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 Horticulture
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Key words:	Container nursery stock, chemical weed control, liner, liverwort, moss, mulch, phytotoxicity, protection.

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DISCLAIMER

This report covers the first season's results of a two year project, and data should therefore be applied with caution at this stage. Further information on crop safety in particular will be available following the experiments being undertaken during 2004/5. Most of the herbicide treatments are off-label permitted under the Long Term Arrangements for Use and are used entirely at grower's risk.

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.

Mr J Atwood
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GROWER SUMMARY

Headline

- Eight herbicide programmes, 11 growing medium amendments or mulches and two natural products were evaluated as winter applications for control of liverwort and mosses on a range of container nursery stock species grown under protection.
- Several treatments showed good potential compared into a grower standard treatment (alternating Ronstar 2G and Flexidor / Panacide) and will be further evaluated in 2004/05.
- Winter application of reduced – rate Lenacil, the impregnation of bark with Lenacil or copper and the use of a wood fibre incorporation all appear to offer good potential.

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 expected deliverables

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 product 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.

With three new herbicides, 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 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. If a mulch absorbs and then slowly releases a mobile herbicide (eg Lenacil), there is potentially great benefit for greater 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^{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 will be 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 first part of the project was undertaken at Darby Nursery Stock Ltd. in three experiments:
1. Shrub Liner Herbicide trial - 8 herbicide programme treatments were tested on 12 woody nursery stock subjects grown in 9 cm pot liners for crop safety. Efficacy against liverwort and moss was tested by using liners that were potted up from contaminated plugs (25-26th July 2003). Crop tolerance was recorded in the spring following treatment.
Herbicides were applied on 2nd August 2003, 7th October 2003 and 15th December 2003.

Herbicides

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	B
Flexidor 125	isoxaben 125 g/L	0.1 mL/ m^2	F
Helmsman	oxadiazon + diflufenican + carbetamide 1:0.1:2% w/w	15 g / m^2	H
Katamaran	metazachlor + quinmerac 375:125 g/L	0.2 mL / m^2	K
Lenacil 80W	lenacil 80% w/w	0.15 g / m^2	L
Panacide M	dichlorphen 360 g/L	2.5 mL/ m^2	P
Ronstar 2G	oxadiazon 2% w/w	20 g / m^2	R
Simazine	simazine 500 g/L	0.2 ml / m^2	S

Herbicide treatment programmes

Treatment	After potting (July)	October	December
1	Untreated	Untreated	Untreated
2	Ronstar 2G	Flexidor125+PanacideM	Untreated
3	Ronstar 2G	Flexidor125+PanacideM	Ronstar 2G
4	Ronstar 2G	Lenacil 80W	Ronstar 2G
5	Ronstar 2G	Flexidor125+PanacideM	Lenacil 80W
6	Ronstar 2G	Flexidor125+PanacideM	Simazine
7	Ronstar 2G	Flexidor125+PanacideM	Butisan S
8	Ronstar 2G	Flexidor125+PanacideM	Katamaran
9	Ronstar 2G	Flexidor125+PanacideM	Helmsman

Liquid herbicide treatments were applied using a gas-pressurised sprayer in a high water volume equivalent to 2500 l/ha i.e. 250 mls/m^2. Granular treatments were applied using a 'pepperpot' sprinkler to ensure even coverage. Note that, due to an application error, the October treatments were applied at 25% of the intended rate.

2. Mulch and growing medium amendments trial - 11 treatments were tested on Cytisus grown in 9 cm pot liners. Efficacy against liverwort and moss was tested by using liners that were potted up from contaminated plugs (25-26th July 2003). Mulches were applied immediately after potting.

Treatment	Material/Source
1. Untreated	
2. Untreated	
3. Biotop mulch 5 mm depth	Starch + Miscanthus fibre product
4. Miscanthus mulch 5 mm depth	Chopped Miscanthus
5. Pine bark mulch 10 mm depth	Melcourt Propagation Bark^{TM}
6. Pine bark + copper fungicide mulch 10 mm depth	Melcourt Propagation Bark^{TM} impregnated with Fungex (2.5 ml / litre, 250ml applied to 1 litre bark)
7. Pine bark + Ferrous sulphate mulch 10 mm depth	Melcourt Propagation Bark^{TM} impregnated with Ferrous sulphate (8 g / litre, 250 ml applied to 1 litre bark)
8. Pine bark + Lenacil 80W mulch 10 mm depth	Melcourt Propagation Bark^{TM} impregnated with Lenacil 80W 1.2 g / litre, 250 ml applied to 1 litre bark)
9. Loam (10%v/v) sterilised incorporated	Rigby Taylor Surrey Loam, autoclaved
10. Loam (10%v/v) unsterilised incorporated	Rigby Taylor Surrey Loam
11. Slyvafibre^{TM} (30%v/v) incorporated	Melcourt Wood fibre product
12. Limnanthes meal (1%) incorporated	Limnanthes seed processed and de-fatted
13. Geodisc^{TM} placed on pot surface	Fargro fabric pot topper copper impregnated

3. Natural products spray trial - 3 treatments were tested on Cytisus grown in 9 cm pot liners. Efficacy against liverwort and moss was tested by using liners that were potted up from contaminated plugs (25-26th July 2003). Treatments were applied immediately after potting and repeated in October. The Mogeton was included as a chemical standard treatment.

Treatment	Material
1. Untreated	
2. Untreated	
3. Orisorb	Citric acid-based product
4. Bionatura GAR	Benazyl ammonium chloride product
5. Mogeton	Quinclamine 25% w/w

Product application rates:
Orisorb 6.25 L/ha applied in 2500 litres water/ha
Bionatural GAR 125 L/ha applied in 2500 litres water/ha.
Mogeton 15 kg/ha applied in 2500 litres water/ha

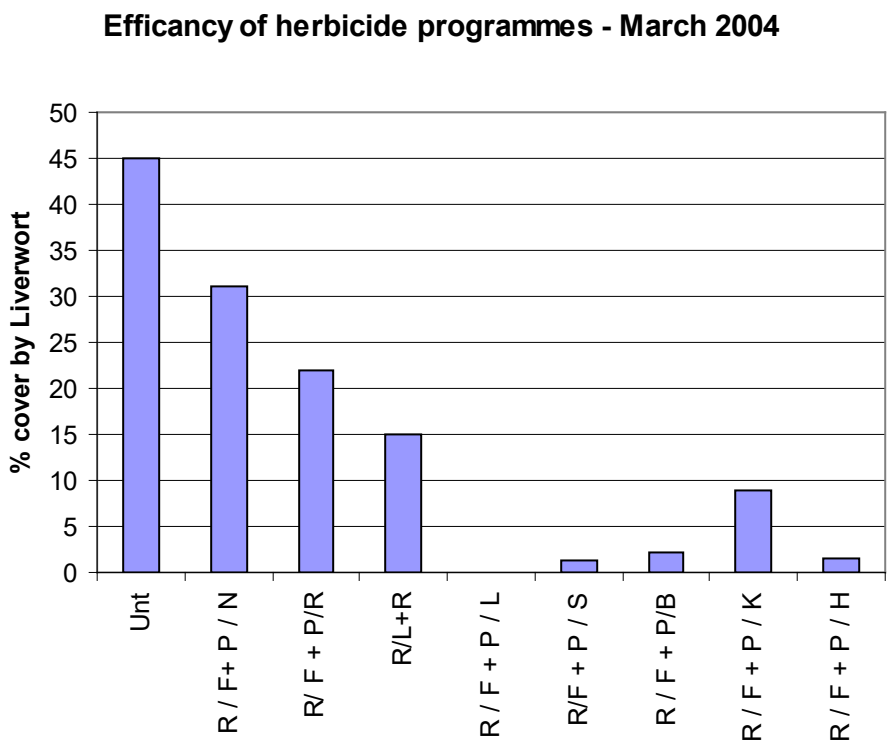
Subjects tested for phytotoxicity – Herbicide trial

Berberis darwinii
Ceanothus 'Blue Mound'
Cornus elegantissima
Cotoneaster horizontalis
Euonymus pulchellus
Hedera 'Goldchild'
Lavandula 'Imperial Gem'
Lonicera 'Lemon Beauty'
Myrtus 'Glanlean Gold'
Potentilla 'Primrose Beauty'
Prunus rotundifolia
Senecio greyii

Herbicide efficacy and safety trial

- 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.
- There was relatively little moss in the trial. Whereas Lenacil 80W, Butisan S and Katamaran controlled moss as well as liverwort, Simazine and Helmsman granules appeared to be relatively ineffective.

- The "growers standard" treatment of alternating Ronstar 2G and Flexidor 125 / Panacide was less effective at controlling liverwort and moss, compared with the experimental winter treatments.
- 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.



Mulch and growing media amendments trial

- All of the mulches and media amendments delayed the onset of liverwort and moss growth.
- 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 an mulch impregnation.
- Of the incorporation treatments, Sylvafibre^{TM} was reasonably effective as a moss/liverwort control, 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.

Natural products spray trial

- None of the natural products were effective when compared with the Mogeton standard.

Financial benefits

Financial benefits from the project will be evaluated and included in the final report.

Action points for growers

- The use of a wood fibre growing media amendment such as Sylvafibre^{TM} can be useful in reducing the incidence of moss and liverwort, but would need to be integrated with other control measures to provide complete control.
- Mulches such as Biotop and Miscanthus, are effective, but are time consuming to apply.

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 once SOLAs have been granted for use under protection.

SCIENCE SECTION

INTRODUCTION

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

Moss 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 reducing value; even dead liverworts are considered unsightly.

Liverworts and mosses are estimated to cost the industry 4% of total product cost. Predominantly the industry uses overhead irrigation, and often plants are over watered resulting 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 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 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 growing medium amendment.

Mustard meal and pellets high in glucosinolates are being developed in Italy and could become available as a source of glucosinolates. The benefit of these treatments will be evaluated and quantified in this project.

This report covers the first year of trials for this project done at Darby Nursery Stock Ltd.

In year two, the most promising treatments will be refined and further validated. An integrated experiment will be set up to test treatments combining both biological and chemical elements of control delivering practical solutions that could be readily adopted by the nursery stock industry.

OBJECTIVES

1. To determine the efficacy and crop safety of new herbicides on liverworts and moss, when used as winter applications 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 addressed the objectives of the project in year 1:

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

1. HERBICIDE TRIAL

This trial looked at both the efficacy and phytotoxicity of 8 herbicide treatment programmes against a non-treated control.

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

Twelve shrub species were used to assess phytotoxicity in the trial.

HNS Woody Species:

Berberis darwinii
Ceanothus 'Blue Mound'
Cornus elegantissima
Cotoneaster horizontalis
Euonymus pulchellus
Hedera 'Goldchild'
Lavandula 'Imperial Gem'
Lonicera 'Lemon Beauty'
Myrtus 'Glanlean Gold'
Potentilla 'Primrose Beauty'
Prunus rotundifolia
Senecio greyii

All plants were supplied from Darby Nursery Stock Ltd.

Plants were supplied as cutting plugs potted into 9 cm liner pots on July 25/6th 2003.

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

See Appendix 1 for plan details
Split plot design:
8 herbicide treatments plus and unsprayed control treatment x 3 replicates = 27 main plots for herbicide treatments
12 HNS shrub species sub-plots x 10 plants

Total 324 sub-plots

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

Herbicide treatments

Herbicides were applied in 2nd August 2003, 7th October 2003 and 15th December 2003.

Table 1: Herbicide products and rates

Product name	Chemical name and a.i. conc.	Rate of product 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	15 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/ll	0.2 ml / m^2

Table 2: Herbicide treatment programmes

After potting (July)	Overwintering on standing beds (October)*	Overwintering on standing beds (December)
Untreated	Untreated	Untreated
Ronstar 2G	Flexidor125+PanacideM	Untreated
Ronstar 2G	Flexidor125+PanacideM	Ronstar 2G
Ronstar 2G	Lenacil 80W	Ronstar 2G
Ronstar 2G	Flexidor125+PanacideM	Lenacil 80W
Ronstar 2G	Flexidor125+PanacideM	Simazine
Ronstar 2G	Flexidor125+PanacideM	Butisan S
Ronstar 2G	Flexidor125+PanacideM	Katamaran
Ronstar 2G	Flexidor125+PanacideM	Helmsman

* ¼ of the of the original rate used.

Herbicide applications

Liquid herbicide treatments were applied using a gas-pressurised sprayer in a high water volume equivalent to 2500 l/ha i.e. 250 ml/m^2. Granular treatments were applied using a 'pepperpot' sprinkler to ensure even coverage. Note that, due to an application error, the October treatments were applied at 25% of the intended rate.

Assessments

i) Liverwort and moss control

Records were taken as follows:

14 October 2003	Onset of infection recorded
1 December 2003	% liner pot cover liverwort/moss
29 March 2004	% liner pot cover liverwort/moss

Each pot was 5cm x 5 cm square and sat within a carrier of 20, therefore each pot surface was 5% of the total area if totally covered.

Assessments on liverwort and mosses were averaged across all woody species treated.

ii) 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 and growth on 29 March 2004 with a visual assessment of size on a scale 0-5.

2. MULCH AND GROWING MEDIUM AMENDMENT TRIAL

This trial looked at the efficacy of 11 mulch and/or growing medium amendment treatments against two non-treated controls.

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

All plants were supplied from Darby Nursery Stock Ltd.

Plants were supplied as cutting plugs potted into 9 cm liner pots on July 25/6th 2003.

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 9-12, the above mix was used, diluted by the addition of the amendments.

Experimental design

See Appendix 1 for plan details
Randomised block design:
13 treatments (includes 2 controls) x 3 replicates = 39 plots

The 13cm pots were placed on Mypex™ covered beds in plastic tunnels after potting. Overhead irrigation was used throughout.

Treatments

Mulches were applied immediately after potting.

Treatment	Material/Source
1. Untreated	
2. Untreated	
3. Biotop mulch 5 mm depth	Starch + Miscanthus fibre product
4. Miscanthus mulch 5 mm depth	Chopped Miscanthus
5. Pine bark mulch 10 mm depth	Melcourt Propagation Bark™
6. Pine bark + copper fungicide mulch 10 mm depth	Melcourt Propagation Bark™ impregnated with Fungex (2.5 mL / litre, 250 mL applied to 1 litre bark)
7. 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)
8. 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)
9. Loam (10%v/v) sterilised incorporated	Rigby Taylor Surrey Loam, autoclaved
10. Loam (10%v/v) unsterilised incorporated	Rigby Taylor Surrey Loam
11. Slyvafibre™ (30%v/v) incorporated	Melcourt Wood fibre product
12. Limnanthes meal (1%) incorporated	Limnanthes seed processed and de-fatted
13. Geodisc™ placed on pot surface	Fargro fabric pot topper copper impregnated

Assessments

i) Liverwort and moss control

Records were taken as follows:

14 October 2003	Onset of infection recorded
1 December 2003	% cover of pot with liverwort or moss
23 January 2004	% cover of pot with liverwort or moss
29 March 2004	% cover of pot with liverwort or moss

Each pot was 5cm x 5 cm square and sat within a carrier of 20, therefore each pot surface was 5% of the total area if totally covered.

ii) Plant growth

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

3. NATURAL PRODUCTS SPRAY TRIAL

This trial looked at both the efficacy and phytotoxicity of two natural products against an industry standard and two non-treated controls.

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

All plants were supplied from Darby Nursery Stock Ltd.

Plants were supplied as cutting plugs potted into 9 cm liner pots on July 25/6th 2003.

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

See Appendix 1 for plan details

Split plot design:
5 Treatments (includes 2 controls) x 4 replicates = 20 plots

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

Treatments

Treatments were applied on 2nd August 2003 and 7th October 2003.

Treatment	Material	Application rate
Untreated		
Untreated		
Orisorb	Citric acid-based product	6.25 L/ha
Bionatura GAR	Benazyl ammonium chloride product	125 L/ha
Mogeton	Quinclamine 25% w/w	15 kg/ha

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

i) Liverwort and moss control

Records were taken as follows:

14 October 2003	Onset of infection recorded
1 December 2003	% cover of pot with liverwort and moss
29 March 2004	% cover of pot with liverwort and moss

Each pot was 5cm x 5 cm square and sat within a carrier of 20, therefore each pot surface was 5% of the total area if totally covered.

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

RESULTS AND DISCUSSION

1. HERBICIDE TRIAL

i) Liverwort and moss control

By 14th October 2003, 3 months after cuttings were potted on, liverwort was starting to become established on all of the plots including those treated with the industry standard treatment of Ronstar 2G followed by and Flexidor 125 + Panacide M. By the time the main winter control treatments were applied on 14th December 2003, liverwort cover had reached an average of 32% on all pots and was not significantly reduced by any of the treatments (Table 3). After application of the December treatments, several treatments significantly reduced liverwort cover and four of them gave excellent control reducing liverwort to less than 5% pot cover (Table 3). Lenacil was outstanding as a winter treatment, reducing liverwort to 1%.

Table 3: Effect of herbicide spray programmes (treatments applied July, October and December) on mean % liverwort cover

	% Liverwort coverage on pots	
Treatments	December 1st 2003	March 29th 2004*
Untreated	35.1	45.3 (42.2) e+
Ronstar 2G – Flexidor125 + Panacide M – Untreated	28.3	31.3 (33.1) de
Ronstar 2G – Flexidor125 + Panacide M – Ronstar 2G	34.1	22.2 (27.1) cd
Ronstar 2G – Lenacil 80W – Ronstar 2G	27.9	15.0 (22.4) cd
Ronstar 2G – Flexidor 125 + Panacide M – Lenacil 80W	29.7	0.1 (0.8) a
Ronstar 2G – Flexidor 125 + Panacide M – Simazine	35.1	1.4 (4.9) ab
Ronstar 2G – Flexidor 125 + Panacide M – Butisan S	22.9	2.1 (8.2) ab
Ronstar 2G – Flexidor 125 + Panacide M – Katamaran	35.5	9.0 (16.9) bc
Ronstar 2G – Flexidor 125 + Panacide M – Helmsman	36.5	1.6 (7.1) ab
Grand Mean	**31.7**	**14.2 (18.1)**
F pr	0.8	<0.001
s.e.d. (df)	8.91 (16)	6.16 (16)
LSD at 5%	-	13.06
% CV	34.5	41.7

* Data from March 29th were skewed. Angular transformation used – transformed means in brackets. Statistical summary refers to transformed data.

+ The letter suffices refer to the mean rankings generated with a Duncan's test. Treatments followed by a common letter are not statistically different at the 5% probability level.

There were no significant differences between treatments for the assessment carried out Dec 1st 2003. On the 29th March assessment, the treatment with the least amount of liverwort was the winter application of Lenacil. This treatment had significantly less liverwort cover than the untreated, untreated winter, both the grower standards and the Experimental with Katamaran.

Treatments 5, 6, 7 and 9 all had significantly less liverwort cover than the untreated treatments and the 2 grower standards.

The development of moss was very limited and insufficient for statistical analysis. However there were indications that whilst Helmsman and Simazine gave excellent control of liverwort, the control of moss was not as good.

ii) Phytotoxicity and quality assessments

No adverse effects were noted following application of any of the experimental treatments. Plants were assessed for quality and growth on 29th March 2004, when the spring flush of growth was underway (Table 4). 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. The figures below are estimated medians. Only data from those varieties that showed a significant vigour response to the treatments are presented below.

Table 4: Effect of herbicide spray programmes on plant vigour (5 = vigorous and healthy, 1 = not vigorous and unhealthy)

Treatment	Test species			
	Cotoneaster	*Potentilla*	*Berberis*	Mean (for whole trial)
Untreated	5.0	5.0	5.0	5.0
Ronstar 2G – Flexidor125 + Panacide M – Untreated	5.0	5.0	5.0	5.0
Ronstar 2G – Flexidor125 + Panacide M – Ronstar 2G	5.0	5.0	5.0	5.0
Ronstar 2G – Lenacil 80W – Ronstar 2G	5.0	5.0	5.0	5.0
Ronstar 2G – Flexidor 125 + Panacide M – Lenacil 80W	5.0	5.0	5.0	5.0
Ronstar 2G – Flexidor 125 + Panacide M – Simazine	5.0	5.0	5.0	5.0
Ronstar 2G – Flexidor 125 + Panacide M – Butisan S	3.1	3.5	4.0	4.4
Ronstar 2G – Flexidor 125 + Panacide M – Katamaran	3.4	4.0	4.0	4.6
Ronstar 2G – Flexidor 125 + Panacide M – Helmsman	4.9	5.0	5.0	5.0
P value	0.005	0.006	0.002	0.011
S	22.33	18.00	24.00	19.89
df	8	8	8	8

The results from plant vigour assessment suggest that the experimental treatments 7 and 8 (with Butisan S and Katamaran respectively) have a statistically significant effect on vigour on certain species in the trial – Berberis, Cotoneaster and Potentilla.

Root data were analysed using Friedman's non-parametric analysis (Table 5). The figures below are estimated medians. Only data from those varieties that showed a significant vigour response to the treatments are presented below.

Table 5: Effect of herbicide spray programmes on root vigour (5 = vigorous and healthy, 1 = not vigorous and unhealthy)

Treatment	Test Plants			
	Potentilla	*Berberis*	*Lavandula*	Mean (for whole trial)
Untreated	5.0	5.0	5.0	5.0
Ronstar 2G – Flexidor125 + Panacide M – Untreated	5.0	5.0	5.0	5.0
Ronstar 2G – Flexidor125 + Panacide M – Ronstar 2G	5.0	5.0	5.0	5.0
Ronstar 2G – Lenacil 80W – Ronstar 2G	5.0	5.0	5.0	5.0
Ronstar 2G – Flexidor 125 + Panacide M – Lenacil 80W	5.0	5.0	5.0	5.0
Ronstar 2G – Flexidor 125 + Panacide M – Simazine	5.0	5.0	5.0	5.0
Ronstar 2G – Flexidor 125 + Panacide M – Butisan S	4.0	4.5	4.5	4.8
Ronstar 2G – Flexidor 125 + Panacide M – Katamaran	5.0	5.0	5.0	5.0
Ronstar 2G – Flexidor 125 + Panacide M – Helmsman	5.0	5.0	5.0	5.0
P value	0.044	0.002	0.002	0.002
S	16.00	24.00	24.00	24.00
df	8	8	8	8

The results from the root vigour assessment show that the experimental treatment 7 (with Butisan S) had a significant negative effect on vigour such that can be detected with a simple visual assessment. This effect was only seen to be significant in *Potentilla, Berberis* and *Lavandula* in the root zone. Root density was less in these species.

No significant long-term adverse effects were caused by any of the treatments, however 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 relatively unaffected.

2. MULCH AND GROWING MEDIUM AMENDMENT TRIAL

By December 2003, a very heavy infestation (84% liverwort cover) of liverwort had developed on the untreated control plots. At this stage all of the treatments gave significant levels of control, the most effective being the mulches and covers, particularly the chemical-impregnated pine barks Geodisc (only 3% liverwort cover) and Biotop (only 4% liverwort cover). Of the media amendments, Sylvafibre™ (only 5.7% liverwort cover), and unsterilised loam were most effective (only 10% liverwort cover), but sterilised loam (38% liverwort cover) and Limnanthes meal (25% liverwort cover) also had some effect.

Liverwort infestations continued to build up through January, but then declined slightly by March to finish at 76% cover in the untreated plots. By March some treatments were becoming less effective, but the treatments still giving significant levels of control were (in order of effectiveness) Pine bark + Lenacil (no liverwort growth), Geodisc (only 1% liverwort cover), unsterilised loam incorporated (5% liverwort cover), Pine bark + copper fungicide (12% cover), Biotop (17% cover), Sylvafibre™ incorporated (18% cover), Miscanthus mulch (22% cover) and Pine bark + Iron sulphate (42% cover).

The unsterilised soil incorporation developed a very high level of other weed cover by March, which may in itself have been responsible for inhibiting liverwort development by shading.

The development of moss was very limited and insufficient for statistical analysis. However there were indications that slightly more moss tended to develop in the loam amendment treatments, and the Sylvafibre™ amendment treatments than the control.

None of the treatments appeared to have any effect, positive or negative, on the vigour of growth of the *Cytisus* used in this trial.

Table 6: Effect of mulches and growing medium amendments on % liverwort cover

	% Liverwort – Assessment Dates		
Treatments	December 1st 2003*	January 23rd 2004	March 29th 2004
1.Untreated	83.9 (70.9) d	88.3 e	76.3 c
2.Biotop Mulch 5mm depth	4.0 (8.9) a	7.0 a	16.7 ab
3.Miscanthus	13.3 (20.5) abc	15.0 ab	21.7 ab
4.Pine bark mulch 10mm depth	27.3 (30.1) bc	51.7 cd	45.0 bc
5.Pine bark + Cu fungicide 10mm	3.0 (9.7) a	9.3 a	12.3 ab
6.Pine bark + Fe Sulph 10mm	8.3 (16.6) ab	25.0 abc	41.7 bc
7.Pine bark +Lenacil 80W 10mm	0.7 (2.7) a	0.0 a	0.0 a
8.Loam (10%v/v) sterilised incorp	38.3 (37.9) c	63.3 de	70.0 c
9.Loam (10%v/v) unsterilised	10.0 (18.0) ab	13.3 ab	5.0 a
10.Sylvafibre (30% v/v) incorp	5.7 (13.2) ab	11.0 a	18.3 ab
11.Limnanthes meal (1%) incorp	25.0 (29.5) bc	41.7 bcd	56.7 c
12.Geodisc	3.3 (8.6) a	3.3 a	0.7 a
Grand Mean	**23.6 (26.0)**	**32.1**	**33.9**
F pr	<0.001	<0.001	<0.001
s.e.d. (df)	8.47 (25)	13.45 (25)	15.33 (25)
% CV	39.9	51.3	55.4
LSD at 5%	17.45	27.71	31.58

*Data from December 1st were skewed. Angular transformation used – transformed means in brackets. Statistical summary refers to transformed data.

3. NATURAL PRODUCTS SPRAY TRIAL

The two products tested, Orisorb and Bionatura GAR appeared to give virtually no control of liverwort. The standard Mogeton, however maintained good control to December, declining a little by March.

Table 7: Effect of two natural products and a chemical herbicide on % liverwort cover

	Assessment dates	
Treatments	1 Dec 03	29 Mar 04
1. Untreated	83.5*	77.5
2. Orisorb	90.0	68.7
3. Bionatura	42.5	75.0
4. Mogeton	8.0	20.0
F pr	<0.001	<0.001
s.e.d. (df)	10.73 (13)	12.10
%CV	24.7	26.8

* percentage of pot covered with liverwort

CONCLUSIONS

From the results of the herbicide trial, 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 liners. From the excellent results achieved, it may be possible to utilise even lower rates, to further reduce the risk of damage. There were indications that even when Lenacil was used in October at 25% of the winter treatment rate, some liverwort control was achieved.

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.

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

In the mulch and media amendment trial, 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, it proposed that these will not be carried forward to the year 2 trial. The Biotop and Miscanthus mulches remained stable and provided reasonable but not complete control. The chopped Miscanthus mulch was messy and unattractive, and as the results were not as good as with Biotop, this material will not be trialled in year 2.

The pine bark much was not sufficiently effective when used "straight", but when impregnated with chemicals, the results were transformed. The Lenacil impregnation was particularly effective. It would be useful to further test this treatment on a known, Lenacil susceptible species, in comparison with the straight Lenacil spray. The copper impregnation was also effective suggesting that other additives to fix the copper treatment to the media surface might be worth investigating. The iron sulphate impregnation was less effective and this treatment will not be trialled in year 2.

Some of the media amendment treatments warrant further development. The most effective was Sylvafibre™. 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 44%. At this rate the media may require different management techniques compared with a peat media. However no adverse effects were noted on the Cytisus liners used.

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 trial little effect could be seen. To obtain useful results with this treatment it may be necessary to increase the incorporation rate.

The two natural spray products tested, Orisorb and Bionatura GAR appeared to give virtually no control of liverwort. These treatments appear to show little potential and will be discontinued. The standard Mogeton, however maintained good control to December, declining a little by March.

REFERENCES

Nakayoma T, Fukushi Y, Mizuntani J & Tahara S (1996). Inhibiting effects of lunularic acid analogs on the growth of liverworts, watercress and Timothy grass. *Bioscience, Biotechnology & Biochemistry* **60**, 862-865.

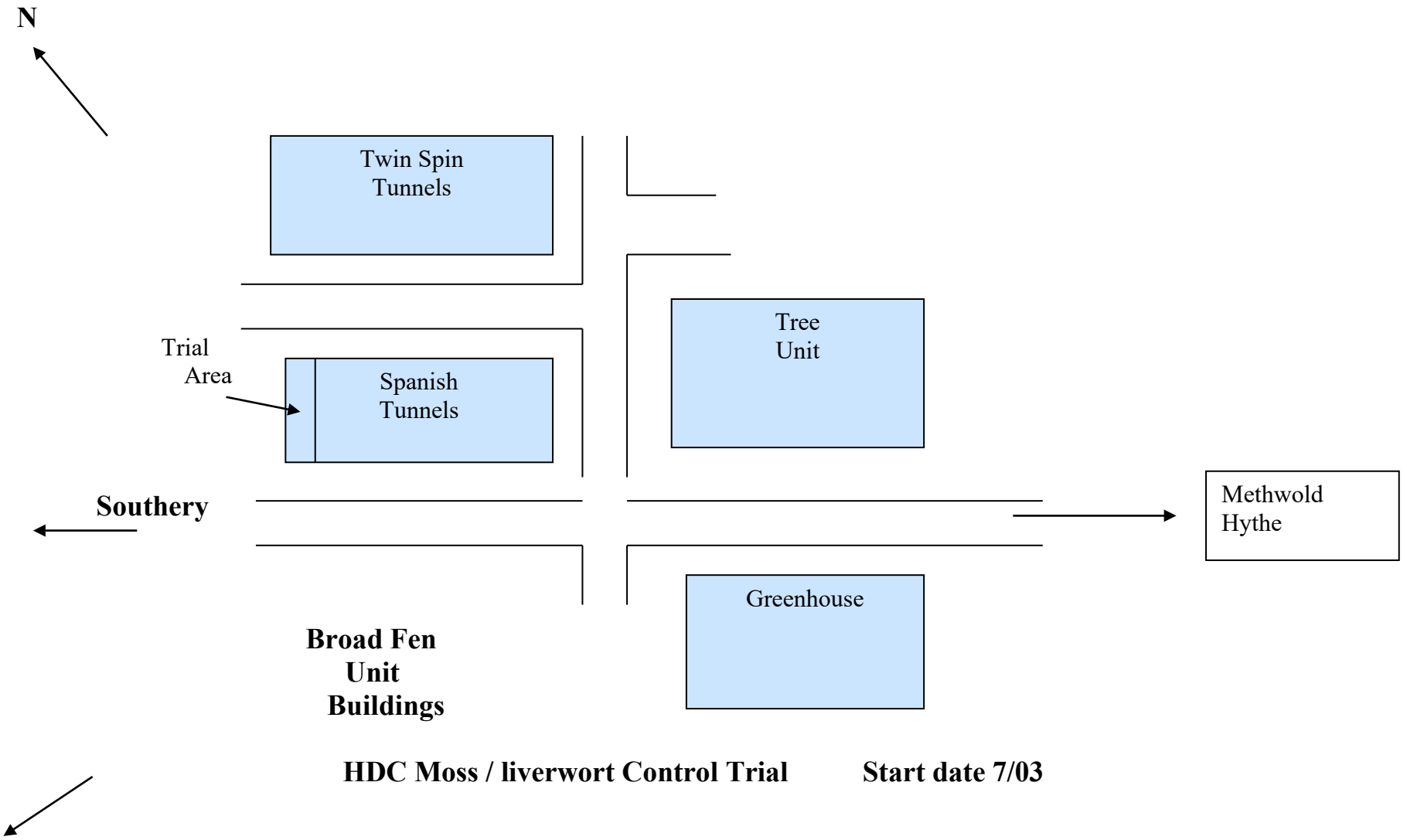
Svenson S E (1997). Suppression of liverwort growth in containers by cinnamic aldehyde. *Proceedings South Nursery Association Research Conference* **42**, 494-496.

ACKNOWLEDGEMNTS

The assistance of the staff of Darby Nursery Stock Ltd in looking after the plants in these trials is gratefully acknowledged.

Appendices

APPENDIX 1 – Site and Experimental Layout



HDC Moss / liverwort Control Trial Start date 7/03

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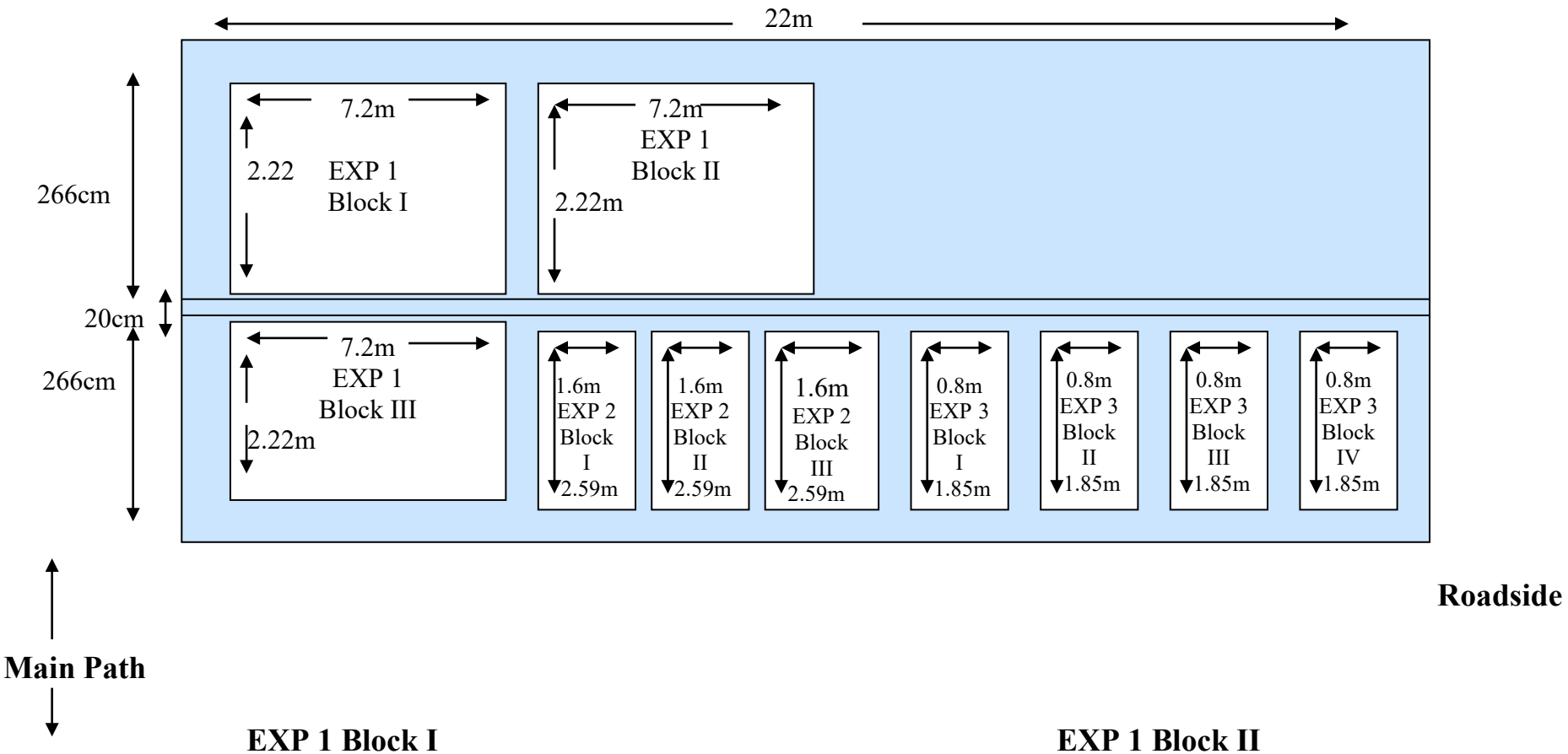
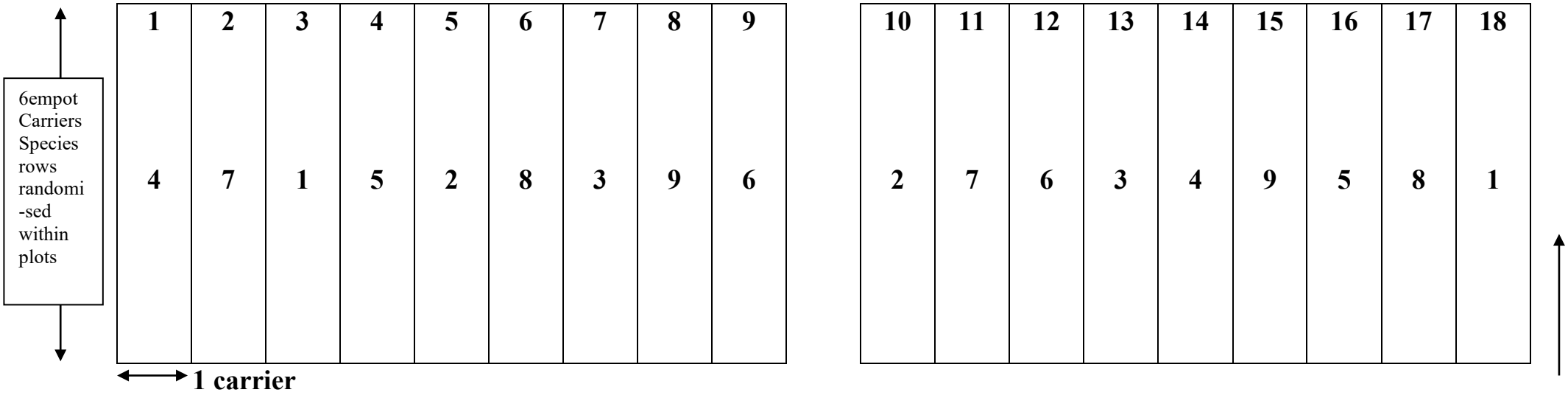
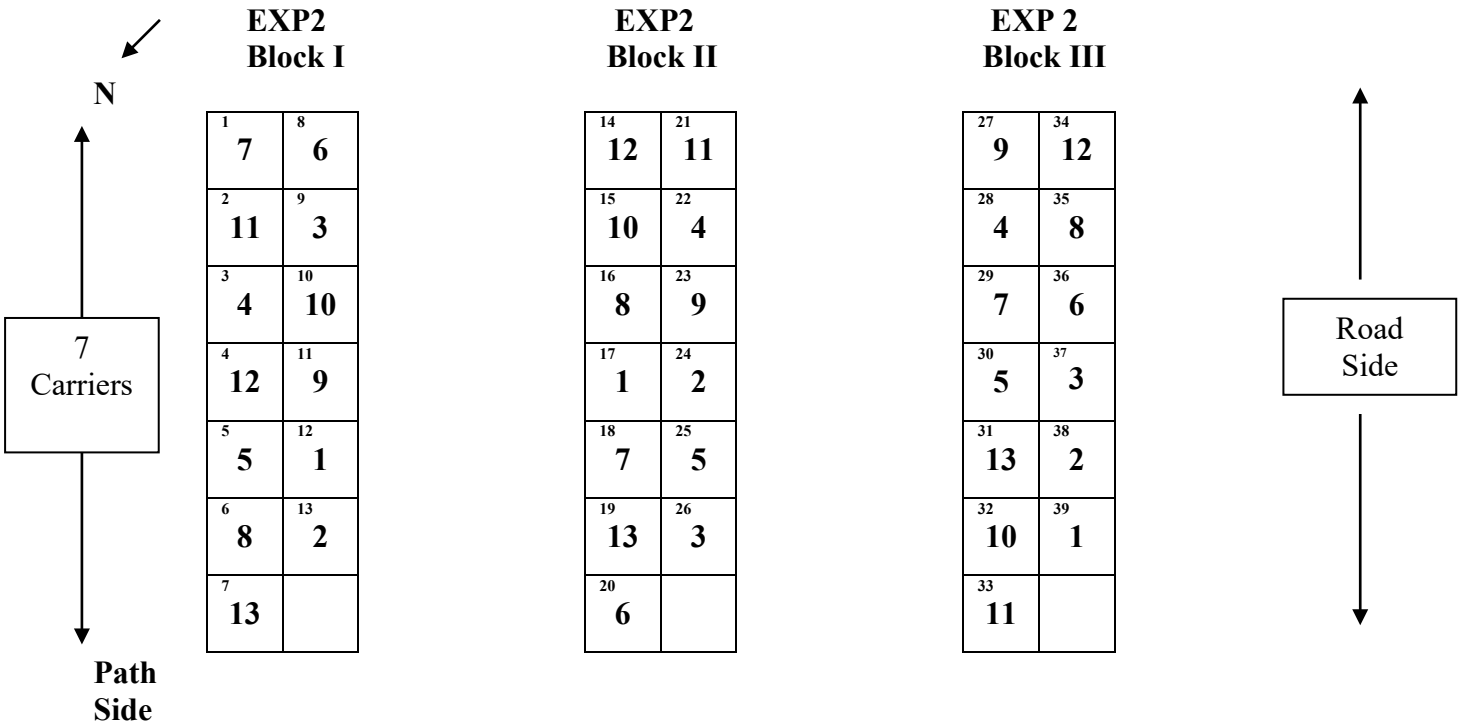




EXP 1 Block III

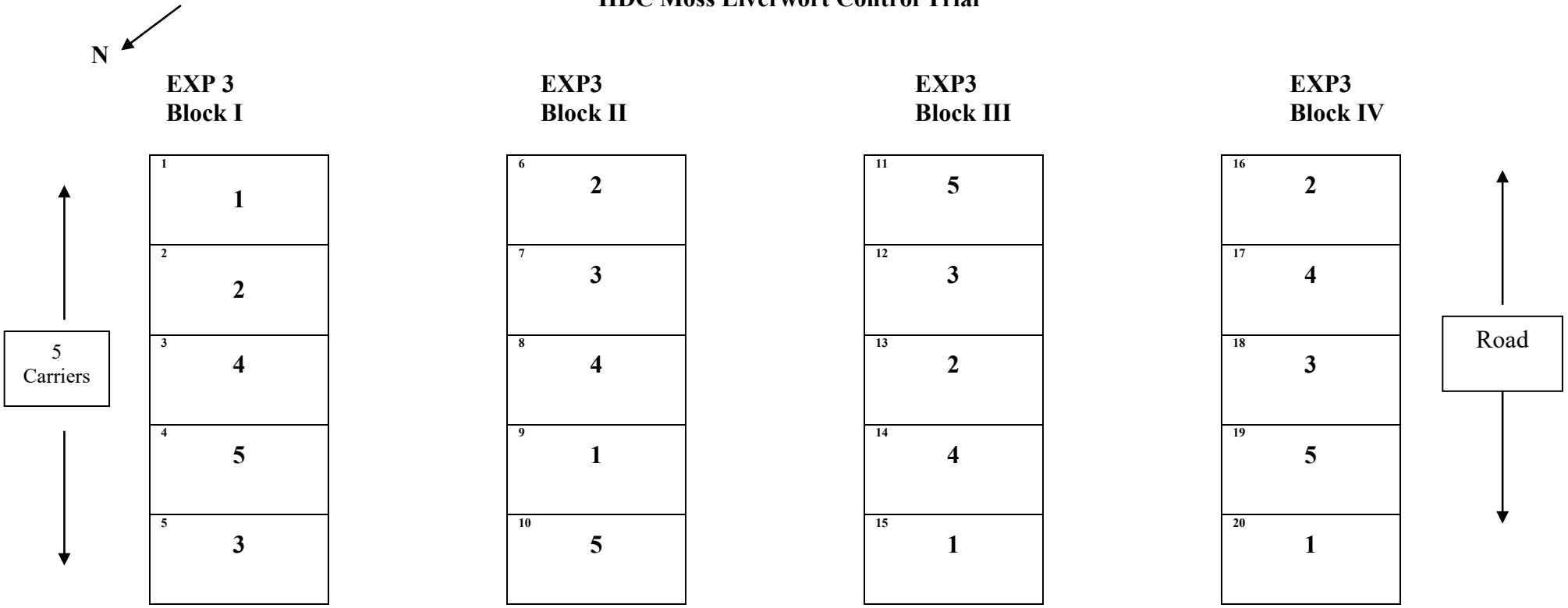
19	20	21	22	23	24	25	26	27
2	6	3	7	9	4	1	8	5

Treatment	After Potting (July)	September	November
1	-	-	-
2	Ronstar 2G	Flexidor + Panacide M	-
3	Ronstar 2G	Flexidor + Panacide M	Ronstar 2G
4	Ronstar 2G	Lenacil 80W	Ronstar 2G
5	Ronstar 2G	Flexidor + Panacide M	Lenacil 80W
6	Ronstar 2G	Flexidor + Panacide M	Simazine
7	Ronstar 2G	Flexidor + Panacide M	Butisan S
8	Ronstar 2G	Flexidor + Panacide M	Katamaran
9	Ronstar 2G	Flexidor + Panacide M	Helmsman



Treatment
1.Untreated
2.Untreated
3.Biotop Mulch 5mm depth
4.Miscanthus mulch 5mm depth
5.Pine bark mulch 10mm depth
6.Pine bark + copper fungicide mulch 10cm depth
7.Pine bark + ferrous sulphate mulch 10cm depth
8. Pine bark + Lenacil 80W mulch 10cm depth
9.Loam (10%v/v) sterilised incorporated
10.Loam (10%v/v) unsteralised
11.Sylvafibre (30% v/v) incorporated
12.Limnanthes meal (1%) incorporated
13.Geodisc placed in pot surface

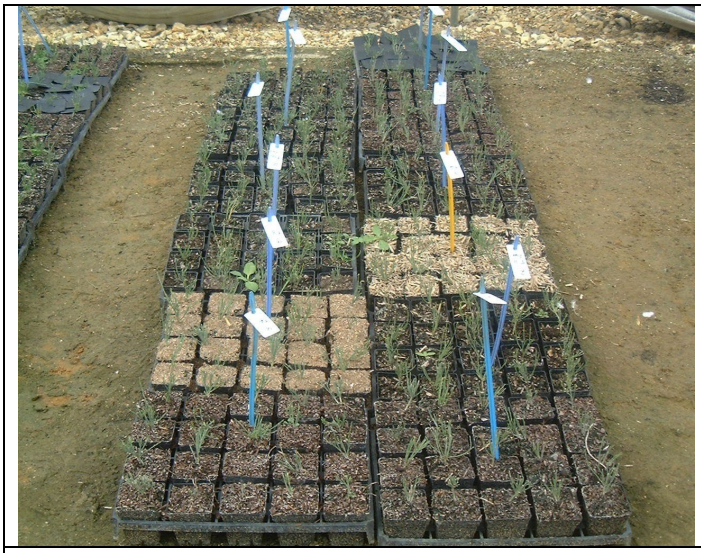
HDC Moss Liverwort Control Trial



Treatment
1.Untreated
2.Untreated
3.Orisorb
4.Bionatura GAR
5.Mogeton

APPENDIX 2

PHOTOGRAPHS

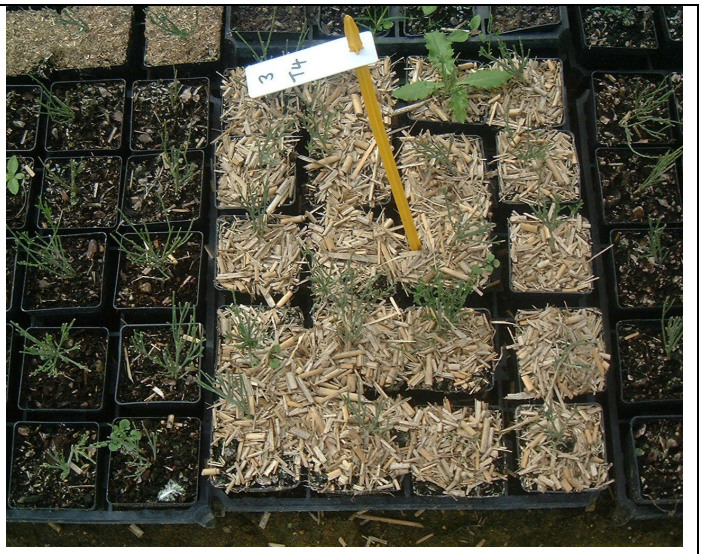


Layout of of Experiment 2 showing mulches and media amendments

Layout of 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) showing delay in maturity caused by treatment with Butisan	