Horticultural Fellowship Awards

Interim Report Form

Project title:	Weed control in ornamentals, fruit and vegetable crops – maintaining capability to devise sustainable weed control strategies
Project number:	CP 86
Project leader:	John Atwood, ADAS UK Ltd.
Report:	Interim report, March 2012
Previous report:	None
Fellowship staff: **("Trainees")**	John Atwood, Project leader Lynn Tatnell, Assistant project leader Harriet Roberts, (fruit) and project management Jessica Sparkes, (weed biology) David Talbot, (ornamentals) Angela Huckle, (vegetables)
Location of project:	ADAS Boxworth
Industry representative:	Wayne Brough, HDC
Date project commenced:	April 2011
Date project completed (or expected completion date):	March 2016

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AUTHENTICATION

We declare that this work was done under our 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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Signature Date 30th March 2012

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GROWER SUMMARY

Headline

- Oil seed meals containing glucosinolates have potential for use as a natural weed control treatment when applied as a mulch either alone or with bark or coir.

Background

The HDC/EMT/HTA Horticultural Fellowship – Weeds is designed to provide training for four recently recruited ADAS consultants/researchers to develop specific expertise in weed control research, and thereby maintain research and consultancy expertise in the UK in this sector.

To help achieve this aim a programme of experimental work is planned and in the first year this has focused on the use of oil seed meals as a natural weed control treatment with potential for use initially in container-grown ornamentals. In HDC projects the potential for oil seed meals as a control for liverwort was first identified in HNS 93c with incorporated treatments. This approach was further developed in HNS 175 again for liverwort control using both incorporated treatments and mulches and it was concluded that effective liverwort control was possible particularly from mulch treatments and that mulch treatments were less likely to cause phytotoxicity to the test crop (Clematis).

Following the work in HNS 175, some questions remain to be answered: could similar treatments be used to control seedling weeds as well as liverwort, how much of the effect is due to the seed meal forming a physical mulch and how much is due to an allelopathic affect of the glucosinolate content and are there likely to be phytotoxicity issues in a wider range of crop species? The first two of these issues were investigated in this study.

Summary

Four experiments were carried out to test the weed control efficacy of two seed meals with a high and low glucosinolate content and a pelleted seed meal based fertiliser product with and intermediate glucosinolate content (Table 1), and using groundsel (*Senecio vulgaris*) and annual meadow-grass (*Poa annua*) as the test weed species.

Table 1. Glucosinolate meal treatment list.

Treatment no.	Glucosinolate meal	Rate	Glucosinolate content (micromoles/g)
1	Untreated	-	-
2	White mustard (*Sinapis alba*)	10 g/1 L pot	179.69
3	‘00’ Oilseed rape (*Brassica napus)*	10 g/1 L pot	16.53
4	Biofence (pelleted *Brassica carinata* seed)	10 g/1 L pot	99.30

An initial experiment tested each of the three products applied pre emergence as a mulch over sown groundsel and annual meadow grass seeds (Figure 1).

All three of the glucosinolate meals significantly reduced the number of emerged seedlings at the end of germination of both weed species. The two treatments with the higher level of glucosinolates appeared to be the more effective with white mustard (*Sinapis alba)* the most effective treatment, allowing no germination of either species Figure 5. Biofence was also particularly effective with very few seedlings of either species germinating. When the weeds managed to germinate and grow through the Biofence treatment they did appear quite healthy and showed very little phytotoxic effects. ‘00’ Oilseed rape meal was the least effective treatment, especially in controlling annual meadow-grass, however the level of reduction was still statistically significant and where weeds were observed there was a considerable level of phytotoxicity and purpling to the leaves of both groundsel and annual meadow grass perhaps a result of the lower glucosinolate content taking longer to kill the seedlings compared to the other two treatments.

In order to test whether the seed meals were acting as a physical mulch preventing germination and also to test the longevity of the treatments, groundsel seed (only) was sown on top of the three seed meals immediately, and three and six weeks after application. There was a significant reduction in the number of seedlings germinating regardless of which seed meal was used (Figure 6). Although there was a trend that efficacy of the glucosinolate seed meal treatments decreased with later application timing, differences were not significant. *S. alba* was again the most effective glucosinolate treatment.

In both experiments all of the seed meal treatments developed a fungal mould shortly after application and this in turn appeared to attract sciarid flies. Although the mould died down subsequently the overall effect was unattractive and would be a disadvantage (Figure 2). For the third experiment the seed meals were applied mixed with bark or coir to see if this reduced the fungal problem. Sowing was carried out both beneath and on top of the mulch. Again, all glucosinolate seed meals proved effective at controlling seedling emergence when groundsel was sown beneath and on top of the seed meal + mulch (Figure 7). The levels of fungal growth were reduced (Figure 3 and 4) but it was decided to test other methods for reducing it further.

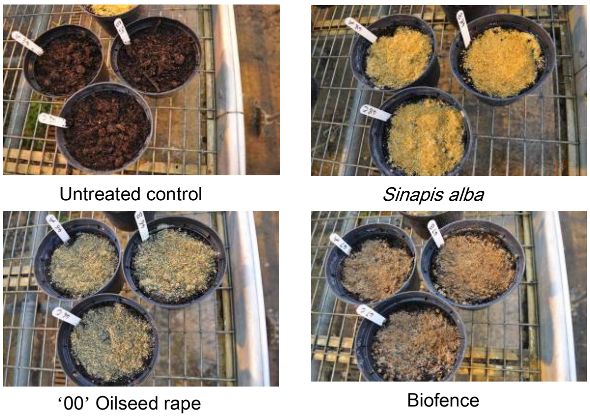

Figure 1. Experiment one set up with each of the 4 treatments

Figure 2. Example of fungal growth observed in Biofence treatment

Figure 3. Biofence and coir – dense grey fungal growth

Figure 4. Oilseed rape and bark – finer grey to white fungal growth

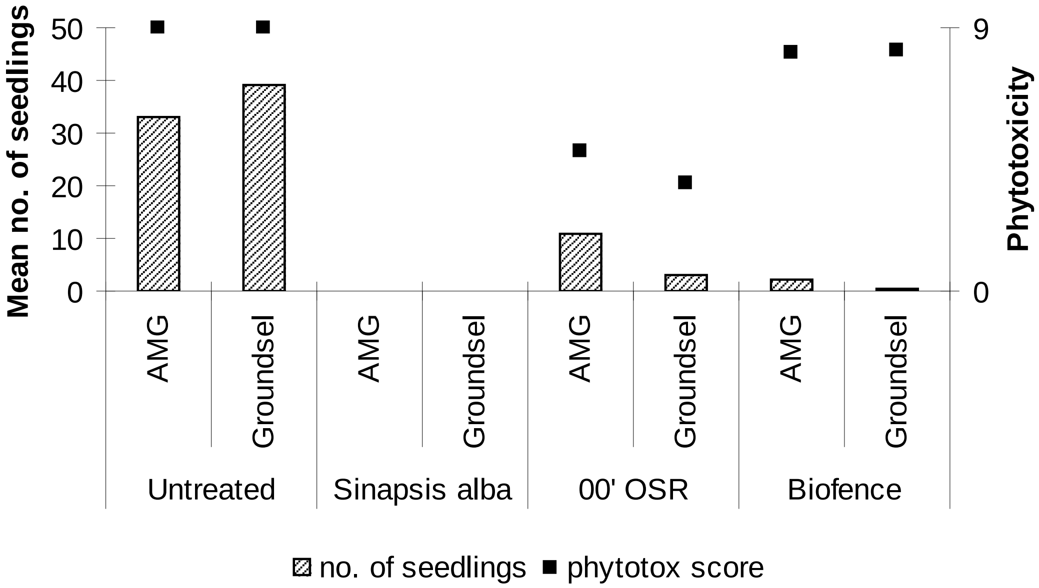

Figure 5. Mean number of seedlings recorded at the end of germination (3/10/12) and phytotoxicity scores (where applicable) seeds sown beneath mulch – Experiment 1. Phytotoxicity scored on a 0-9 scale (9 no effect 1 complete kill, 0 no seedlings to assess). AMG – annual meadow-grass, OSR – oilseed rape.

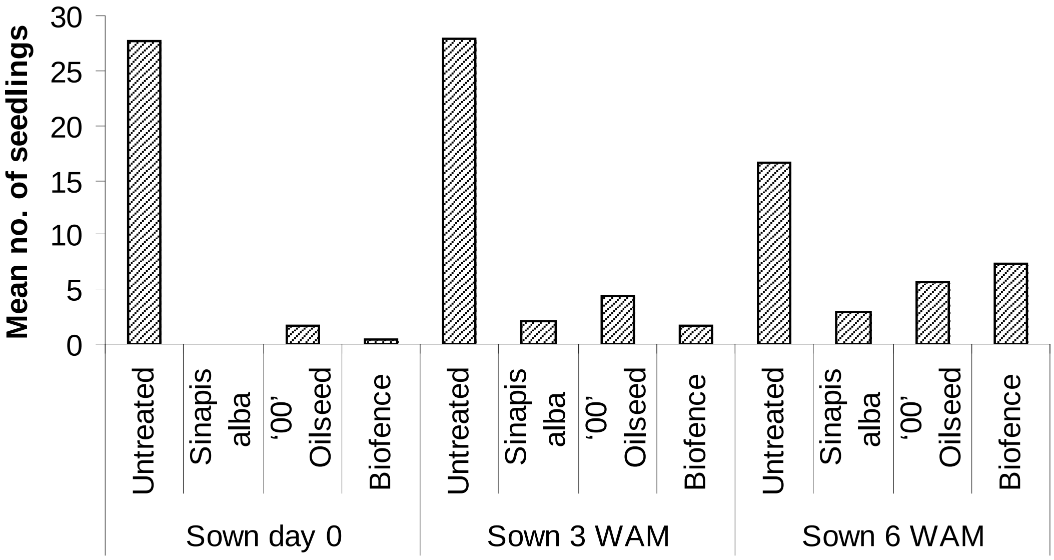

Figure 6. Mean number of seedlings recorded at the end of experiment (12/1/12) seeds sown sequentially 0, 3 and 6 weeks after mulch was applied on top of mulch – Experiment 2. WAM – weeks after mulch.

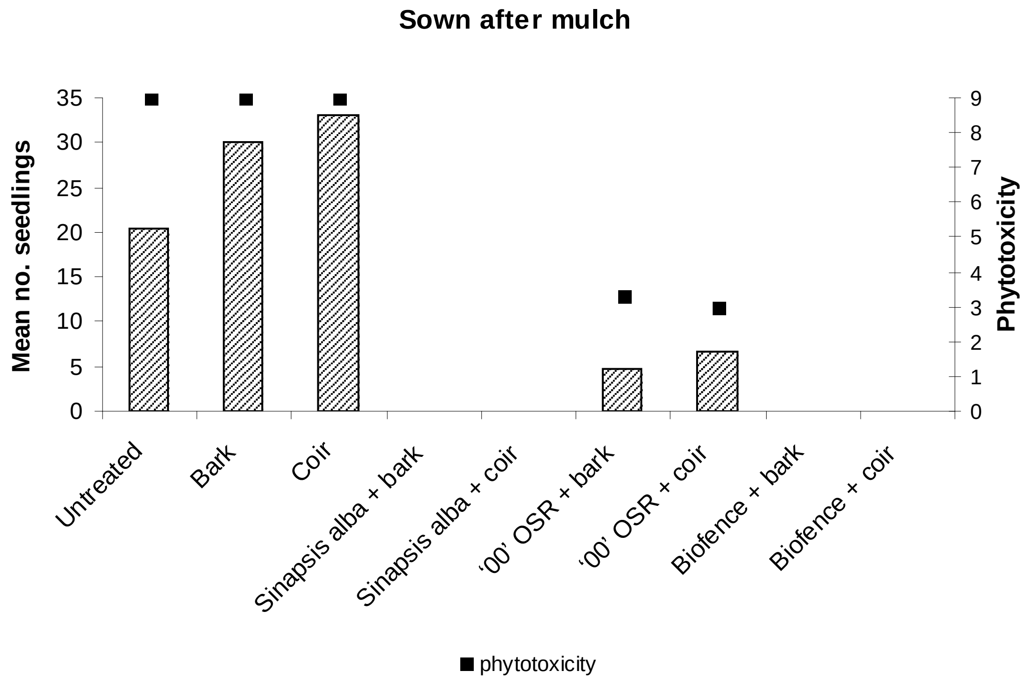

Figure 7. Mean number of groundsel seedlings recorded at the end of germination (09/12/2012) and phytotoxicity scores (where applicable) (03/01/2012) when seeds were sown under the seed meal – Experiment 3. Data for seeds sown beneath the mulch were similar. Phytotoxicity scored on a 0-9 scale (9 no effect, 1 complete kill, 0 no seedlings to assess). OSR – oilseed rape.

As a further investigation into reducing the development of this fungal growth, a fourth trial examined the use of Signum (boscalid and pyraclostrobin) and the biofungcide Serenade ASO (*Bacillus subtilis*) to control fungal development. Signum significantly reduced development of fungal growth but did not give complete control and further growth 10-14 days after application suggests further applications would be required, perhaps in combination with other fungicides. As a non chemical approach to weed control the use of a fungicide is counter intuitive therefore further investigation could look at the potential for steam treating the seed meals or using compost tea products to try and reduce the fungal development.

Following the four experiments it was concluded that:

- *Sinapis alba,* Biofence and '00' oilseed rape seed meals effectively controlled groundsel and annual meadow-grass, with the highest glucosinolate material, *S. alba* being the most effective.
- There was no difference in the level of weed control when seeds were sown before (beneath) or after (on top of) the treatment indicating that the physical mulch effect of the seed meal is probably relatively insignificant.

- Although there were indications that the efficacy of the products decrease over time, there was no significant difference when seeds were sown immediately or up to six weeks after treatment.
- The positive results of the glucosinolate seed meals was spoiled by the fungal growth associated with their use.
- Incorporation of the seed meals into a bark or coir mulch did not reduce mould to an acceptable level.
- Work to reduce the mould showed that an application of Signum after applying the Biofence and '00' oilseed rape mulch can significantly reduce but not eliminate the level of fungal growth.
- In other HDC trials soil incorporated seed meals have shown significant phytotoxic affects, seed meal applied as a mulch in trials on Clematis in 2011 showed phytotoxicity and a slight decline in height but were commercially acceptable, crop safety will be investigated in 2012 as part of the nursery stock screens.

Financial benefits

Further work is needed to resolve the fungal mould problem and test the treatments on a range of crops and weed species before this technique can be recommended to growers. Therefore there are no financial benefits at this stage. Costs associated with mulching HNS with some seed meal products have been calculated (England J. 2012) and vary from £4,350/ha for "00" oilseed rape, £8175/ha for Biofence and £11,550/ha for *Sinapis alba* including application costs (Hewson A 2012) of £1,875/ha.

Action points

- Oil seed meals containing glucosinolates have potential for use as a natural weed control treatment when applied as a mulch either alone or with bark or coir but further work is needed before this technique can be adopted by growers.

Future projects

In year 2 (2012) there will be three experimental projects and some preparatory work for projects in 2013:

- Screening of two new active ingredients for control of a range of weeds important to horticulture. Pot experiments at ADAS Boxworth.
- Phytotoxicity and efficacy testing of new active ingredients in a container-grown nursery stock, on a commercial nursery.

- Phytotoxicity and efficacy testing of new active ingredients as additions to standard programmes in field grown budded trees, on a commercial nursery.
- Preparatory work for vegetable weed control projects and cover crops in fruit crops planned for 2013.

SCIENCE SECTION

Introduction

Weed control in container-grown nursery stock production is becoming more difficult due to the fact that no new herbicides have been developed specifically for HNS in many years. This is because it is a relatively small market, and developing herbicides safe to such a diverse range of plant species is a complex and expensive process. Weed control is currently reliant on old active ingredients from other horticultural sectors, which may not suit the diverse growing systems employed by HNS growers and using a limited range of active ingredients may lead to herbicide resistance developing. Identifying novel biological methods for weed control will provide an extra weapon in the nurseryman's armoury.

Plant produced compounds which affect the growth and vigour of other plants are known as allelochemicals. Glucosinolates have been identified as a viable source of allelochemicals with the potential to control weed seed germination (Brown and Morra, 1996). More specifically, the glucosinolates found in Brassicaceous seed meal residue, a by-product of the oil extraction process, appear to be a promising alternative weed control strategy. Studies have shown that weed seed emergence can be reduced by incorporating a Brassicaceous crop into the soil as a green manure (Boydston and Hang, 1995; Al Khatib *et al.,* 1997; Brown and Morra, 1997) and by applying the seed meal residues directly onto the soil surface. In HDC projects the potential for oil seed meals as a control for liverwort was first identified in HNS 93c (Atwood, 2005) with incorporated treatments. This approach was further developed in HNS 175 (England, 2011) again for liverwort control using both incorporated treatments and mulches. It was concluded that effective liverwort control was possible particularly from Brassicaceous seed meal mulch treatments and that mulch treatments were less likely to cause phytotoxicity to the test crop (Clematis).

This study examined three different Brassicaceous seed meals, *Sinapis alba* (White mustard), a ''00' oilseed rape and Biofence, all of which contain glucosinolates but at differing levels. The objective was to determine if the use of any of these seed meals could effectively control weeds species that commonly occur in container-grown nursery stock.

Materials and methods

Experiment one – initial screen

This experiment was carried out in a glasshouse at ADAS Boxworth, Cambridgeshire between August and October 2011. The experiment examined the herbicidal activity of three glucosinolate meals (Table 2) on three common weed species; annual meadow-grass (*Poa annua*), groundsel (*Senecio vulgaris*) and chickweed (*Stellaria media*). The seed meals were *Sinapis alba* (white mustard cv. Braco); '00' Oilseed rape (*Brassica napus);* and Biofence a proprietary seed meal product derived from *Brassica carinata* seed, marketed by Plant solutions Ltd. The experiment was a full factorial design. Plots, which consisted of three pots, were fully randomised in a block design replicated four times. Trial plans are displayed in Appendix 5.

Table 2. Experiment one – treatment list

Treatment no.	Glucosinolate meal	Rate	Glucosinolate content (micromoles/g)
1	Untreated	-	-
2	Sinapis alba	10 g/1 L pot	179.69
3	'00' Oilseed rape	10 g/1 L pot	16.53
4	Biofence (ground)	10 g/1 L pot	99.30

Samples each of *Sinapis alba* 'Braco' seeds (Supplier: Farm Direct, Cumbria) and '00' oilseed rape (OSR) seeds *Brassica napus* (Supplier: Selby House Farm, Stanton) were crushed and the oil extracted by Alan Brewer (Selby House Farm, Stanton, cold extraction), then reformed into pellets prior to supply. The Biofence was sourced from Plant solutions Ltd. this product is derived from a specially bred brassica crop, the seeds of which are harvested, and formed into small pellets. All three products were ground to a fine powder separately in a food processor prior to application. Samples of these products were sent to NIAB for analysis of glucosinolate content by high performance liquid chromatography (HPLC) these are displayed in Table 2. The '00' OSR had the lowest glucosinolate content and based on previous trials (HNS 157) this level can be quite variable in oil seed rape. Rates applied were related to the volume of the seed meal required to cover the surface of the pot in a 5 mm layer rather than the glucosinolate content.

One litre pots were filled to within 20 mm of the rim with peat based growing media (Clover container compost) and watered to field capacity. Fifty weed seeds (sourced from Herbiseed, Berkshire, UK) were sown into each pot with care being taken not to sow any seeds within 12mm of the edge of the pot to ensure seeds did not germinate around the edges i.e. not coming into contact with the seed meal. Following seed sowing the media surface was lightly dampened and the glucosinolate meal was applied evenly on top. Pots were gently watered overhead, as required, for the duration of the experiment.

Seedling emergence was monitored and counted every few days from the time that germination began in the untreated plots. Three weeks after it was decided that no more seeds would germinate in the treated plots, a final seedling count was done as well as a seedling phytotoxicity assessment. Phytotoxicity was assessed on a scale of 1 – 9, where 1 represents a severe effect and 9 represents no effect. Additional symptoms and other comments were recorded as necessary and digital photographs were taken to show the phytotoxic effects.

Data from each of the three pots per plot was averaged and an analysis of variance (ANOVA) was performed for the number of seedlings which germinated and the number of seedlings which remained after three weeks as some treatments caused collapse of seedlings once germinated. As phytotoxicity could only be recorded in the pots which had germination, these results were unbalanced and therefore analysed by a regression model.

Two key issues were highlighted in this first experiment 1) that the seed meal forms quite a crusted layer on the media surface potentially physically suppressing germination and 2) saprophytic fungi rapidly colonised the seed meal mulch causing an unsightly grey mould and attracting sciarid flies. Following the results of the experiment further trials were designed to address the above issues the aims of which were to; 1) identify if the weed control observed in Experiment 1 is the result of allelopathy from the glucosinolate meals or due to a physical barrier being created and 2) see if the levels of mould and sciarid flies could be reduced by incorporating the seed meals into a bark or coir mulch?

Experiment two – position of sowing and longevity

This trial was set up to examine if a physical barrier resulting from the glucosinolate meal was the cause of the weed reduction and also to test the persistence of the glucosinolate meals. The experiment was carried out in a polythene tunnel at ADAS Boxworth, Cambridgeshire between November and December 2011. The experiment was a full factorial split plot design with the same three glucosinolate treatments applied at the same rates plus an untreated control (Table 2) with three sowing timings (day 0, after three weeks and after six weeks), this time only groundsel was used and seeds were sown on the surface of the mulch. There were three replicates and all treatments were randomised in a block design. Trial plans are displayed in Appendix 5.

The experiment was established and assessed, and data were analysed as described above for experiment one.

Experiment three – application in different mulches

This experiment was set up to assess whether the levels of mould and sciarid flies present in the previous glucosinolate meal trial could be controlled by incorporating the seed meal in a bark or coir mulch. The experiment was carried out in a polythene tunnel at ADAS Boxworth, Cambridgeshire between November and December 2011. There were three treatment factors; three glucosinolate treatments, two types of mulch (bark at 30 g/pot and coir at 60 g/pot) and two sowing treatments (beneath mulch and above mulch) replicated three times in a fully randomised split plot design. Again only groundsel was sown. Trial plans are displayed in Appendix 5. The rates of bark and coir used gave a similar depth of mulch (10 mm). Treatment details are given in Table 3.

Table 3. Experiment three – application in different mulches treatment list

Treatment no.	Treatment	Glucosinolate meal	Mulch
1	Untreated	-	-
2	Bark	-	30 g/pot
3	Coir	-	60 g/pot
4	*Sinapis alba* + bark	10 g/pot	30 g/pot
5	*Sinapis alba* + coir	10 g/pot	60 g/pot
6	'00' OSR + bark	10 g/pot	30 g/pot
7	'00' OSR + coir	'10 g/pot	60 g/pot
8	Biofence + bark	10 g/pot	30 g/pot
9	Biofence + coir	10 g/pot	60 g/pot

One litre pots were filled to within 20mm of the rim with peat based growing media (clover container compost) and watered to field capacity. Glucosinolate seed meals were incorporated into the mulches by hand mixing and applied evenly to each pot to a depth of approximately 10 mm. 50 groundsel seeds were sown either before or after the mulch was applied, depending on treatment. All pots were gently watered overhead, as required, for the duration of the experiment.

Seedling assessment and data analysis were as described previously.

Experiment four – application of fungicides to control fungal growth

Based on the results of the second and third glucosinolate screen where fungal growth on the seed meal was still very obvious it was decided a further trial would be useful to explore if the fungal growth observed on the seed meals could be suppressed as this was unsightly and impractical for the HNS industry.

For this screen, the three seed meals were examined in a fully randomised block design with four replicates. The experiment was carried out in a polythene tunnel at ADAS Boxworth, Cambridgeshire in March 2012 trial plans are displayed in Appendix 5. 1 L pots were filled with a peat based growing media (Clover container compost). The seed meals were applied at the rates shown in Table 4. No seeds were sown in this screen. Spray treatments were applied once pots had been wetted up; treatments were applied at 1000 L water/ha using a knapsack sprayer. Signum (active ingredient boscalid and pyraclostrobin) and Serenade ASO (active ingredient *Bacillus subtilis*) were applied.

Table 4. Experiment four – application of fungicides to control fungal growth treatment list applied 16th March 2012

Treatment no.	Treatment	Rate of seed meal	Rate of fungicide spray
1	*Sinapis alba*	10 g pot	-
2	'00' OSR	10 g pot	-
3	Biofence	10 g pot	-
4	*Sinapis alba* + Signum	10 g pot	1 kg/ha
5	'00' OSR + Signum	10 g pot	1 kg/ha
6	Biofence+ Signum	10 g pot	1 kg/ha
7	*Sinapis alba* + Serenade	10 g pot	10 L/ha
8	'00' OSR + Serenade	10 g pot	10 L/ha
9	Biofence+ Serenade	10 g pot	10 L/ha

The pots were monitored daily and an assessment was carried out once fungal growth has started on the untreated pots; the presence of any fungal growth and percentage of the pot surface covered in fungal growth was recorded as well as any comments on the fungal species present. This was repeated five days later.

Results

Experiment one – initial screen

Seedling emergence of *S. vulgaris* (groundsel) began seven days prior to that of *P. annua* (annual meadow-grass). No germination occurred in the *Stellaria media* it was assumed the seed was not viable so no data is displayed for that species. All three of the glucosinolate meals significantly reduced the number of emerged seedlings at the end of germination (14/09/2011) of both weed species ($F_{3, 24}$=26.70, p<0.001) as well as the total number of seedlings recorded three weeks after the start of emergence (26/09/2011 for *S. vulgaris* and 03/10/2011 for *P. annua*) ($F_{3, 24}$= 358.57, p<0.001). *Sinapis alba* was the most effective treatment, allowing no germination of either species (Figure 6). Biofence was also particularly effective with very few seedlings of either species able to emerge. When the weeds managed to germinate and grow in the Biofence treatment they did appear quite healthy and showed very little phytotoxic effects. '00' Oilseed rape meal was the least effective treatment, especially in controlling annual meadow-grass, however the level of reduction was still statistically significant and where weeds were observed there was a considerable level of phytotoxicity (Appendix 1, Image 3).

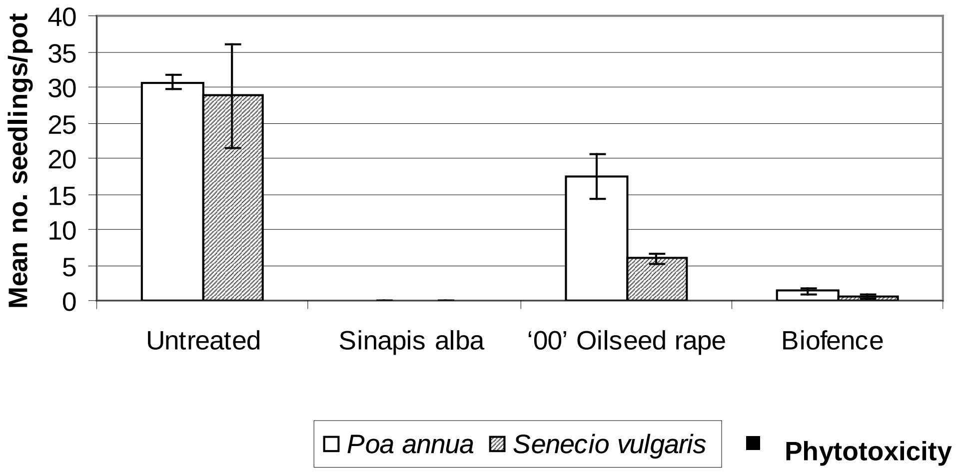

Figure 6. Mean number of seedlings recorded 14/09/2011 when untreated plots fully emerged

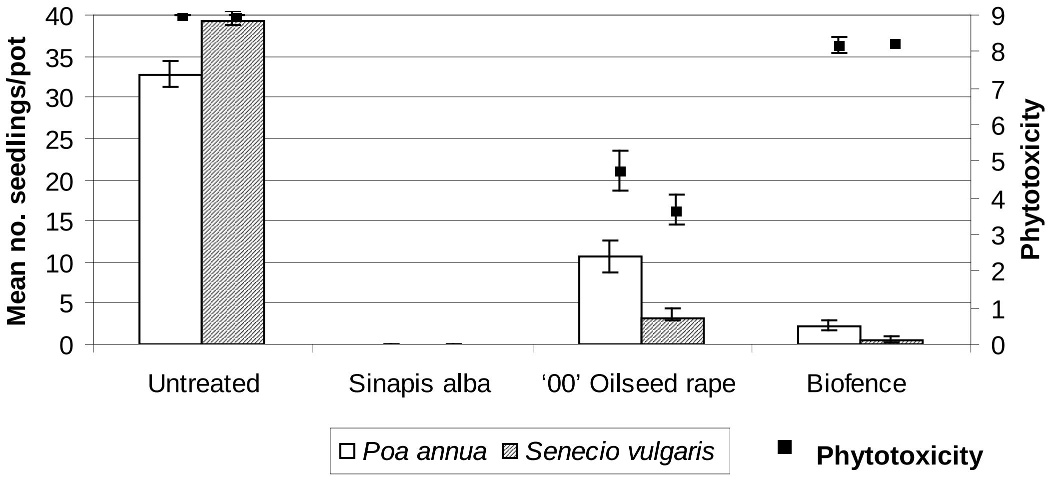

Figure 7. Mean number of seedlings recorded three weeks after first emergence (*S. vulgaris* assessed 26/09/2011, *P. annua assessed* 03/10/2011) and the mean phytotoxicity score of those that emerged. 0-9 scale (9 no effect, 1 complete kill, 0 no seedlings to assess).

A large amount of fungal growth occurred soon after the treatments were applied in all pots treated with glucosinolate meals (see Appendix 1, Images 4, 5 and 6). There was also a problem with sciarid flies feeding on the seed meal and associated fungal growth noted during the experiment.

Experiment two – position of sowing and longevity

When seeds were sown on top of the seed meals there was a significant reduction in the number of seedlings regardless of which seed meal was used ($F_{3, 23}$=24.22, p<0.001). Although there was a trend that efficacy of the glucosinolate seed meal treatments decreased over time (Figure 8) these differences were not significant ($F_{6, 23}$=1.56, p=0.204). As in Experiment 1, *S. alba* was the most effective glucosinolate treatment. Once again, fungal growth was very evident in all glucosinolate seed meal treatments. Although sciarid flies were less of a problem most probably due to the cooler conditions in the polythene tunnel. Trial images can be seen in Appendix 2.

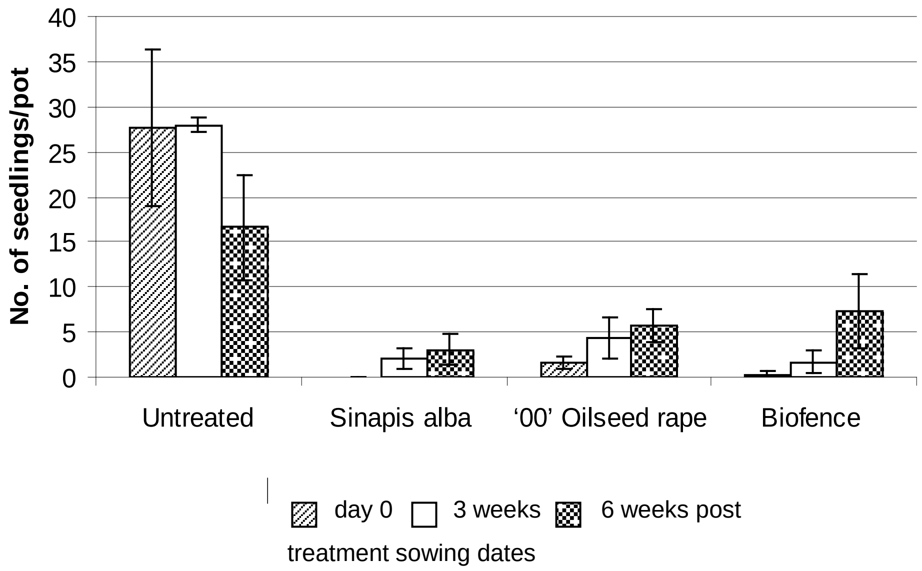

Figure 8. Mean number of *S. vulgaris* seedlings recorded at the end of germination (01/12/2012) when sown on the same day of glucosinolate meal treatment, three weeks later and six weeks later. 0-9 scale (9 no effect 1 complete kill, 0 no seedlings to assess).

Experiment three – application in different mulches

All three glucosinolate seed meals controlled *S. vulgaris* when sown both before (Figure 9) and after (Figure 10) the seed meal + mulch was applied. Complete control of *S. vulagris* was achieved with *S. alba* and Biofence regardless of sowing timing or mulch type. There were low numbers of seedlings after treatment with '00' OSR and these showed signs of phytotoxicity, purpling to the leaves (Appendix 3, Image 3). The bark and coir mulches applied without addition of a seed meal had no effect on weed emergence. Despite the addition of mulch, the fungal growth was still evident in all seed meal treatments (Appendix 3, Images 4-7).

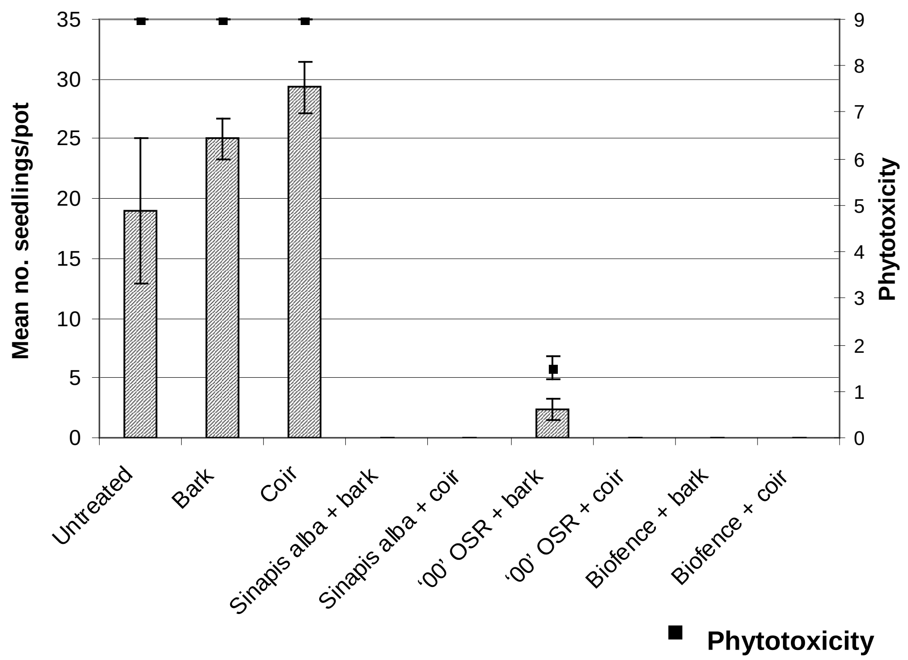

Figure 9. Mean number of *S. vulgaris* seedlings recorded at the end of germination (09/12/2012) and phytotoxicity scores (where applicable) (03/01/2012) when seeds were sown before the mulch. 0-9 scale (9 no effect, 1 complete kill, 0 no seedlings to assess).

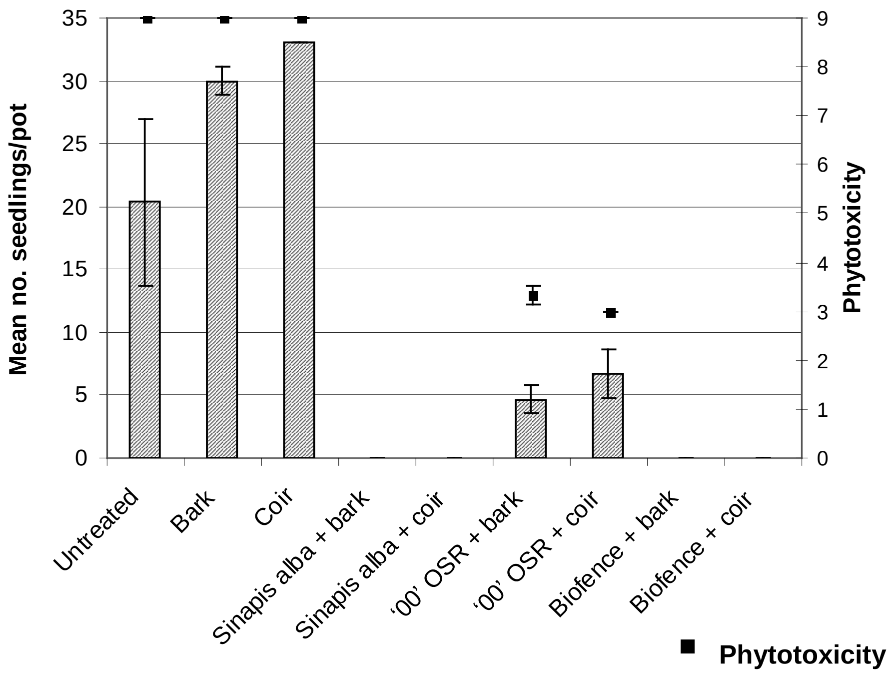

Figure 10. Mean number of *S. vulgaris* seedlings recorded at the end of germination (09/12/2012) and phytotoxicity scores (where applicable) (03/01/2012) when seeds were sown on top of the mulch. 0-9 scale (9 no effect 1 complete kill, 0 no seedlings to assess).

Experiment four – application of fungicides to control fungal growth

Fungal growth took six days to develop from seed meal application but from day six grew very rapidly and was assessed daily. Fungal growth was greatest with the '00' OSR seed meal as observed in previous trials and least with the *Sinapis alba* (Appendix 4, Images 2-

6). With the Biofence and OSR the fungal growth consisted of *Mucor* species. and *Botrytis* species. With the *Sinapis alba* the fungal growth was not identified but consisted of a denser whiter mycelial growth. Signum gave significantly better control of fungal growth in the Biofence and '00' OSR treatment (p=0.016) but did not give complete control, with all pots showing increasing levels of fungal growth by day 10 (Figure 11). Serenade ASO gave no fungicidal control in any of the seed meals compared with the untreated pots.

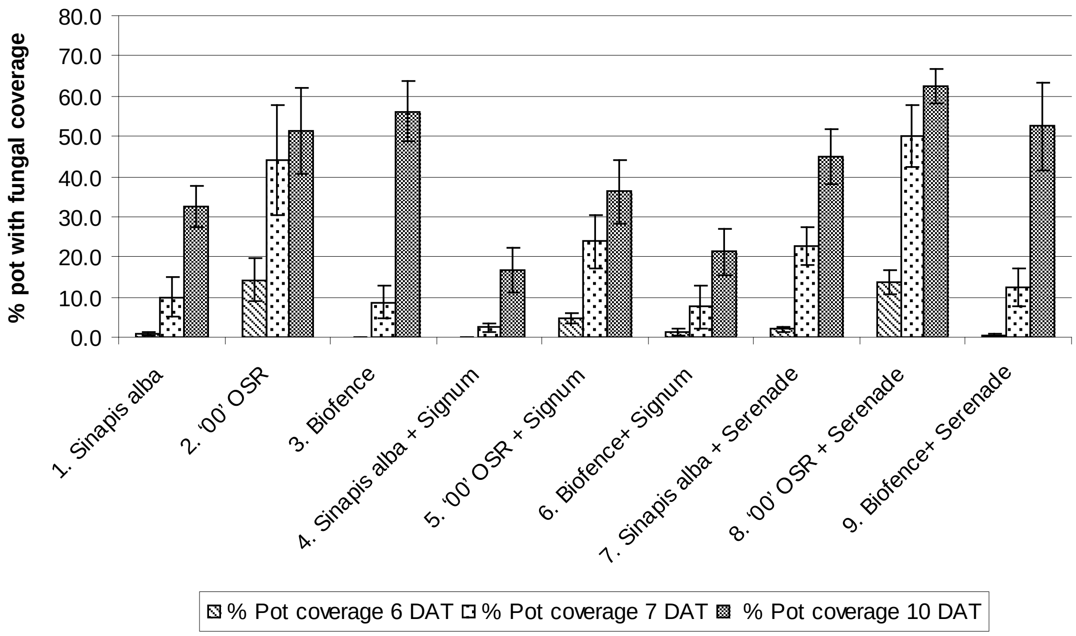

Figure 11. Mean Percentage pot surface area covered in fungal growth after fungicide application 16/3/12, recorded on three assessment occasions. DAT – days after treatment

Discussion

Experiment one – initial screen

Based purely on the efficacy of the glucosinolate meal treatments, the results obtained in Experiment one seem very promising. All three of the treatments effectively controlled groundsel and annual meadow-grass, with *S. alba* meal providing 100% control and Biofence providing greater than 90% control. The *S. alba* had the greatest glucosinolate content indicating the greater the concentration of these compounds the greater the allelopathic effect. One problem noted was the significant fungal growth that developed on the seed meal and the consequent increase in sciarid flies. As the mould grew over the glucosinolate meals and subsequently died, it formed a hard layer which covered the surface of each treated pot. Many of the weed seedlings which were able to emerge from the treated pots did so through the cracks in this surface and as such it was unclear whether the reduction in weed emergence could be attributed to the allelopathic effect of the glucosinolates or rather, the physical barrier which had been created by the mould collapsing down and drying out.

Experiment two – position of sowing and longevity

In order to determine whether the reduction in weed emergence was caused by the chemicals in the glucosinolate seed meal or the physical barrier created as a result of the severe mould growth on top of the meals, weed seeds were sown above the glucosinolate meals. Results showed that all of the glucosinolate seed meal treatments effectively controlled groundsel when sown on top of the seed meal thus indicating that the reason for control is more than simply the physical barrier created by the treatment and mould growth. Seeds were also sown three and six weeks after treatment to test the persistence of the products. Although there was an indication that the efficacy of each of the three treatments declined over time this was not statistically significant.

As in Experiment one, a significant fungal mould growth developed over all of the seed meal treatments. For application of these glucosinolate seed meal products to be considered a reasonable weed control method in nursery stock this issue would need to be overcome.

Experiment three – application in different mulches

The incorporation of the seed meal products into a bark or coir mulch was expected to decrease levels of fungal growth. Both wood bark and coir were included in this study as was sowing beneath and on top of the mulch. Again, all glucosinolate seed meals proved effective at controlling groundsel when sown beneath and on top of the seed meal + mulch. The levels of fungal growth did appear to be reduced but this was not measured and visually, levels were still considered too high to be acceptable in a nursery situation. The failure of a 1cm deep bark or coir mulch alone to have any weed control efficacy was unexpected particularly when the seeds were sown beneath the mulch.

Experiment four – application of fungicides to control fungal growth

The use of Signum as a fungicidal application appeared to suppress the development of fungal mycelium in the Biofence and '00' OSR treatment, but this control was not fully effective or long lasting so further applications may be required. *Sinapis alba* showed only low levels of fungal growth. Serenade ASO showed no level of control, however the trial was carried out in a polythene tunnel and there were fluctuations in day and night time temperatures with 30 °C being reached in the day and 2 °C overnight which may have affected the efficacy of the Serenade ASO which is most effective in a narrower temperature and humidity range. As this project was looking at non pesticide control of weeds the use of a fungicide negates the benefits of using a seed meal therefore it would be important to investigate other methods of controlling this growth perhaps using a compost tea or steam treatment.

Conclusions

This study examined the weed control capability of various glucosinolate seed meals. Weeds were sown before and after treatment to mimic situations where seeds were present in the medium and were also blown in after treatment and to discount the mulch effect. Additionally, the persistence of the products was tested by sowing seeds three and six weeks after treatment. Increased fungal growth and sciarid flies proved to be an issue associated with all of the products and as such the products were incorporated with mulch or sprayed with fungicides to try to reduce the problem. Based on these four experiments the following conclusions could be drawn regarding the use of glucosinolate seed meal treatments as an alternative weed control strategy:

- *Sinapis alba,* Biofence and '00' OSR seed meals effectively controlled groundsel and annual meadow-grass.
- There was no difference in the level of weed control when seeds were sown before (beneath) or after (on top of) the treatment.
- Although there were indications that the efficacy of the products decreased over time, there was no significant difference when seeds were sown on the day of, three weeks after or six weeks after treatment;
- The positive results of the glucosinolate seed meals was spoiled by the increased fungal growth associated with their use.
- The incorporation of the seed meals into a bark or coir mulch did not reduce mould to an acceptable level.
- Work to reduce the mould showed that an application of Signum after applying the Biofence and '00'OSR mulch can significantly reduce but not eliminate the level of fungal growth and may need reapplication after 10-14 days to maintain control.
- In other HDC trials soil incorporated seed meals have shown significant phytotoxic affects, seed meal applied as a mulch in trials on Clematis in 2011 showed phytotoxicity and a slight decline in height but were commercially acceptable, crop safety will be investigated in 2012 as part of the nursery stock screens.

Knowledge and technology transfer

HDC/EMT/HTA Horticultural Fellowship award day presentation 28th April 2011.
HDC/EMT/HTA Horticultural Fellowship Studentship day 6th July 2011.

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Al Khatib, K., Libbey, C., Boydston, R. (1997). Weed suppression with Brassica green manure crops in green pea. *Weed Science* 45, 439-445.

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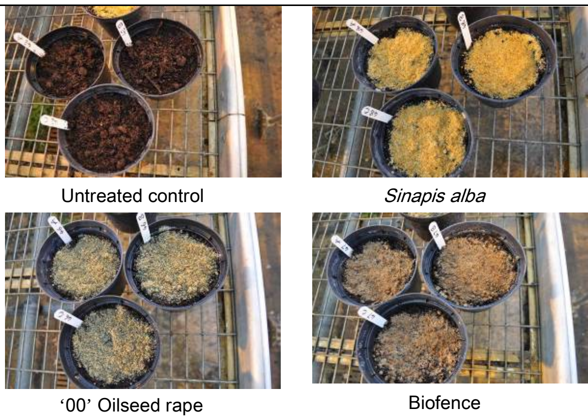
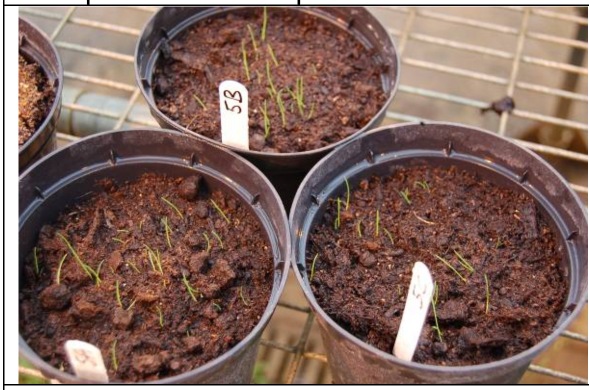
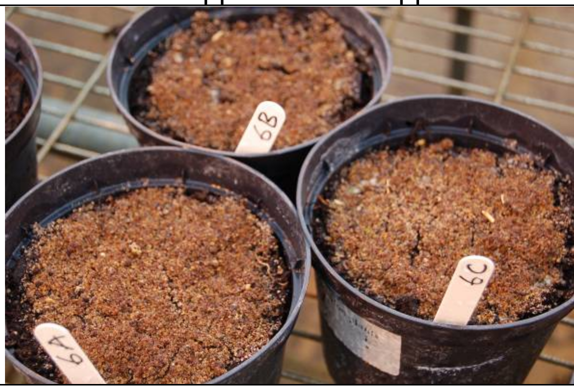
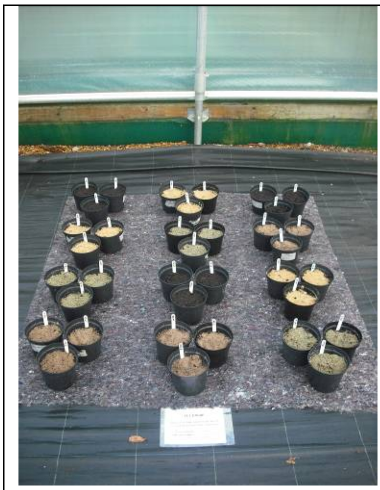
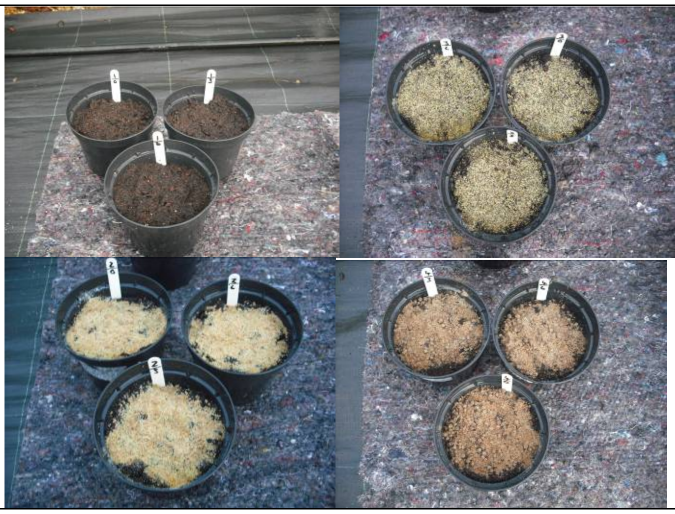
England, J. (2011 and 12). Liverwort control using novel techniques. HDC project report HNS 195. and HNS 157 Liverwort control using novel techniques.

Hewson, A. (2012). Non-chemical weed control for container-grown hardy nursery stock. HDC Factsheet 25/12.

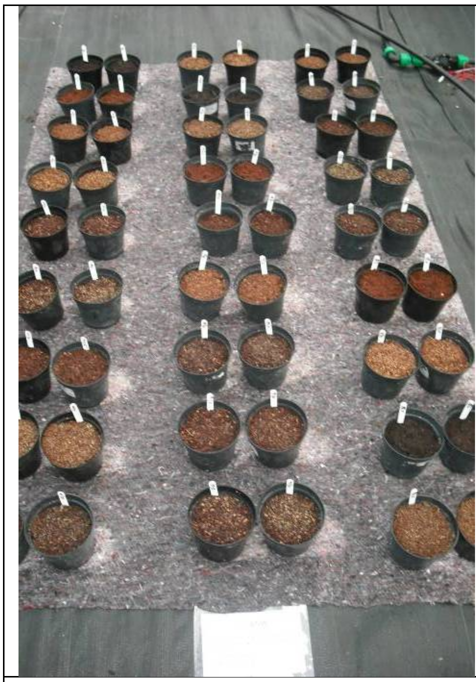
Appendix 1 – Photographs of Experiment 1

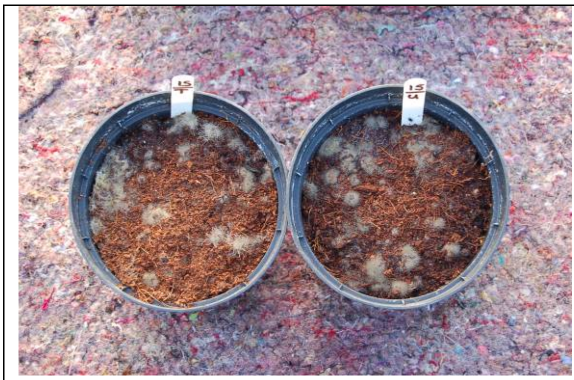
	
1. Experiment 1 set up at end of trial	2. Seed meal appearance at application
	
3. Un treated plot 2 weeks after treatment (WAT)	4. '00' OSR plot 2 WAT – fungal development
	
5. *S. alba* plot 2 WAT – fungal development	6. Biofence plot 2 WAT – white dense mycelium

Appendix 2 – Photographs of Experiment 2

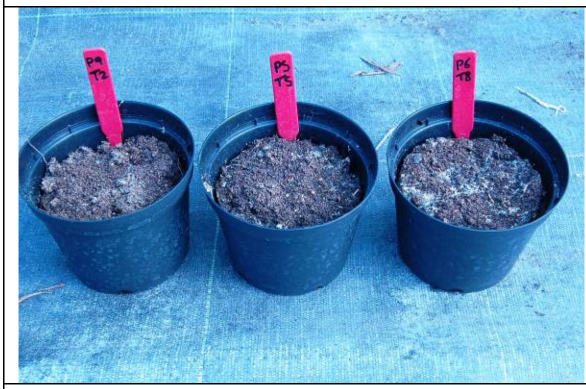
	
1. Experiment 2 - trial set up	2. Clockwise from top left UT, '00' OSR, Biofence and *S. alba* seed meal appearance at application
	
3. Untreated plot 2 months after treatment application	4. *S. alba* plot 2 months after treatment application – no seed germination
	
5. OSR plot 2 months after treatment application -some seed germination around edges and cracks in seed meal, seed meal broken down over time	6. Biofence plot 2 months after treatment application – some seed germination around edges and cracks in seed meal

Appendix 3 – Photographs of Experiment 3

	
1. Experiment 3 set up	2. Experiment 3 - 6 weeks after treatment
	
3. UT plot – left sown on top, right sown beneath, 6 weeks after treatment	4. *S. alba* and coir - grey to white fungal growth, 6 weeks after treatment
	
5. Biofence and coir – dense grey fungal growth, 6 weeks after treatment	6. OSR and bark – finer grey to white fungal growth, 6 weeks after treatment

	
7. OSR and coir – Botrytis growth around clumps of the seed meal, 6 weeks after treatment	8. Purpling of groundsel through OSR and coir, 6 weeks after treatment

Appendix 4 – Photographs of Experiment 4

	
1. Experiment 4 trial set up	2. *Sinapis alba* plots from left UT, Signum and Serenade - 10 days after application
	
3. '00' OSR plots from left UT, Signum and Serenade - 10 days after application	4. Biofence plots from left UT, Signum and Serenade - 10 days after application

	
5. Example of fungal growth observed in Biofence treatment - 10 days after application	6. Example of fungal growth observed in ‘00’ OSR treatment - 10 days after application

Appendix 5 - Trial plans

Experiment one

Block 1		
Plot	**Trt**	**Spp**
1	4	2
2	2	2
3	4	3
4	3	1
5	1	2
6	3	2
7	1	3
8	2	1
9	3	3
10	4	1
11	2	3
12	1	1

Block 2		
Plot	**Trt**	**Spp**
13	1	2
14	2	2
15	1	1
16	4	3
17	3	1
18	1	3
19	4	2
20	2	3
21	2	1
22	3	2
23	4	1
24	3	3

Block 3		
Plot	**Trt**	**Spp**
25	2	2
26	3	1
27	4	1
28	1	3
29	2	1
30	2	3
31	3	2
32	4	3
33	1	2
34	4	2
35	3	3
36	1	1

Block 4		
Plot	**Trt**	**Spp**
37	1	3
38	4	1
39	3	2
40	1	2
41	2	2
42	1	1
43	3	3
44	2	1
45	4	3
46	3	1
47	4	2
48	2	3

Treatment	Pre emergence	Rate	Active ingredient
1	Untreated		
2	*Sinapis alba*	(10g/1 L pot)	glucosinolate
3	'00' Oilseed rape	(10g/1 L pot)	glucosinolate
4	Biofence	(10g/1 L pot)	glucosinolate

Spp.	Weed species
1	*Stellaria media* (Seeds did not germinate)
2	*Poa annua*
3	*Senecio vulgaris*

Experiment two

Block 1			Block 2			Block 3		
Plot	Treatment	Timing	Plot	Treatment	Timing	Plot	Treatment	Timing
1	4	1	5	2	2	9	1	2
		2			3			3
		3			1			1
2	2	1	6	3	3	10	4	2
		3			1			1
		2			2			3
3	3	3	7	1	2	11	2	1
		1			3			3
		2			1			2
4	1	2	8	4	2	12	3	2
		3			1			3
		1			3			1

Treatment	Pre emergence	Active ingredient
1	Untreated	
2	*Sinapis alba* (10g/1 L pot)	glucosinolate
3	‘00’ Oilseed rape (10g/1 L pot)	glucosinolate
4	Biofence (10g/1 L pot)	glucosinolate

Timing	Sowing date
1	Sown day 0
2	Sown week 3
3	Sown week 6

Experiment three

Block 1		
Plot	Treatment	Sowing
1	1	2
		1
2	3	1
		2
3	9	1
		2
4	5	2
		1
5	8	2
		1
6	4	1
		2
7	2	2
		1
8	7	1
		2
9	6	2
		1

Block 2		
Plot	Treatment	Sowing
10	5	1
		2
11	1	1
		2
12	7	2
		1
13	3	1
		2
14	2	1
		2
15	9	2
		1
16	6	2
		1
17	8	1
		2
18	4	1
		2

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

Treatment no.	Treatment	Mulch:seed meal ratio	Rate of mix/plot
1	Untreated	-	
2	Bark	01:00	30g
3	Coir	01:00	60g
4	*Sinapis alba* + bark	01:03	40g
5	*Sinapis alba* + coir	01:06	70g
6	‘00’ OSR + bark	01:03	40g
7	‘00’ OSR + coir	01:06	70g
8	Biofence + bark	01:03	40g
9	Biofence + coir	01:06	70g

Sowing	Sowing position
1	Sown before mulch
2	Sown after mulch

Experiment four

Block 1	
Plot	**Treatment**
1	6
2	3
3	9
4	7
5	5
6	8
7	1
8	4
9	2

Block 2	
Plot	**Treatment**
10	8
11	5
12	3
13	6
14	9
15	1
16	4
17	2
18	7

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

Block 4	
Plot	**Treatment**
28	9
29	6
30	2
31	3
32	4
33	5
34	8
35	7
36	1

Treatment no.	Treatment	Rate
1	*Sinapis alba*	10g/1 L pot
2	‘00’ OSR	10g/1 L pot
3	Biofence	10g/1 L pot
4	*Sinapis alba* + Signum	10g/1 L pot + 1kg/ha (1,000 L water/ha)
5	‘00’ OSR + Signum	10g/1 L pot + 1kg/ha (1,000 L water/ha)
6	Biofence+ Signum	10g/1 L pot + 1kg/ha (1,000 L water/ha)
7	*Sinapis alba* + Serrenade	10g/1 L pot + 10 L/ha (1,000 L water/ha)
8	‘00’ OSR + Serrenade	10g/1 L pot + 10 L/ha (1,000 L water/ha)
9	Biofence+ Serrenade	10g/1 L pot + 10 L/ha (1,000 L water/ha)