Liverwort Control Using Novel Techniques©

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INTRODUCTION

Liverwort growing on the surface of growing media is a major problem in nursery stock production, affecting both protected and outdoor-grown crops: removal has been estimated at 4% of total annual production costs (Scott and Hutchinson, 2001), equivalent to £1,763 per hectare based on Horticultural Business Data 2008–9 figures (Crane and Vaughan, 2009). Zero tolerance of liverwort in certification schemes and a lack of approved chemical products make its control a technical priority for growers. This paper reports on a project funded by the Horticultural Development Company (HDC) to investigate the herbicidal effect on liverwort of glucosinolate hydrolysis products found in oil seeds, and the suppression of liverwort growth by unknown biological or physical factors within certain growing media components.

Seed Meal Suppressive Effect. Glucosinolates (GSLs) and their hydrolysis products (isothiocyanates, ITCs) are responsible for the distinctive pungent smell and hot taste of cabbages, mustards, and other brassicas and have shown toxicity against root knot nematodes, fungal species, and plants (Bialy et al., 1990). Such GSLs could potentially be used to control liverwort — each brassica species has a distinctive profile of one or more glucosinolates, each of which could have a different effect.

These GSLs are nontoxic thioglucosides with a common core comprised of a β-d-thioglucose group with a sulphonated oxime and a variable side chain ("R" group) that largely determines the biological activities of the degradation products (Brown and Morra, 1999). The hydrolysis of GSL is catalysed by a myrosinase enzyme released following mechanical damage in the presence of water; GSLs and myrosinase are stored separately within the plant and come into contact only following mechanical damage. The products of this reaction are primarily ITCs, thiocyanates, nitriles, or epithionitriles, depending on the "R" group present and environmental conditions (Vaughn et al., 2006). These ITCs are the most bioactive products of GSL hydrolysis and have been shown to exhibit a herbicidal effect on liverwort: ITCs adversely affected liverwort gemmae (vegetative propagules produced by gemma cups on the liverwort surface) comparable to two herbicides (lenacil and metazachlor) when tested under laboratory conditions in a previous HDC project (Jeger, 2008); *Limnanthes alba* seed meal provided short-term liverwort control when incorporated into growing media (HDC project HNS 93c); and *Sinapis alba* 'Ida Gold' applied as a mulch has been found to control established liverwort (Boydston et al., 2008).

Growing Media Suppressive Effect. Observations made by ADAS (formerly Agricultural Development and Advisory Service) consultants during an earlier HDC-funded project (HNS 93c) suggested a suppressive effect on liverwort growth where the growing media was amended with loam or the proprietary wood-fibre-based growing media ingredient Sylvafibre® (Melcourt Industries), possibly indicating natural microbial suppression in addition to any physical effect (Atwood, 2005). Work carried out for the U.K. government-funded "Peatering Out" project also suggested a suppressive effect of green compost on liverwort growth (Adlam and Rainbow, 2002).

Two trials were completed in Year 1 (2009–2010) of the project, sited on commercial nurseries, investigating the effect of brassica seed meal species and application method, and the effect of growing medium amendments on liverwort infestation.

MATERIALS AND METHODS

Seed Meal Suppressive Effect. Five seed meals were selected: *Camelina sativa* (false flax), *Brassica carinata* (Abyssinian mustard), *Sinapis alba* 'Albatross' (white mustard), and *Brassica napus* (oilseed rape) from two different sources. The seed meals were ground to fine meal and analysed for glucosinolate content (undertaken at NIAB [formerly National Institute of Agricultural Botany], Table 1). Each was applied both as a mulch (M) and incorporated (I) into the growing media. Irrigation was applied via overhead sprinklers and by hand during the winter. The potting mix was 100% Sinclair Professional Peat®, with Osmocote® Exact 11N-11P-18K + 2 MgO + trace elements, 8–9 months formulation (3 kg·m^{-3}) and the pH adjusted to 5.5 with lime. The trial was set up on 21 Sept. 2009.

Growing Media Suppressive Effect. Five products were included in this trial (Melcourt Sylvafibre®, Melcourt Growbark®, perlite, Vital Earth® green compost,

Table 1. Seed meal glucosinolate analysis.

Glucosinolate (μmol·g^{-1})	*Brassica carinata*	*Sinapis alba* 'Albatross'	*Brassica napus* '00'	*Brassica napus* RMF	*Camelina sativa*
Sinigrin	95.4	0	-	-	-
Glucosinalbin	33.9	187.8	-	-	-
4OH glucobrassicin	2.8	0	0.19	2.12	-
Glucoberin	-	-	0.15	0.89	-
Progoitrin	-	-	6.26	6.32	-
Epi Progoitrin	-	-	0.17	0	-
Glucoraphanin	-	-	0.53	0.54	-
Glucoalyssin	-	-	0.7	0.37	-
Gluconapin	-	-	2.49	2.64	-
Glucobrassinapin	-	-	0.76	1.13	-
Gluconasturtiin	-	-	0.15	0.26	-
Glucocamelinin	-	-	-	-	19.75
9-methylsulfinylnonyl-GLS	-	-	-	-	5.57
11-methylsulfinylundecyl-GLS	-	-	-	-	4.62
Total content	132.2	187.8	11.4	14.3	29.9

and sterilised loam). Sinclair Professional Peat was used as a base with added nutrients (Osmocote Exact Mini, 16N-8P-11K + 2 MgO + trace elements, 3–4 month formulation, 1.0 kg·m^{-3}, and Dolomitic lime, 500 g·m^{-3}). Lime was added to the Sylvafibre® treatment at 1.0 kg·m^{-3} as per the manufacturer's instructions. No lime was added to the green compost. Treatments were incorporated into the peat at a standard rate of 50%, except for the sterilised loam (20%). Irrigation was applied by hand in addition to overhead irrigation to maintain high water levels, excluding any effects caused by improved drainage due to the amendments increasing liverwort pressure. The trial was set up on 27 July 2009.

Both trials were carried out under protection, with treatments arranged in randomised block designs with 4-fold replication. Each plot consisted of a tray of 17 liners (9-cm pots), with one additional pot containing liverwort to introduce inoculum; no plants were used in the trials.

RESULTS AND DISCUSSION

Seed Meal Suppressive Effect. Over the whole trial, the least liverwort established in the *S. alba* (incorporated), *C. sativa* (mulch), and *B. napus* '00' (incorporated) treatments, and most liverwort established in the control pots (Fig. 1). Of the two *B. napus* seed meals ('00' and RMF), *B. napus* '00' had less liverwort infestation. After 22 weeks many of the pots were extremely dry, and this contributed to the decreased liverwort across the trial after 26 weeks.

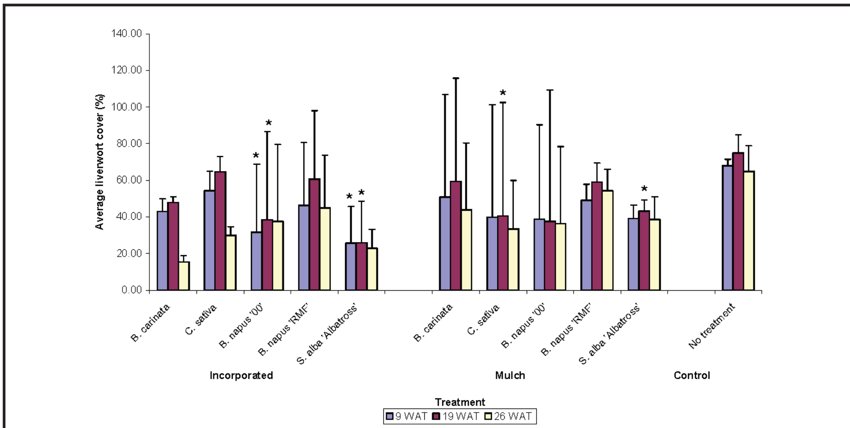

Figure 1. Seed meal suppressive effect (WAT = weeks after treatment). Least significant differences: 9 WAT = 10.35, 19 WAT = 13.75, 26 WAT = 26.12. *Average liverwort cover differs significantly from other treatments.

Data collected after 26 weeks was not found to be significant. However, data collected after 19 weeks, analysed using analysis of variance, showed a highly significant difference in liverwort cover between treatments ($F_{4,27} = 5.06$, $P<0.05$). Closer inspection of the data indicated that liverwort cover in the *S. alba* (incorporated and mulch), *B. napus* '00' (incorporated and mulch), and *C. sativa* (mulch) treatments was significantly less than in other treatments and the control. However, liverwort cover was highly variable in the majority of treatments. The most consistent results were within the *S. alba* plots.

Although statistical analysis using data gathered after 19 weeks did not identify a significant difference due to application method ($F4,27 = 2.71$, $p = 0.051$) it did suggest a trend towards less liverwort establishment where treatments were applied as a mulch (Fig. 2). After 19 weeks there was less liverwort cover in the mulch rather than incorporated *B. napus* RMF, *B. napus* '00', and *B. napus* '00' treatments; however even less liverwort cover developed in the incorporated *S. alba* and *B. carinata* treatments.

Growing Media Suppressive Effect. Peat treatments had a high level of liverwort infestation from early in the trial, as expected. Average pot cover in excess of

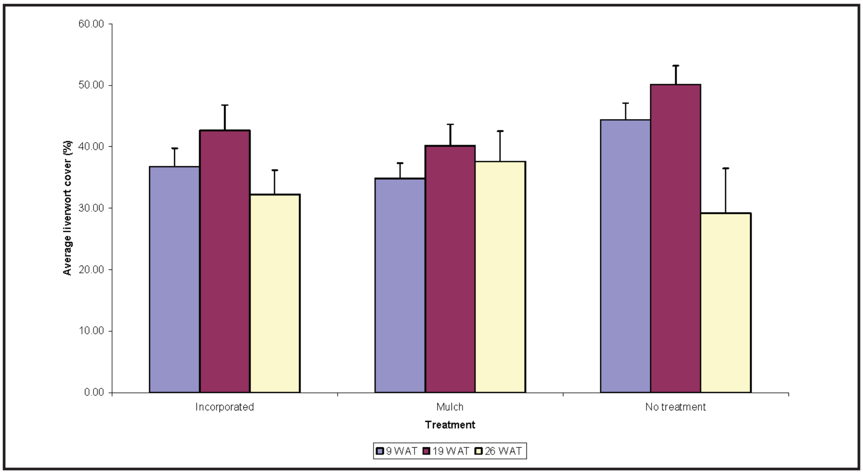

Figure 2. Comparison of application method (WAT = weeks after treatment). Least significant difference = 8.89.

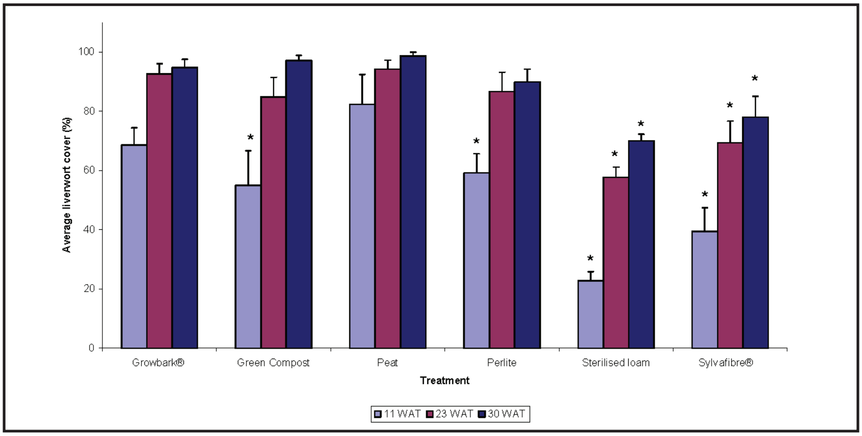

Figure 3. Growing media suppressive effect (WAT = weeks after treatment). Least significant differences: 11 WAT = 19.51, 23 WAT = 14.49, 30 WAT = 10.28. *Average liverwort cover differs significantly from the respective peat treatment.

82% was recorded after 11 weeks and 99% after 30 weeks. Liverwort growth was strong and healthy in this trial and the liverwort inoculant had spread into adjacent pots across all treatments after 4 weeks. Liverwort was slow to establish in the Vital Earth green compost treatments early in the trial, but 100% pot coverage was recorded in some plots after 30 weeks. Small black snails (*Oxyloma pfeifferi)* infested these treatments after 4 weeks, and the growing media slumped by approximately 10 mm in the pots.

Growbark® and perlite increase drainage and one would expect this to reduce liverwort infestation. However, under the moist conditions provided for this trial, after 30 weeks liverwort infestation was approaching that recorded in the peat and Vital Earth green compost treatments. Liverwort was also slow to establish in the Sylvafibre treatments although 78% pot cover was recorded after 30 weeks. Throughout the trial the sterilised loam showed least liverwort establishment. While this may show promise in reducing liverwort infestation, the weight and cost of loam may restrict the proportion that could be included in commercial growing media.

Statistical analysis using analysis of variance showed a very highly significant difference in liverwort cover between treatments ($F5,15 = 11.54$, $P<0.05$) after 30 weeks. The data indicated that liverwort cover in both the sterilised loam and Sylvafibre treatments was significantly less than in the Vital Earth green waste, perlite, Growbark and peat treatments.

CONCLUSIONS

The dry conditions of the seed meal trial meant the final results after 26 weeks were not reliable. The *S. alba, B. napus* '00', and *C. sativa* treatments all showed promise, and merit further investigation. The seed meals had individual GSL profiles (Table 1), although the two *B. napus* seed meals had similar profiles the proportions of each differed and this could be responsible for the different effects on liverwort infestation. Overall *S. alba* and *B. carinata* had the greatest GSL content, but this did not translate into greatest liverwort control in both cases, suggesting a greater influence of individual GSL characteristics than GSL quantity.

For short-term crops, or those potted up and due for sale within a short time frame, use of Sylvafibre may reduce the amount of liverwort herbicides applied or pre-sale pot cleaning. The Sylvafibre treatment produced promising results, maintaining liverwort cover less than 40% for 11 weeks. The most promising results were obtained using sterilised loam where liverwort cover was less than 23% after 11 weeks.

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