Project title:	Protected container-grown nursery stock: Chemical and non-chemical screening for moss and liverwort control in liners.
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Project leaders:	J G Atwood, ADAS UK Ltd.
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Key words:	Container nursery stock, chemical weed control, liner, liverwort, moss, mulch, phytotoxicity, protection.

AUTHENTICATION

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

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GROWER SUMMARY

- **Fourteen herbicide programmes, 11 growing medium amendments or mulches, two natural products and copper treatments were evaluated for control of liverwort and mosses on a range of container nursery stock species grown under protection.**
- **Programmes with winter applications of Lenacil, Butisan S and Helmsman granules were significantly more effective than standard treatment (alternating Ronstar 2G and Flexidor 125 / Panacide M).**
- **Using Ronstar 2G – the winter wood fibre media incorporation at 30% v/v and the use of mulches with copper impregnation substantially reduced liverwort and moss development.**

Commercial benefits of the project

This project has identified and evaluated growing media amendments and mulches that should substantially reduce moss and liverwort infestation when used with currently approved herbicide programmes or as stand-alone treatments. Further information on herbicide safety and use has been gained to support SOLA applications for those herbicides not currently approved for use under protection.

Background and objectives

Growth of liverworts and mosses on the pot surface of container plants is a persistent problem on many nurseries, especially under protection on weaned plugs and liners. Liverworts and mosses are estimated to cost the industry 4% of total production cost. The predominant use of overhead irrigation, with watering to the level of the –thirstiest species, results in conditions ideal for development of liverwort and mosses.

With alternative herbicides, there is an opportunity to improve on the level of control over that provided by the current industry standards (Ronstar 2G and Panacide M). One approach to improved control could come from products such as Lenacil 80W and Butisan S which can be phytotoxic during the growing season but might be safer during the autumn or winter months. Other, newer products such as Helmsman granules might potentially have a wider window of use if proved effective.

However, the industry is also urgently seeking to reduce their routine use of pesticide for moss and liverwort control. Current usage is often of short-persistent control measures necessitating multiple applications. Progress on non-chemical control measures integrated with reduced chemical input would assist nurseries in meeting environmental targets set by retail customers.

There is an increasing range of materials available with potential for use as mulches. Chemical pre-treatment of the mulch could provide more effective control but crop phytotoxicity needs to be

evaluated. There appear to be opportunities to enhance and develop natural biological control, by amendments in the growing media or spray application. For example, observations by ADAS consultants suggest a reduced problem where loam or Sylvafibre^{TM} are used in the growing medium, possibly indicating natural, biological suppression. Polyphenolic secondary metabolites appear to offer potential for control, recently, seedmeal from *Limnanthes* plants (which produce glucosinolates and other secondary metabolites) have been shown to provide effective liverwort control when used as growing medium amendment. The benefit of these treatments has been evaluated and quantified in this project.

The commercial objective is to develop an integrated strategy for cost-effective control of moss and liverworts in liners grown under protection. Such an approach could utilise both chemical and non-chemical control measures.

Summary of the project and main conclusions

The project was undertaken at Darby Nursery Stock Ltd. in three parts, over two years:
1. Shrub Liner Herbicide experiment - herbicide programme treatments were tested for crop safety in two experiments, 2003/4 and 2004/5, on a total of 18 woody nursery stock subjects grown in 9 cm pot liners. Efficacy against liverwort and moss was tested by using liners that were potted up from contaminated plugs in July 2003 & June 2004.
Experimental programmes consisted of Ronstar 2G applied after potting, Flexidor 125 + Panacide M applied in September/October, then either Butisan S, Helmsman, Katamaran, Lenacil 80W, Ronstar 2G or untreated in November/December. Helmsman was also tested as a post potting treatment. Crop tolerance was recorded in the spring following treatment. In the 2004/5 experiment a 30% wood fibre (Silvafibre^{TM}) media was tested with the herbicide treatments.

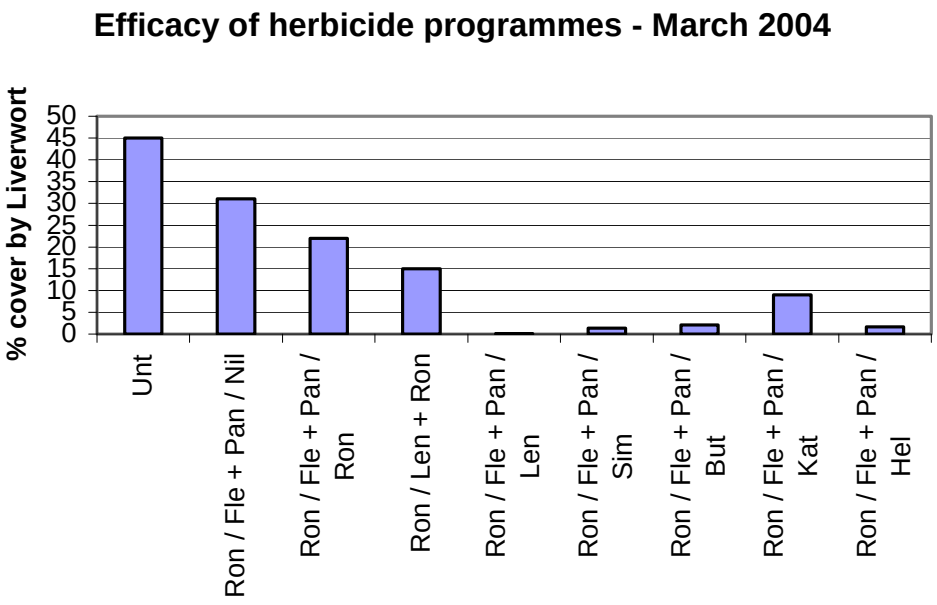
Herbicide Treatments

Product name	**Chemical name and a.i. conc.**	**Rate of <u>product</u> used**	**Code**
Untreated	water		Unt
Butisan S	metazachlor 500 g/L	0.25 ml / m^2	But
Flexidor 125	isoxaben 125 g/L	0.1 ml / m^2	Fle
Helmsman	oxadiazon + diflufenican + carbetamide 1:0.1:2% w/w	15 g / m^2 (yr1) 12 g / m^2 (yr2)	Hel
Katamaran	metazachlor + quinmerac 375:125 g/L	0.2 ml / m^2	Kat
Lenacil 80W	lenacil 80% w/w	0.15 g / m^2	Len
Panacide M*	dichlorphen 360 g/L	2.5 ml / m^2	Pan
Ronstar 2G	oxadiazon 2% w/w	20 g / m^2	Ron
Simazine	simazine 500 g/L	0.2 ml / m^2	Sim

* Panacide M is no longer available but similar products e.g. Enforcer are still available

HNS Species tested for phytotoxicity:

- As a winter treatment, Lenacil 80W gave the best control of moss and liverwort, followed by Simazine, Helmsman granules, and Butisan S. All of these gave commercially acceptable levels of control although Simazine was less effective on moss.
- The "grower's standard" treatment of alternating Ronstar 2G and Flexidor 125 / Panacide M was less effective at controlling liverwort and moss in the standard peat based media, compared with the experimental winter treatments.
- Where Silvafibre™ was incorporated moss plus liverwort infestation was reduced from 40% to 5% with no herbicides and the "grower's standard" programme reduced it further to 0.7%
- No significant effects on plant growth were recorded with Lenacil 80W, Simazine, Helmsman granules or the "growers standard" treatments.
- Butisan S and to a lesser extent Katamaran caused a slight delay to the onset of spring growth in *Euonymus*, *Cotoneaster*, and *Berberis*. No long term damage was caused however and root growth was unaffected.



2. Mulch, growing medium amendments and copper experiments - treatments were tested on *Cytisus* (yr1) or *Genista* (yr2) grown in 9 cm pot liners in two experiments, 2003/4, and 2004/5. Efficacy against liverwort and moss was tested by using liners that were potted up from contaminated plugs in June/July. Mulches and copper treatments were applied immediately after potting. Media amendments were mixed into the existing liner mix. No additional herbicides were used.

Treatment	**Material/Source**
Untreated	
Fungex 9.5 ml / litre + Majestik 25 ml / litre, 250ml / m^2	Fungex (copper ammonium carbonate, 8% copper); Majestik (natural plant extracts)
Fungex 9.5 ml / litre + PVA glue 200 ml / litre, 250ml / m^2	Fungex (copper ammonium carbonate, 8% copper); PVA commercial glue
Biotop mulch 5 mm depth	Starch + Miscanthus fibre product (has since been replaced by new Biotop / Basotop)
Miscanthus mulch 5 mm depth	Chopped Miscanthus
Pine bark mulch 10 mm depth	Melcourt Propagation Bark™
Pine bark + Fungex, mulch 10 mm depth	Melcourt Propagation Bark™ impregnated with Fungex (2.5 ml / litre, 250ml applied to 1 litre bark)
Pine bark + Ferrous sulphate mulch 10 mm depth	Melcourt Propagation Bark™ impregnated with Ferrous sulphate (8 g / litre, 250 ml applied to 1 litre bark)
Pine bark + Lenacil 80W mulch 10 mm depth	Melcourt Propagation Bark™ impregnated with Lenacil 80W 1.2 g / litre, 250 ml applied to 1 litre bark)
Loam (10%v/v) sterilised incorporated	Rigby Taylor Surrey Loam, autoclaved
Loam (10%v/v) unsterilised incorporated	Rigby Taylor Surrey Loam
Slyvafibre™ (30%v/v) incorporated	Melcourt Wood fibre product
Limnanthes meal (1%yr1, 2%yr2) incorporated	Limnanthes seed processed and de-fatted
Geodisc™ placed on pot surface	Fargro fabric pot topper copper impregnated

- All of the mulches and media amendments delayed the onset of liverwort and moss growth.
- Original Biotop and chopped miscanthus mulch were effective as a moss/liverwort control where the surface of the mulch was undisturbed. Both were considered visually unattractive.
- The pine bark mulches were partially effective when used alone, but efficiency was considerably improved by impregnation with Lenacil 80W or Fungex (copper fungicide). Ferrous sulphate was less effective as a mulch impregnation.
- Copper (Fungex) spray treatments applied after potting gave about 5 months control when applied with a sticker such as PVA or Majestik. PVA was more persistent.

- Of the incorporation treatments, Sylvafibre™ was reasonably effective as a moss/liverwort control even without herbicides, sterilised loam and Limnanthes meal had a short term effect.
- Unsterilised loam was effective as a moss/liverwort control but suffered from considerable weed infestation.
- Geodiscs were effective whilst they were in place, but were easily dislodged, even under protection.

3a. Natural products spray experiment - Three treatments; Orisorb 6.25 L/ha, Bionatural GAR 125 L/ha, and Mogeton 15 kg/ha (standard) were tested for moss/liverwort control on *Cytisus* potted from contaminated plugs into 9 cm pot liners. None of the natural products were effective when compared with the Mogeton standard.

3b. Lenacil timing experiment – Lenacil was applied as a spray treatment at high and low rates at three timings, and as an impregnated pine mulch after potting, compared with Ronstar 2G (20 g / m^2) and Mogeton (1.5 g / m^2) as standard treatments. A Lencil sensitive subject (*Vinca*) was tested for phytotoxicity with a thin canopy, non-sensitive subject (*Genista*) included alongside to measure liverwort and moss infestation. Treatments were:

Treatment	After potting (June)	October	November
1	Untreated	Untreated	Untreated
2	Ronstar 2G	Lenacil (0.15 g / m^2)	Untreated
3	Ronstar 2G	Lenacil (0.075 g / m^2)	Untreated
4	Ronstar 2G	Untreated	Lenacil (0.15 g / m^2)
5	Ronstar 2G	Untreated	Lenacil (0.075 g / m^2)
6	Lenacil (0.15 g / m^2)	Untreated	Untreated
7	Bark + Lenacil*	Untreated	Untreated
8	Ronstar 2G	Mogeton	Untreated

* Melcourt Propagation Bark™ impregnated with Lenacil 80W 1.2 gm / litre, 250 ml applied to 1 litre bark)

- All treatments significantly reduced the moss and liverwort cover compared with the control, the higher rate Lenacil, and Mogeton treatments only applied in October according to the table above.
- The Lenacil impregnated mulch treatment was highly phytotoxic to *Vinca.*
- The June and October applications of both rates of Lenacil were also phytotoxic to *Vinca* but the November applications were safe.
- *Genista* was unaffected by any of the treatments.

Action points for growers

- The use of a wood fibre growing media amendment such as Sylvafibre^{TM} at 30% v/v should be included as part of a strategy to reduce the incidence of moss and liverwort. When used with a suppressive media such as this, the standard herbicide programme Ronstar 2G, Flexidor 125 / Panacide M, Ronstar 2G will give adequate control.
- Mulches such as Biotop and Miscanthus and bark impregnated with copper are safe and effective, but time consuming to apply. Copper impregnated bark is particularly effective but would require approval of a proprietary product.
- There is good potential for the safe use of herbicides such as Lenacil 80W, Butisan S and Helmsman granules under protection, but it will only be possible to use these products if SOLAs are granted for use under protection. An application is underway.
- The use of a copper fungicide could be used as a preventative strategy, but would require the addition of an effective sticker. PVA glue was used in this experiment, but is not approved as an adjuvant. PVA formulations however are also available as anti-transpirant products.

Anticipated practical and financial benefits

Best practice for controlling moss and liverwort should now include the use of growing media with wood fibre as well as bark. By replacing part of the peat content with wood fibre and bark to around 50% the problem with moss and liverwort is so reduced that a standard herbicide programme based on Ronstar 2G, Flexidor 125, and Panacide M will give good control. By using a proportion of wood fibre as well as bark the water availability of the media is not adversely affected.

The cost of wood fibre is £19 / m^2 compared with peat and bark at £13 / m^2. Therefore the cost of a media with 30% wood fibre will be £1.80 / m^3 more or 0.05p per 9 cm pot. This can be compared with the cost of cleaning up moss and liverwort, estimated at 4% of production cost.

For those growers who prefer to rely solely on herbicides without changing the growing media, if a SOLA application is successful for Butisan S, Lenacil 80W or Helmsman granules, these products could be used under protection as a winter treatment all at lower cost than Ronstar 2G granules.

SCIENCE SECTION

INTRODUCTION

Growth of liverwort (*Marchantia polymorpha)* and moss (*Funaria hygrometrica)* on the pot surface of container plants is a persistent problem on many nurseries, especially under protection on weaned plugs and liners.

Moses and liverworts have a number of detrimental effects on nursery stock production by:

- limiting water infiltration and intercept water and nutrients meant for the crop,
- smothering slow-growing seedlings,
- reducing root growth,
- encouraging slugs, snails and fungus gnats,
- imposing high extra labour costs for cleaning up before sale,
- detracting considerably from the plant appearance, suggesting poor quality, and hence reduce value; even dead liverworts are considered unsightly.

Liverworts and mosses are estimated to cost the industry 4% of the total production cost. The predominant use of overhead irrigation, with watering to the level of the most thirsty species, results in conditions ideal for development of liverwort and mosses. Accreditation schemes have a zero tolerance for them.

With alternative herbicides on the market, and two from earlier studies which showed promise in certain situations, there is now opportunity to improve on the level of control over that provided by the current industry standards (Ronstar 2G and Panacide M). One approach to improved control could come from products such as Lenacil 80W and Butisan S which can be phytotoxic during the growing season but might be safer during the autumn or winter months. Other, newer products such as Helmsman granules and Katamaran might potentially have a wider window of use if proved effective. Part of this project will be to evaluate these herbicides when used as winter treatments under protection.

The surface cleaner, Mogeton, is commercially available as a liverwort and moss control agent. However, because it is only approved as a surface cleaner it is not legally possible for growers to apply Mogeton over crops, although such use is approved in other EC countries. Simazine was also considered a potential treatment for liverwort control, but since the start of this project it has failed to achieve on the Annex 1 list of the approved products, so is currently only approved as an essential use for nursery stock until December 2007.

The industry is also urgently seeking to reduce their routine use of pesticide for moss and liverwort control. Current usage of herbicides and biocides are often short-persistent control measures

necessitating multiple applications. Progress on non-chemical control measures integrated with reduced chemical input would assist nurseries in meeting environmental targets set by retail customers.

There is an increasing range of materials available with potential for use as mulches. Chemical pre-treatment of the mulch could provide a more effective control.

If a mulch absorbs and then slowly releases a mobile herbicide (eg Lenacil), there is potentially great benefit for increased persistence of control and reduced phytotoxicity. There appears to be opportunities to enhance and develop natural biological control, by amendments in the growing media or spray application. For example, observations by ADAS consultants suggest a reduced problem where loam or Sylvafibre™ are used in the growing medium, possibly indicating natural, biological suppression. Some polyphenolic secondary metabolites appear to offer potential for control (Nakayomo *et al*., 1996; Svenson, 1997). Recently, seedmeal from *Limnanthes* plants (which produce glucosinolates and other secondary metabolites) have been shown to provide effective liverwort control when used as a growing medium amendment.

OBJECTIVES

1. To determine the efficacy and crop safety of new herbicides used for control of liverwort and moss, when applied during winter on a range of woody, hardy nursery stock subjects.

2. To evaluate the effect of different mulch and media incorporation treatments on the establishment and development of liverwort and moss in contaminated liners

MATERIALS AND METHODS

Three experiments were devised to address the objectives of the project in year 1:

1. Herbicide experiment
2. Mulch and growing medium amendment experiment
3. Natural products spray experiment

In year 2 the natural products experiment was discontinued and the project was again split into three experiments:

1. Herbicide experiment - using the most effective treatments from year 1 and testing efficacy when used with wood fibre incorporated media.
2. Copper, mulch and growing medium experiment – using the most effective treatments from year 1 and further testing copper treatments in different formulations.
3. Lenacil timing experiment – as lenacil proved to be particularly effective, timing of application were investigated on a lenacil susceptible crop (*Vinca*)

1. HERBICIDE EXPERIMENT

In year 1, this experiment looked at both the efficacy and phytotoxicity of eight herbicide treatment programmes against a non-treated control. In year 2, five of the treatment programmes were repeated and used in conjunction with wood fibre incorporated media to see if further reductions of liverwort and moss development could be achieved.

The plug plants used were already contaminated with liverwort obviating the need to artificially infect the pots.

Twelve shrub species were used to assess phytotoxicity in the experiment in year 1, and a further six species in year 2.

HNS Woody Species:

Genista lydia
Hydrangea hortensis
Lavendula 'Vera'
Spiraea 'Shirobana'
Viburnum opulus 'Sterile'
Vinca major 'Maculata'

All plants were supplied from Darby Nursery Stock Ltd. Plants were supplied as cutting plugs potted into 9 cm liner pots on 21 June 2004.

Potting Mix

Standard (Treatment 1)

80% Medium grade peat

20% Pine bark

10% Potting grit (does not increase the volume of substrate)

5.0 kg/m^3 Osmocote Exact Standard 12-14 month

1.8 kg/m^3 Magnesian limestone

0.5 kg/m^3 12:12:12 Compound fertiliser

Silvafibre™ incorported (Treatments 2-7)

56% Medium grade peat

14% Pine bark

30% Silvafibre™

(10%) Potting grit

5.0 kg/m^3 Osmocote Exact Standard 12-14 month

1.8 kg/m^3 Magnesian limestone

0.5 kg/m^3 12:12:12 Compound fertiliser

0.3 kg/m^3 Ammonium nitrate

Experimental design

The experiment was a split plot design.
7 treatments (includes 1 control) x 3 replicates = 21 main plots for herbicide treatments
6 HNS shrub species sub-plots x 10 plants

Total 126 sub-plots

The pots were placed under plastic protection on Mypex^{TM} covered beds after potting. Overhead irrigation was used throughout.

Herbicide treatments

Herbicides were applied on 21st June, 19th September and 23rd November 2004.

Table 1. Herbicide products and rates used for Experiment 1

Product name	**Chemical name and a.i. conc.**	**Rate of <u>product</u> used**
Untreated	Water	
Butisan S	metazachlor 500 g/L	0.25 ml / m^2
Flexidor 125	isoxaben 125 g/L	0.1 ml / m^2
Helmsman	oxadiazon + diflufenican + carbetamide 1:0.1:2% w/w	12 g / m^2
Katamaran	metazachlor + quinmerac 375:125 g/L	0.2 ml/ m^2
Lenacil 80W	lenacil 80% w/w	0.15 g / m^2
Panacide M	dichlorphen 360 g/L	2.5 ml/ m^2
Ronstar 2G	oxadiazon 2% w/w	20 g / m^2
Simazine	simazine 500 g/L	0.2 ml / m^2

Table 2. Herbicide treatment programmes for Experiment 2

Treatment	After potting (June)	September	November
1	Untreated	Untreated	Untreated
2	Untreated	Untreated	Untreated
3	Ronstar 2G	Flexidor125+PanacideM	Ronstar 2G
4	Ronstar 2G	Flexidor125+PanacideM	Lenacil 80W
5	Ronstar 2G	Flexidor125+PanacideM	Butisan S
6	Ronstar 2G	Flexidor125+PanacideM	Helmsman
7	Helmsman	Flexidor125+PanacideM	Ronstar 2G

Herbicide applications

Liquid herbicide treatments were applied using a gas-pressurised sprayer in a high water volume equivalent to 2500L l/ha i.e. 250 ml/m^2. Granular treatments were applied using a 'pepperpot' sprinkler to ensure even coverage.

Assessments

Liverwort and moss control-

Records were taken as follows:

14 September 2004 % liner pot cover liverwort or moss

1 February 2005 % liner pot cover liverwort or moss

29 March 2005 % liner pot cover liverwort/moss

Records were only taken from *Genista lydia* plants as other species in the experiment did not develop extensive liverwort or moss growth due to the shading caused by the denser foliage.

Phytotoxicity and quality assessments

Written observations on phytotoxic symptoms and possible growth effects were made as and when they occurred.

All plants were scored for quality growth on 29 March 2005 with a visual assessment of size on a scale 0-5 when the spring flush of growth was underway. Root vigour was scored by removing the pots from plants and giving an assessment of root density at the edge of the root ball. Plant and root vigour score data were analysed using Friedman's non-parametric analysis.

2. COPPER, MULCH AND GROWING MEDIUM AMENDMENT EXPERIMENT

In year 1, this experiment looked at the efficacy of 11 mulch and/or growing medium amendment treatments against two non-treated controls.

In year 2, following the success of the copper impregnated mulch treatment, further copper treatments were included together with a re-appraisal of the previous years mulch and incorporation treatments.

The *Cytisus* plug plants used for the experiment were already contaminated with liverwort obviating the need to artificially infect the pots. Only one plant species was used in this experiment.

All plants were supplied from Darby Nursery Stock Ltd. Plants were supplied as cutting plugs potted into 9 cm liner pots on 21 June 2004.

Potting mix

80 % Medium grade peat
20% Pine bark
10% Potting grit (does not increase volume of substrate)
5.0 kg/m^3 Osmocote Exact Standard 12-14 month
1.8 kg/m^3 Magnesian limestone
0.5 kg/m^3 12:12:12 Compound fertiliser

For the growing media amendment treatments 8 and 9, the above mix was used, diluted by the addition of the amendments.

Experimental design

Randomised block design:
9 treatments (includes 1 control) x 3 replicates = 27 plots

The pots were placed on Mypex™ covered beds after potting. Overhead irrigation was used throughout. Plants were placed in tunnels.

Treatments

Thirteen treatments were tested on *Genista* grown in 9 cm pot liners.
Mulches were applied immediately after potting.

Table 3. Copper, mulch and growing media amendment treatments used in Experiment 2

Treatment	Material/Source
1. Untreated Control	
2. Fungex 9.5 ml / litre, + Majestik 25 ml / litre, 250ml / m^2	Applied as spray after potting
3. Fungex 9.5 ml / litre, + PVA glue 200 ml / litre, 250ml / m^2	Applied as spray after potting
4. Biotop mulch 5mm depth	Starch + Miscanthus fibre product
5. Pine bark mulch 10 mm depth	Melcourt Propagation Bark™
6. Pine bark + Fungex mulch 10 mm depth	Melcourt Propagation Bark™ impregnated

	with Fungex (2.5 ml / litre, 250 ml applied to 1 litre bark)
7. Pine bark + Lenacil 80W mulch 10 mm depth	Melcourt Propagation Bark™ impregnated with Lenacil 80W 1.2 gm / litre, 250 ml applied to 1 litre bark)
8. Slyvafibre™ (30%v/v) incorporated + Ammonium Nitrate 300 gm / m^3	Melcourt Wood fibre product + agricultural prill fertiliser
9. Limnanthes meal (2%) incorporated	Limnanthes seed processed and de-fatted

Assessments

Liverwort and moss control

Records were taken as follows:

14 September 2004	% liner pot cover with liverwort/moss
11 October 2004	% liner pot cover with liverwort/moss
1 February 2005	% liner pot cover with liverwort/moss
29 March 2005	% liner pot cover with liverwort/moss

Plant growth

Plants were observed throughout the experiment for signs of phytotoxicity or reduced growth resulting from the treatments.

3. LENACIL APPLLICATION TIMING EXPERIMENT

In year 2, an experiment was set up to investigate lenacil application timing on a lencil sensitive subject (*Vinca*), with a non-sensitive subject (*Genista*).

The *Vinca* and *Genista* plug plants used for the experiment were already contaminated with liverwort obviating the need to artificially infect the pots.

All plants were supplied from Darby Nursery Stock Ltd. Plants were supplied as cutting plugs potted into 9 cm liner pots on 21 June 2004.

Potting mix

80 % Medium grade peat
20% Pine bark
10% Potting grit (does not increase volume of substrate)
5.0 kg/m^3 Osmocote Exact Standard 12-14 month
1.8 kg/m^3 Magnesian limestone
0.5 kg/m^3 12:12:12 Compound fertiliser

Experimental design

Split plot design:

8 treatments (includes 1 control) x 3 replicates = 24 main plots for herbicide treatments

2 *Vinca* and *Genista* sub-plots x 10 plants

Total 48 sub-plots

All plants placed in 4 x 5 plant empot carriers, 2 sub-plots per carrier

The pots were placed on Mypex™ covered beds in a polytunnel after potting. Overhead irrigation was used throughout.

Treatments

Table 4. Herbicides used in Experiment 2

Product name	**Chemical name and a.i. conc.**	**Rate of <u>product</u> used**
Lenacil 80W	lenacil 80% w/w	0.15 g / m^2 (higher rate) 0.075 g / m^2(lower rate)
Mogeton	dichlorphen 360 g/l	1.5 g / m^2
Ronstar 2G	oxadiazon 2% w/w	20 g / m^2

Treatments were applied on 21 June, 18 October and 23 November 2004

Table 5. Herbicide treatment programmes for Experiment 2

Treatment	After potting (June)	October	November
1	Untreated	Untreated	Untreated
2	Ronstar 2G	Lenacil (higher rate)	Untreated
3	Ronstar 2G	Lenacil (lower rate)	Untreated
4	Ronstar 2G	Untreated	Lenacil (higher rate)
5	Ronstar 2G	Untreated	Lenacil (lower rate)
6	Lenacil (higher rate)	Untreated	Untreated
7	Bark + Lenacil*	Untreated	Untreated
8	Ronstar 2G	Mogeton	Untreated

* Melcourt Propagation Bark^{TM} impregnated with Lenacil 80W 1.2 gm / litre, 250 ml applied to 1 litre bark)

Spray Applications

Spray treatments were applied using a gas-pressurised sprayer in a high water volume equivalent to 2500 L/ha i.e. 250 mL/m^2.

Assessments

Liverwort and moss control

Records were taken as follows:

14 September 2004 % cover liverwort/moss
1 February 2005 % cover liverwort/moss
29 March 2005 % cover liverwort/moss

Phytotoxicity

Vinca plants were scored for phytotoxicity on 14 September 2004, 11 October 2004, 1 February 2005 and 29 March 2005. *Genista* plants were scored for phytotoxic effects and growth retardation as and when they occurred.

RESULTS & DISCUSSION

1. HERBICIDE EXPERIMENT

Liverwort and moss control

Following the successful use of wood fibre growing media incorporation in reducing the incidence of moss and liverwort, it was decided to integrate the use of herbicides with a similar growing media in year 2. As noted in year 1 the Sylvafibre™ incorporation treatment substantially reduced liverwort infestation, initially in September (1.7%) compared with the control (50%) (Table 6). By February, levels had increased to 10.7% compared with 36.7% in the control, before dropping back to 4.7%, compared with 20%. Liverwort levels suffered a natural decline over this period. The addition of all of the herbicide programmes reduced the liverwort infestation still further to virtually zero. Because of the low levels recorded there were no significant differences between herbicide treatments.

Moss infection levels were higher in the year 2 experiment compared with year 1 when levels were not high enough to analyse. Levels reached 26.7% on the untreated control in February (Table 7). Again, the Sylvafibre™ incorporation treatment substantially reduced moss infestation, this time down to 0.7%. As a result the herbicide treatments did not significantly improve the control achieved.

Table 6. Effect of herbicide spray programmes (treatments applied June, September and November) on mean % liverwort cover

	%Liverwort – Assessment dates		
Treatments	September 14th 2004	February 1st 2005	March 29th 2005
1. Untreated, no Sylvafibre™ incorp.	50	36.7	20
2. Untreated, + Sylvafibre™ incorp.	1.7	10.7	4.7
3. Ronstar 2G, Flexidor + Panacide, Ronstar 2G, + Sylvafibre™ incorp.	0	0.3	0
4. Ronstar 2G, Flexidor + Panacide, Lenacil, + Sylvafibre™ incorp.	0	0	0
5. Ronstar 2G, Flexidor + Panacide, Butisan S, + Sylvafibre™ incorp.	1.7	0.3	0.3
6. Ronstar 2G, Flexidor + Panacide, Helmsman, + Sylvafibre™ incorp.	0	0	0.7
7. Helmsman, Flexidor + Panacide, Ronstar 2G, + Sylvafibre™ incorp.	0	0.3	0
Grand Mean	**7.6**	**6.9**	**3.7**
F pr	<0.001	<0.001	<0.001
s.e.d. (df)	1.15 (12)	5.98 (12)	2.9 (12)
LSD at 5%	2.51	13.04	6.32
%CV	18.5	106.1	96.9

For all assessment dates the untreated control (treatment 1) had significantly more liverwort than any of the other treatments. Differences between treatments 2-5 were not significant.

Table 7. Effect of herbicide spray programmes (treatments applied June, September and November) on mean % moss cover

	%Moss – Assessment dates		
Treatments	September 14th 2004	February 1st 2005	March 29th 2005
1. Untreated, no Sylvafibre™ incorp.	0	26.7	20
2. Untreated, + Sylvafibre™ incorp.	0	0.7	0.7
3. Ronstar 2G, Flexidor + Panacide, Ronstar 2G, + Sylvafibre™ incorp.	0	0.3	0
4. Ronstar 2G, Flexidor + Panacide, Lenacil, + Sylvafibre™ incorp.	0	0	0
5. Ronstar 2G, Flexidor + Panacide, Butisan S, + Sylvafibre™ incorp.	0	0.3	0.3
6. Ronstar 2G, Flexidor + Panacide, Helmsman, + Sylvafibre™ incorp.	0	0	0
7. Helmsman, Flexidor + Panacide, Ronstar 2G, + Sylvafibre™ incorp.	0	0.3	0
Grand Mean	**0**	**4**	**3**
F pr		0.024	0.030
s.e.d. (df)		7.24 (12)	5.64 (12)
LSD at 5%		15.78	12.29
%CV		219.2	230.2

No moss was recorded on the first assessment. For all subsequent assessment dates the untreated control (treatment 1) had significantly more moss than any of the other treatments; differences between treatments 2-1 were not significant.

Phytotoxicity and quality assessments

No adverse effects on plant growth or quality were noted following application of any of the experimental treatments.

The species used in this experiment are not known to be sensitive to Butisan S.

2. COPPER, MULCH AND GROWING MEDIUM AMENDMENT EXPERIMENT

The liverwort infestation was reduced in the year 2 compared with year 1, possibly as a result of a drier growing regime adopted by the nursery. Levels reached 28.3% in the untreated by 11 October 2004, before declining to 14% in March (Table 7).

The copper (Fungex) spray treatments (Treatments 2 & 3) with "stickers" gave control of liverwort for 5 months but then lost persistence. The use of PVA as a sticker appeared slightly more effective than Majestic, although this difference was not significant.

As in the previous year the mulch treatments (Treatments 4 & 5) were very effective in controlling liverwort and moss.

The treated mulches (Treatments 6 & 7) were only slightly better at controlling liverwort and moss infestations than untreated pine bark (Treatment 5).

A 2% incorporation of Limnanthes meal was used this year, however, as in the previous year, although there was initial control, infestation increased so that by the end of the experiment there was no significant difference between the treatment and the control.

For the first 4 assessments all treatments gave a significant level of liverwort control compared with the untreated, but differences between treatments were not significant. At the final assessment the level of liverwort in the untreated control had reduced naturally and none of the differences between treatments and the control were significant.

Moss infestation was at a relatively low level, reaching 6.3% in the control by March 2005. Moss control followed a similar pattern to that of liverwort, with the mulch and incorporation treatments proving effective (Table 8). However the copper fungicide (Fungex) was less effective on moss than on liverwort.

Table 8. Effect of copper, mulches and growing medium amendments on % liverwort cover

	Assessment Dates - % Liverwort cover/pot				
Treatments	12th Aug 2004	14th Sep 2004	11th Oct 2004	1st Feb 2005	29th Mar 2005
1. Untreated Control	25	26.7	28.3	24.7	14
2. Fungex 9.5 ml / litre, + Majestik 25 ml / litre, 250ml / m^2	2	6.7	9.2	12.3	11.7
3. Fungex 9.5 ml / litre, + PVA glue 200 ml / litre, 250ml / m^2	0	1.7	2.3	10.2	13.5
4. Biotop mulch 5mm depth	0	0	0.7	0	0.5
5. Pine bark mulch 10mm depth	0	0.3	1	0.7	0.3
6. Pine bark + Fungex mulch 10mm depth	0	0	0	0	0
7. Pine bark + Lenacil 80W mulch 10mm depth	0	0	0	0	0
8. Limnanthes meal (2%) incorporated	0	3.3	6.7	11.8	15.2
Grand Mean	**3**	**4.3**	**5.4**	**7.8**	**6.6**
F pr	0.015	0.007	0.008	0.248	0.591
s.e.d. (df)	6.24(16)	5.98(16)	6.39(16)	9.87(16)	10.6(16)
%CV	254.6	169.0	144.3	154.7	194.5
LSD at 5%	13.2	12.7	13.55	20.93	22.38

Table 9. Effect of copper, mulches and growing medium amendments on % moss cover

	Assessment Dates - % Moss Cover	
Treatments	1st February 2005	29 March 2005
1. Untreated Control	5.3	6.3
2. Fungex 9.5 ml / litre, + Majestik 25 ml / litre, 250ml / m^2	5.7	3
3. Fungex 9.5 ml / litre, + PVA glue 200 ml / litre, 250ml / m^2	9.2	8.3
4. Biotop mulch 5mm depth	4	2.3
5. Pine bark mulch 10mm depth	0.7	1.7
6. Pine bark + Fungex mulch 10mm depth	0	0
7. Pine bark + Lenacil 80W mulch 10mm depth	0	0
8. Limnanthes meal (2%) incorporated	1	0.7
Grand Mean	**2.9**	**2.6**
F pr	0.531	0.626
s.e.d. (df)	4.81(16)	4.70(16)
%CV	200.1	225
LSD at 5%	10.2	9.95

3. LENACIL APPLICATION TIMING EXPERIMENT

The liverwort infestation in this experiment was relatively low and variable. As a result the initial assessment in September did not show any significant differences between treatments. However by February levels in the untreated control reached 16.7%, all treatments gave a significant level of control (Table 10). Differences between treatments were not significant. Assessments were made for moss infestation, but the level only reached 4% in the control and there were no significant differences (Table 11).

Table 10: Effect of lenacil timing on % liverwort cover

	%Liverwort – Assessment dates		
Treatments	September 14th 2004	February 1st 2005	March 29th 2005
1. Untreated	12	16.7	8.3
2. Ronstar 2G, Lenacil 0.15 g/m^2, untreated	1	0	0
3. Ronstar 2G, Lenacil 0.075 g/m^2, untreated	11	0	0
4. Ronstar 2G, untreated, Lenacil 0.15 g/m^2	1.7	3.3	0
5. Ronstar 2G, untreated, Lenacil 0.075 g/m^2	5.7	7	5
6. Lenacil 0.15 g/m^2, untreated, untreated	2	2.3	3.3
7. Pine bark + Lenacil mulch 10mm depth, untreated, untreated	2.3	0	0
8. Ronstar 2G, Mogeton, untreated	4.3	0	0
Grand Mean	**5**	**3.7**	**2.1**
F pr	0.546	0.027	0.178
s.e.d. (df)	6.48(14)	4.51(14)	3.41(14)
LSD at 5%	13.9	9.68	7.31
%CV	158.6	150.7	200.3

At the February assessment, compared with the control, all treatments except treatment 5 significantly reduced the liverwort cover, but differences between treatments were not significant. At the March assessment all treatment except 5 and 6 significantly reduced the liverwort cover, but differences between treatments were not significant.

Table 11: Effect of lenacil application timing on % moss cover

	Assessment dates	
Treatments	February 1st 2005	March 29th 2005
1. Untreated	3.3	4
2. Ronstar 2G, Lenacil 0.15 g/m^2, untreated	0	1
3. Ronstar 2G, Lenacil 0.075 g/m^2, untreated	0.7	0
4. Ronstar 2G, untreated, Lenacil 0.15 g/m^2	3	3
5. Ronstar 2G, untreated, Lenacil 0.075 g/m^2	1.7	5.3
6. Lenacil 0.15 g/m^2, untreated, untreated	5	5
7. Pine bark + Lenacil mulch 10mm depth, untreated, untreated	0	0
8. Ronstar 2G, Mogeton, untreated	0	0.3
Grand Mean	**1.7**	**2.3**
F pr	0.589	0.630
s.e.d. (df)	2.96(14)	3.68(14)
LSD at 5%	6.34	7.90
%CV	212	193.3

Moss cover was low and variable, no differences were significant.

The main focus of this experiment, however, was to assess the timing effect of different application times methods on lenacil phytotoxicity in a sensitive subject – *Vinca*.

The impregnated mulch treatment was the most phytotoxic. It would appear that the lenacil was readily leached down to the plant roots. As a result all plants from this treatment were nearly killed. The higher rate of lenacil applied after potting in June, also proved phytotoxic, although growth was only slightly affected, phytotoxic symptoms would have affected saleability of the plants. Slight effects were also noted from the October application of both rates of lenacil, however, the November treatment, when the plants were fully dormant had no noticeable effect. Plant score details are shown below. The *Genista* plants were not affected by any of the lenacil treatments.

Table 12: Effect of herbicide spray programmes on growth of Vinca (5 = vigorous and healthy, 1 = not vigorous and unhealthy, 0 = dead)

	Assessment dates			
Treatments	September 14th 2004	October 11th 2004	February 1st 2005	March 29th 2005
1. Untreated	5	5	5	5
2. Ronstar 2G, Lenacil 0.15 g/m^2, untreated	5	5	5	4.3
3. Ronstar 2G, Lenacil 0.075 g/m^2, untreated	5	5	5	4
4. Ronstar 2G, untreated, Lenacil 0.15 g/m^2	5	5	5	5
5. Ronstar 2G, untreated, Lenacil 0.075 g/m^2	5	5	5	5
6. Lenacil 0.15 g/m^2, untreated, untreated	4	4	4.7	4.7
7. Pine bark + Lenacil mulch 10mm depth, untreated, untreated	1	0.7	1	1
8. Ronstar 2G, Mogeton, untreated	5	5	5	5
Grand Mean	**4.4**	**4.3**	**4.5**	**4.25**
F pr	<0.001	<0.001	<0.001	<0.001
s.e.d. (df)	0.289(14)	0.333(14)	0.315(14)	0.413(14)
LSD at 5%	0.619	0.715	0.675	0.886
%CV	8.1	9.4	8.7	11.9

CONCLUSIONS

The best winter herbicide treatment for liverwort control was Lenacil, giving outstanding results, and significantly better that the "grower standard" based on a programme of Ronstar 2G, Flexidor + Panacide M and Ronstar 2G.

The rate of Lenacil product used for the winter treatment (1.5 kg/ha) was around half the maximum label rate for Lenacil (2.8 kg/ha), and this may account for the absence of herbicide damage seen on the liner species tested. Although it was thought possible to utilise even lower rates, there were indications that the 0.75 kg/ha rate tested in year 2 (Exp. 3) was less effective and might not be sufficient. The timing experiment indicated that for sensitive species such as *Vinca,* growing season (e.g. June), and late autumn (October) treatments carried a risk of damage, but a November or December treatment was safe in these experiments.

The use of Butisan S, Helmsman granules and Simazine also gave very good control, but Butisan S and to a lesser extent Katamaran caused a slight delay to the onset of spring growth in *Euonymus*, *Cotoneaster*, and *Berberis*. No long-term damage was caused however and root growth was unaffected. A further range of species tested in 2004/5 were not affected in this way. Although Katamaran proved to be relatively safe there appeared to be no particular weed control advantages in this product compared with Butisan S. The main benefit of Katamaran – (Control of cleavers) – is not generally relevant in container production. No damage was recorded from the use of Helmsman granules, even when it was applied immediately after potting in June in year 2.

Since commencing this experiment, the use of Simazine has become restricted and its use will no longer be permitted after 2007. Therefore it was not included in the year 2 experiment.

In the mulch and media amendment experiment, the mulches and toppers performed particularly well. The Geodisc pot toppers were effective, but were time-consuming to apply, and tended to become dislodged requiring frequent replacement. As the benefits and drawbacks of these products are well enough known, these were not included in the year 2 experiment.

The Biotop and Miscanthus mulches remained stable and provided reasonable, but not complete control. For this experiment old formulation Biotop (miscanthus) was used. New formulation Biotop Excellent and Basotop (crushed nut shell) were not available in time to include in the experiment, however small observation plots were set up along side the main experiment. Results appeared comparable with the pine bark mulch, the glue formulation formed a more complete cover.

The chopped Miscanthus mulch was messy and unattractive, and as the results were not as good as with Biotop, this material was not used in the experiment in year 2.

The pine bark much was not sufficiently effective in year 1 when used done, but when impregnated with chemicals, the results were transformed. The Lenacil impregnation was particularly effective, however when tested on a known, Lenacil susceptible species (*Vinca)* in comparison with the straight Lenacil spray the mulch was more phytotoxic. The copper impregnation was also particularly effective and did not appear to carry the phytotoxicity risks of Lenacil. It would be useful if a proprietary impregnated mulch product could be developed.

Further work on copper treatments confirmed activity against liverwort, but less effect on moss. Heavy metal ions such as Copper are known to be toxic to some fungal spores and it is possible that similar effects may occur with lower plants such as liverworts. The use of stickers with copper sprays were effective, but may not have sufficient longevity for a full seasons control. The use of PVA as the sticker was more effective than Majestic. In continental Europe, irrigation water treatment with copper is sometimes practised for general nursery hygiene – it is likely that such a treatment could have an effect in suppressing liverwort infestation.

Some of the media amendment treatments are very promising. The most effective was Sylvafibre^{TM}. The effect of woodfibre in reducing liverwort infestation may be partly due to a reduction in the water holding capacity of the media, but the biological activity of microbes breaking down the wood fibre may also be partly responsible; similar effects have also been noted where green waste composts have been used. The indications are that the use of wood fibre products such as this could provide a significant contribution to liverwort control, but would need to be used in conjunction with other control measures. The rate of use (30%) is relatively high, considering the media already had 20% bark incorporated, the resulting percentage of wood product (bark and wood fibre) in this mix is 48%. At this rate the media may require different management techniques compared with a peat media. However no adverse effects were noted on the liners used. In this experiment when used in conjunction with the growers "standard" herbicide regime (Ronstar 2G, Panacide M / Flexidor 125, Ronstar 2G complete control of liverwort and moss was achieved, whereas normally this regime allows some infestation to develop.

The sterilised soil media amendment had some effect initially, but the results were not sustained. The unsterilised soil was more effective, initially (in December) this could be attributed to a "biological" factor, as the result was significantly more effective than the unsterilised soil, and at this stage there was little difference in weed infestation. The heavy infestation of weed later developed in the unsterilised soil would undoubtedly have further reduced the development of liverwort. It is interesting to confirm a "biological" factor present in soil that inhibited liverwort development, but the practical problems in using soil with a potential weed seed level would prevent its use in practice. Culturing of samples from dying liverwort in the soil incorporated treatment indicated the presence of the fungus *Trichoderma*; the nature of this association is unknown.

The addition of Limnanthes meal at 1% had an effect initially, at preventing liverwort development, though by the end of the experiment little effect could be seen. Increasing the rate to 2% in year 2 again gave good initial control, but the results were not sustained.

The two natural spray products tested, Orisorb and Bionatura GAR appeared to give virtually no control of liverwort and were dropped from the experiment in year 2. The standard Mogeton, however maintained good control to December, declining a little by March.

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ACKNOWLEDGEMNTS

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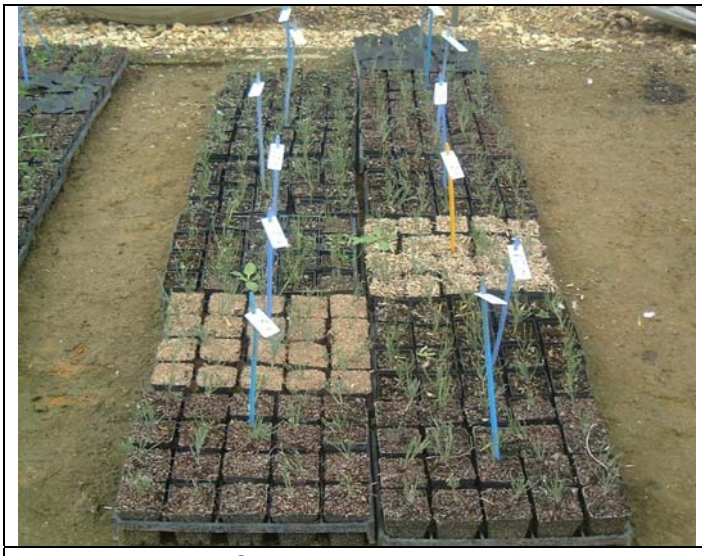
TECHNOLOGY TRANSFER

1. Article for HDC News, December 2004
2. Results incorporated in weed control handbook revision, December 2004.

Appendices

APPENDIX 2



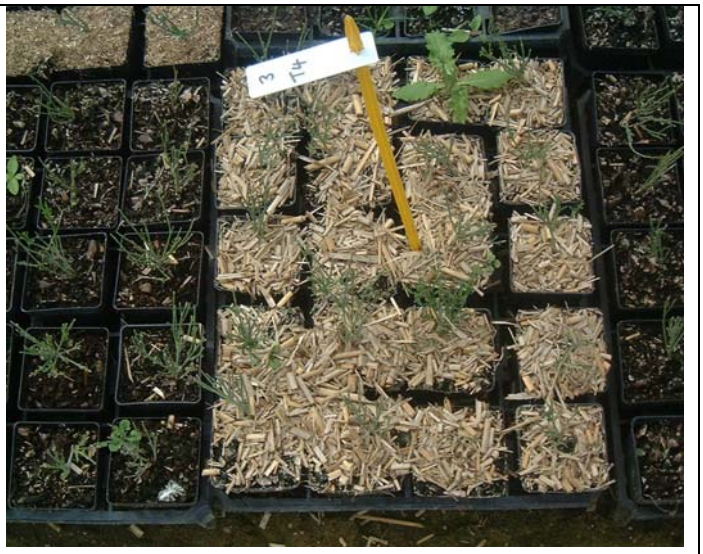
General view of Experiment 2 showing mulches and media ammendments

General view of Experiment 1

Geodisc pot toppers

Biotop Mulch

Pine bark impregnated with copper fungicide



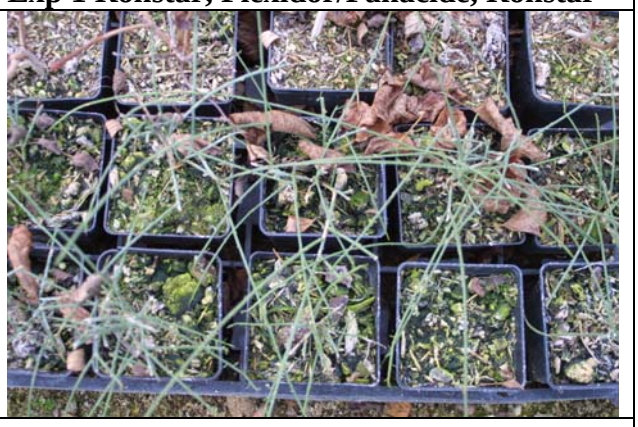
Chopped Miscanthus mulch

Euonymus – treated with Butisan S (LHS) Untreated control – (RHS)

New Biotop LHS, Untreated C, New Biotop + Glue RHS

Lenacil damage from impregnated bark mulch

Old Biotop, incomplete cover

	
Untreated showing moss & liverwort	**Exp 1 Untreated, no wood fibre**
	
Exp 1 Untreated, + wood fibre incorp.	**Exp 1 Ronstar, Flexidor/Panacide, Ronstar**
	
Exp 1 Ronstar, Flexidor/Panacide, Lenacil	**Exp 1 Ronstar, Flexidor/Panacide, Butisan**

	
Ronstar, Flexidor/Panacide, Helmsman	**Helmsman, Flexidor/Panacide, Ronstar**