in outdoor crisp lettuce, the product has now been superseded with an alternative formulation Bavistin DF. This new formulation contains the same wetting agents, possibly the components with activity against *O. brassicae*, but they are present in different proportions. Whether Bavistin DF could therefore provide the same level of control when used at the same rate or whether an increased rate would be necessary, was open to some speculation. If a higher rate was required for effective control would the increased dose of carbendazim be phytotoxic? Fortunately, these trials would appear to demonstrate that Bavistin DF is equally, if not slightly more, effective than Bavistin WP when used at the same rate. Surprisingly there appeared to be little evidence of increased effectiveness at the higher rates used though in the protected lettuce trials in 1992 and 1993 some phytotoxicity symptoms were recorded post-planting. This did not appear to affect the yield significantly in the 1992 trial where yield was recorded.

Further evaluation will clearly be necessary to ensure the DF formulation of Bavistin is not phytotoxic at the lower rate tested. In the meantime, however preliminary discussions should commence with the manufacturer to determine whether this use can be transferred to the new formulation. Alternatively, residue data could be generated as part of the SOLA programme to secure a new Specific Off-Label Approval for this use.

Aliette applied as a block incorporation according to label recommendations provided an outstanding suppression of big-vein in the first year's trial on 'flat' lettuce under protection. Unfortunately, the same degree of control was not achieved in subsequent trials where only moderate control was recorded. Why this variable control should occur is open to some speculation though one possibility is the source of infection. In 1991, when the most effective control was secured, inoculum was introduced via the propagation block precisely where the fungicide was targeted. In later trials infection relied on 'natural' soil infection and the Aliette within the block may have been unable to provide protection from soil-borne *O. brassicae* as the lettuce rooted out from the blocks into the soil. However, this fails to explain why the same fungicide applied as a drench in propagation followed by HV sprays post-planting (ie the SOLA treatments) tended to be even less effective. Clearly this aspect requires further study, but in the meantime the industry can use Aliette legally in an attempt to suppress big-vein virus. Certainly its use is already advocated for the control of downy mildew (*B. lactucae*), most growers opting for the SOLA use rather than the block incorporation due to the relatively high cost of the latter treatment. Where big-vein virus is troublesome growers should consider using Aliette in the blocks (NB. The label recommendation is for use during September - April only). This will also provide effective control of downy mildew for 6-8 weeks after which time Filex can safely be used for downy mildew control in conjunction with other products.

Hymush (thiabendazole) identified as a fungicide with potential activity in pot studies at HRI, Wellesbourne has been demonstrated to be effective in field-scale trials in this project. Unfortunately, however, it has also been shown to be phytotoxic reducing yield significantly in the outdoor trial in 1993. There are currently no Approved uses of this product and because of the yield reduction recorded it would be unadvisable to pursue this product further.

Numerous other products were also evaluated in this project but without success even though they were effective in pot studies at HRI, Wellesbourne. There is clearly a need for a better understanding of the epidemiology of the vector and the mode of action of the products under test in order that pot studies can be correlated more closely with commercial-scale studies in the future.

Since this project was undertaken further new oomycete products have been launched on the market and others are currently under development. It is likely that further products could be found with activity against *O. brassicae* in the future.

The identification of effective disinfectants will now allow propagators to kill the resting spores of the fungus adhering to trays and other surfaces and thus break this part of the infection cycle. As well as the products that worked it is important to list all those that did not work, as some are currently being used by propagators. Growers should note that products tested as disinfectants are for the disinfection of trays and other surfaces and not for use directly on plants or in the field.

Conclusions

- A laboratory-based pot assay for testing fungicides and other products for their ability to control big-vein symptoms was successfully devised and deployed.
- Some of the twenty products identified as effective by this pot assay proved effective in field trials, these included: Bavistin WP, Bavistin DF and Hymush/Tecto (thiabendazole).
- Fluazinam was identified as effective in the pot assay and warrants further evaluation in field and polytunnel experiments.
- Symptoms consistent with those of big-vein virus could be readily reproduced in both protected 'flat' and outdoor crisp lettuce following artificial inoculation using soil/root debris from a known contaminated site.
- Bavistin WP applied as a block incorporation treatment provided a moderate suppression of big-vein virus. It should be noted however that the label recommendation for this product has now lapsed.
- Bavistin DF was as effective as Bavistin WP when applied at the same rate though there was some evidence of phytotoxicity when it was used at higher rates. Again, there is currently no approval for use of this product on lettuce.
- Aliette applied as a block incorporation treatment according to label recommendations gave outstanding results in protected lettuce in 1991 but only moderate control in other trials. At reduced block incorporation rate or application according to the Specific Off-Label Approval (+/- modification) was much less effective.
- Hymush provided a very good suppression of big-vein in later trials but was phytotoxic on plants in the commercial trial on crisp lettuce in 1993, reducing yield significantly.
- Numerous other products with known activity against oomycete fungi failed to provide an effective suppression of big-vein virus.
- A laboratory-based test for determining the efficacy of disinfectants in killing resting spores of *Olpidium brassicae*, the vector of big-vein was successfully designed and deployed.
- Iodel FD, Jet 5, sodium hypochlorite, Iodosan B and Medentech A, B and D killed all resting spores in the absence of soil at the rates tested.
- In the presence of soil only Jet 5, Iodel FD and sodium hypochlorite killed all resting

spores at the rates tested.

- On a cost basis sodium hypochlorite was more effective than Jet 5 and Jet 5 was more effective than Iodel FD.

Acknowledgements

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The project builds on earlier MAFF funded research. Other research funded by MAFF on LBVV includes the development of diagnostics, the development of lettuce with resistance to big-vein and the potential for biological control of big-vein. Ultimately we are working towards an integrated strategy in which host plant resistance, appropriate chemical inputs, cultural practices and possibly biological agents will be used in concert to provide stable control.

The part of the project based at Wellesbourne was carried out on behalf of the HDC by Judith Bambridge, Fleur Stevenson and John Walsh.

Early field and polytunnel trials in this programme were carried out jointly with staff from HRI, Stockbridge House and ADAS, Leeds. Later studies were conducted by staff from HRI only, following transfer of Martin McPherson. The assistance of all staff involved in the programme was greatly appreciated. The work in Year 3 (1993) was conducted on commercial sites with the help of Mr J Sykes, 13 West Bank, Carlton and Mr L Arundel of Triffetts Nurseries, Thornton, York and their help and assistance is acknowledged.

APPENDIX I

Table 11a: Interim assessment of big-vein symptoms in protected lettuce - HRI Stockbridge House (Autumn 1991).

Treatments	Interim Assessment (23 September)
	Disease Index
Uninoculated control	17.1
Inoculated control	52.8
Bavistin WP (0.02 g)	56.2
Bavistin DF (0.02 g)	57.4
Bavistin DF (0.04 g)	51.6
Bavistin DF (0.04 g) + Drench	51.6
Iodel	53.3
Agral	59.5
Aliette BI (900 g/m^3)	22.0
Filex	67.8
Agribrom	73.3
Tachegaren	44.9

Raw data presented. For statistical analysis see transformed data in Table 11.

Table 16a: Untrimmed head weight of outdoor lettuce at harvest - HRI Stockbridge House (Autumn 1991).

Treatments	Harvest Assessment (6 November)
	Mean untrimmed head weight/plant (g)
Uninoculated control	329.3
Inoculated control	290.0
Bavistin WP (0.02 g)	287.5
Bavistin DF (0.02 g)	251.3
Bavistin DF (0.04 g)	310.0
Bavistin DF (0.04 g) + Drench	267.5
Iodel	246.3
Agral	196.3
Aliette BI (900 g/m^3)	281.3
Filex	198.8
Agribrom	221.3
Tachegaren	118.3

Raw data presented. For statistical analysis see transformed data in Table 16.

Table 17a: Assessment of big-vein symptoms in protected lettuce - HRI Stockbridge House (Autumn 1992).

Treatment	Interim Assessment (19 September)
	% Plants with big-vein symptoms
Untreated control	13.80
Bavistin WP (0.02 g)	10.00
Bavistin DF (0.02 g)	7.50
Bavistin DF (0.04 g)	11.30
Bavistin DF (0.04 g) + Drench	7.50
Hymush	5.00
Aliette BI (450 g)	7.50
Aliette BI (900 g)	1.30
Aliette (modified SOLA)	23.80
Aliette (SOLA)	12.50
Filex	16.30
Sodium Dodecyl Sulphate	26.30

Raw data presented. For statistical analysis see transformed data in Table 17.

Table 18a: Assessment of big-vein symptoms in protected lettuce at crop termination - HRI Stockbridge House (Autumn 1992).

Treatments	Harvest Assessment (27 October)	
	% Plants with big-vein symptoms	Disease Index
Untreated control	63.8	36.7
Bavistin WP (0.02 g)	60.0	38.3
Bavistin DF (0.02 g)	48.8	27.1
Bavistin DF (0.04 g)	43.8	29.6
Bavistin DF (0.04 g) + Drench	23.8	15.0
Hymush	25.0	14.6
Aliette BI (450 g)	45.0	29.6
Aliette BI (900 g)	53.8	27.1
Aliette (modified SOLA)	50.0	13.3
Aliette (SOLA)	47.5	25.0
Filex	47.5	23.8
Sodium Dodecyl Sulphate	66.3	37.9

Raw data presented. For statistical analysis see transformed data in Table 18.

Table 19a: Assessment of bottom rots in protected lettuce at crop termination - HRI Stockbridge House (Autumn 1992).

Treatments	Harvest Assessments (27 October)	
	% Plants with bottom rots	Disease Index
Untreated control	26.3	10.8
Bavistin WP (0.02 g)	47.5	21.7
Bavistin DF (0.02 g)	56.3	25.8
Bavistin DF (0.04 g)	43.8	18.8
Bavistin DF (0.04 g) + Drench	46.3	18.3
Hymush	22.5	8.3
Aliette BI (450 g)	31.3	14.2
Aliette BI (900 g)	40.0	17.9
Aliette (modified SOLA)	20.0	7.9
Aliette (SOLA)	13.8	5.4
Filex	21.3	7.5
Sodium Dodecyl Sulphate	31.3	14.2

Raw data presented. For statistical analysis see transformed data in Table 19.

Table 21a: Interim assessment of big-vein symptoms in outdoor lettuce - HRI Stockbridge House (Autumn 1992).

Treatments	Interim Assessment (24 September)
	% Plants with big-vein symptoms
Uninoculated control	0.0
Inoculated control	15.7
Bavistin WP (0.02 g)	2.9
Bavistin DF (0.02 g)	1.7
Bavistin DF (0.04 g)	0.0
Bavistin DF (0.04 g) + Drench	3.8
Hymush BI + Drench	0.0
Aliette BI (900 g/m^3)	1.8
Aliette (modified SOLA)	18.3
Aliette (SOLA)	7.9
Filex	6.3
Sodium Dodecyl Sulphate	12.8

Raw data presented. For statistical analysis see transformed data in Table 21.

Table 22a: Assessment of big-vein symptoms in outdoor lettuce at crop termination - HRI Stockbridge House (Autumn 1992).

Treatments	Harvest Assessments (16 October)	
	% Plants with big-vein symptoms	Disease Index
Uninoculated control	0.0	0.0
Inoculated control	27.1	17.6
Bavistin WP (0.02 g)	6.8	4.3
Bavistin DF (0.02 g)	0.8	0.6
Bavistin DF (0.04 g)	2.1	1.0
Bavistin DF (0.04 g) + Drench	8.9	5.3
Hymush BI + Drench	0.0	0.0
Aliette BI (900 g/m^3)	4.4	2.7
Aliette (modified SOLA)	27.3	20.1
Aliette (SOLA)	14.1	9.8
Filex	9.7	6.3
Sodium Dodecyl Sulphate	20.0	12.4=3

Raw data presented. For statistical analysis see transformed data in Table 22.

APPENDIX II

Pesticides applied to the protected lettuce crop in Autumn 1991.

Chemical	Date Applied
Thiram	23.9.91
Ambush C	23.9.91

Chemicals applied at rates recommended by manufacturers.

Pesticides applied to the protected lettuce crop in Autumn 1992.

Chemical	Date Applied
Ambush C	29.9.92

Chemicals applied at rates recommended by manufacturers.

No details are provided for the protected lettuce trial in 1993 as it was terminated prematurely and results are not presented.

Pesticides applied to the outdoor lettuce crop in Autumn 1991.

Chemical	Date Applied
Kerb	22.8.91
Rovral	29.8.91 12.9.91
Ambush C	10.9.91
Pirimor	10.9.91
Benlate	25.9.91

Chemicals applied at rates recommended by manufacturers.

Pesticides applied to the outdoor lettuce crop in Autumn 1992.

Chemical	Date Applied
Pirimor (pre-planting drench)	4.8.92
Kerb	11.8.92
Pirimor	13.8.92
Ambush C	13.8.92
Pirimor	24.8.92
Rovral	24.8.92

Chemicals applied at rates recommended by manufacturers.

Pesticides applied to the outdoor lettuce crop in Autumn 1993.

Chemical	Date Applied
Ramrod	17.8.93
Kerb	19.8.93
D.S.M	20.8.93

Chemicals applied at rates recommended by manufacturers.

(AMENDED 21/7/93)

Contract No: FV/PC 62

1. TITLE OF PROJECT

CONTROL OF BIG VEIN VIRUS SYMPTOMS AND ITS VECTOR OLPIDIUM BRASSICAE IN PROTECTED AND OUTDOOR LETTUCE CROPS

2. BACKGROUND

Lettuce big-vein virus, transmitted by the soil-borne fungus O. brassicae, is becoming increasingly prevalent in the main lettuce production areas of the UK, affecting both protected and outdoor crops. The symptoms are often not well recognised, particularly on butterhead cultivars, and a large proportion of affected plants are marketed. It may only be a matter of time before buyers begin to recognise the symptoms of the disease and reject affected consignments.

Growers frequently place the blame with plant raisers and certainly there have been instances where these allegations could be substantiated. However, the problem lies not only with the propagators. It is often the growers themselves, who are not aware that they have areas of contaminated land and return heavily contaminated trays to the plant raiser thereby risking contamination of the young plants in propagation.

It is in the interests of the lettuce industry as a whole to resolve the problem of lettuce big-vein. Already some of the leading propagators have recognised their responsibility and installed comprehensive tray washing facilities at no small expense and yet with no increased return on the plants. Important decisions regarding control measures are being taken without essential information e.g. which is the most effective disinfectant? What is the shortest contact time to kill oospores of the fungus?

A label recommendation for compost (block) incorporation of Bavistin WP for the prevention of big-vein was available until quite recently. This product (or at least certain components in the formulation) was effective in delaying infection and the onset of symptoms and allowed some crops to be grown without visible signs of infection. Unfortunately the manufacturers have reformulated the product into a dry flowable (DF) form and the new product does not have a recommendation for the control of lettuce big-vein. R & D is required to demonstrate the efficacy of this and other new products and to ensure there is no risk from phytotoxicity. If products are identified with activity against the disease preliminary negotiations will be made with the manufacturers to encourage them to collect residue data for an "On-Label" recommendation. If this approach is unsuccessful "Off-Label" Approval would be necessary.

3. OBJECTIVES

There are five primary objectives to this study:

1. To identify the effectiveness of Bavistin DF.

2. To attempt to secure an "On-" or "Off-Label" recommendation for the use of Bavistin DF or other formulations for the control of lettuce big-vein in protected and outdoor lettuce, assuming 1 above is confirmed.

3. To evaluate the potential of other fungicides and wetting agents for the control of lettuce big vein in protected and outdoor lettuce.

4. To evaluate a range of disinfectants with a view to identifying those with activity against the resting spores of O. brassicae with a short contact time and to determine the risk from phytotoxicity.

4. POTENTIAL BENEFIT TO THE INDUSTRY

Plant raisers will benefit through an improved customer confidence in their product and will themselves be in a stronger market position which may in the long-term increase sales. Growers will benefit with improved quality and productivity therefore, avoiding future market rejection due to big-vein infection. More importantly, the risk of site contamination would be greatly reduced if oospores of the fungus could be inactivated thereby reducing infection during propagation on "dirty" trays.

It is difficult to estimate the financial benefit to the industry. Assuming 10% of outdoor and protected crops were affected by the disease and in each of these crops up to 10% of plants were infected and therefore unmarketable the financial loss attributable to big-vein could be in the region £1 million/annum.

Some of the research findings e.g. disinfectant studies could be taken up by the industry almost immediately. "On-Label" Approval may be delayed by the back-log of products awaiting registration at Harpenden or prevented if the manufacturers decide not to pursue such a "minor" use. However, "Off-Label" Approvals could be sought or maintained as soon as the appropriate residue date had been obtained.

5. CLOSELY RELATED WORK

Work is currently being undertaken at Horticulture Research International at Wellesbourne. A small part of the programme is being funded commercially and is therefore confidential. However, the valuable expertise available at Wellesbourne could be utilised by developing a collaborative research programme to help resolve the current problems faced by lettuce growers with this disease. Outside funding from HDC would be required for near-market research of this nature at Wellesbourne.

6. **DESCRIPTION OF THE WORK**

1. Pot tests would be continued at HRI, Wellesbourne to further evaluate fungicides and other products which have already been identified as having activity in suppressing lettuce big-vein virus.

2. Two fully replicated trials would run concurrently on both protected and outdoor lettuce on growers sites in autumn when environmental conditions are conducive to infection and symptom expression.

   Fungicide treatments that have been identified as effective at Stockbridge House and Wellesbourne will be block incorporated or drenched onto blocks. Control treatments will be included in the trial. These blocks will then be seeded with susceptible lettuce cultivars suitable for protected and outdoor production. Olpidium inoculum will not be introduced into the blocking compost this year; the blocks will be transplanted into contaminated soil and subject to natural infection. The crops will be grown-on until maturity, assessments for big-vein symptoms made and yield data recorded.

3. Further disinfectants will be tested for their effectiveness in killing resting spores of the fungus using the bioassay developed in year 1. The most effective disinfectants already identified will be further evaluated to determine (i) the minimum effective dose and (ii) whether they are equally effective in killing resting spores in soil. Control treatments with untreated resting spores would be run concurrently.

7. **STARTING DATE AND DURATION**

The projected commenced in July 1991, and was planned to continue for 3-years. This proposal is for year 3, commencing in Autumn 1993.

8. **STAFF RESPONSIBILITIES**

Project Leaders:

Dr G. M. McPherson, HRI, Stockbridge House
Dr J. A. Walsh, HRI, Wellesbourne

Local co-ordinators:

Mr J Davies, HRI, Stockbridge House
Mr M. Harriman, HRI, Stockbridge House
Mrs J. Bambridge, HRI, Wellesbourne

Recruitment would not be necessary for the programme of work at HRI Stockbridge House (i.e. the field trials). However, at Wellesbourne a temporary ASO (Mrs J. Bambridge) will continue to be employed to carry out the work programme (i.e. pot tests and disinfectant studies/bioassays).

9. LOCATION

The work would be carried out at commercial nurseries and at HRI Wellesbourne, Warwickshire.