MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

CSG 15

Research and Development

Final Project Report

(Not to be used for LINK projects)

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Project title	Overwinter transplant production for extended season organic cropping.
MAFF project code	**OF0144**
Contractor organisation and location	Elm Farm Research Centre Hamstead Marshall Newbury Berkshire RG20 0HR
Total MAFF project costs	£ 120,999
Project start date	01/12/97
Project end date	31/03/01

Executive summary (maximum 2 sides A4)

The previous MAFF-funded project (OF0109/CSA 2634) addressed the pressing needed by the organic horticultural sector to produce vegetable transplants within an organically acceptable production system. This project was successful in developing protocols for the production of a range of vegetable transplants including brassica, allium, lettuce and others during the spring. There were continuing concerns about the production of transplants during the more demanding late autumn, winter and early spring period and MAFF subsequently commissioned this project to address these concerns.

The overall objective of this project was to develop and evaluate protocols for organic transplant production during autumn, winter and early spring, taking particular account of nutrient supply, cell size and disease (particularly mildew) control for brassicas, allium and lettuce. The work was split into 4 areas; (i) identification and evaluation of organically acceptable control methods (biocidal and physical), (ii) development of production protocols, (iii) evaluation of these protocols under commercial conditions and (iv) dissemination of the findings.

A range of biocides were evaluated under laboratory and glasshouse conditions for their efficacy in controlling mildew. The objective was to identify organically acceptable fungicidal products. L-Carvone, Mycosin, Fennel and Clove oils all showed potential in controlling mildew on a range of crop species. Experiments of combinations of these compounds showed not increased benefits. Products that induced systemic acquired resistance (SAR) showed some potential. Salicyclic acid produced no effect but Bion successful protected the plants from mildew infection. However, there has been on going discussions of the acceptability of such compounds in organic production and therefore work on SAR inducing compounds was not continued within the project.

The work on spectral filters was disappointing with no benefits being found. This was preliminary work and should not be taken as proof that spectral filters could not be used in as part of an integrated control programme within organic production systems.

The effect of cell size on disease spread was minimal with both the cell sizes tested having similar spread of disease over 12 – 14 days. This would suggest that cell size is not a suitable method to control the spread of disease in organic transplant production systems.

Information from previous experiments on crop types and varieties, growing media, block and cell size and feeding regimes were brought together to develop protocols for overwinter transplant production. The use of biocides was not included in the protocols as disease levels were relatively low and plants grew out of the infection with little effect.

The overall findings of this objective was that production protocols could be relatively easily produced and tested successfully on a range of crops in a research scale situation. Production time for overwinter production was longer than for production in the spring. Lettuce was relatively easy to produce with acceptable plants being raised in a range of media and block sizes; no feed is needed for lettuce. Cabbage transplants were also relatively easy to produce in a range of media, and cell sizes. However, feeding was needed for cabbage. The second brassica tested – Cauliflower – may have been affected by improving conditions in the glasshouse and high levels of nutrition in one of the media (Sinclair organic). Acceptable transplants were produced for cauliflower using smaller a cell size (345) and full nutrient compost. The knowledge gained under this objective was used to further test the protocols under commercial conditions.

Protocols were tested for a range of crop species and varieties, growing media, block or cell size and feeding regimes over three seasons under commercial conditions. It was considerably easier than initially feared to produce organic transplants of suitable quality during the overwinter period. However, propagation time was generally longer than would be needed to produce comparable transplants at more favourable times of the year. Overall conclusions are shown in Table A.

Table A: Overwinter organic transplant propagation systems – conclusions of trials 1997 – 2000.

	Brassica				
	Cabbage	Cauliflower	Calabrese	Leek	Lettuce
Cell/block sizes	308, 150	126, 216, 345	216	216	3.2cm^3 4.3cm^3
Growing medium[1]	S, B	S,	SLow, VLow	S, K, V, VVeg	S, K
Feeding	Nu-Gro , Fish emulsion	Nu-Gro	Nu-Gro	Nu-Gro	Not required
Species/variety	Only 1 variety tested	Similar requirements	Only one variety tested	Only 1 variety tested	Set & Little Gem similar
Propagation period (days)	55	123 -159	132	68	24-38

[1]Growing media: B = Bullrush Peat Free, K = Klasmann Organic; S = Sinclair Organic; SLow = Sinclair Low Nutrient; V = Vapo-Gro Organic; VLow = Vapo-Gro Low nutrient; VVeg = Vapo-Gro Organic Veg-based.

A range of technology transfer and dissemination events and publications have occurred during the project. The events were aimed at organic growers, plant raisers, scientists and the organic sector as a whole. The primary event was a plant propagators day held at HDRA in October 2000 where it was believed that representatives of over 90% of the organic plant raisers in the UK attended. A supplement to the EFRC Bulletin that covered the work of the project was also published to coincide with this event.

As with many scientific projects this project has raised as many questions as it has answered. The main outstanding questions that require future work are; To development of a range of a full protocols for other vegetables; establishment and performance trials of organic transplants; Organic seed health and seed borne diseases; The production of organic growing media and feeds; and registration issues of organically acceptable biocides.

Scientific report (maximum 20 sides A4)

Background

The previous MAFF-funded project (OF0109/CSA 2634) addressed the pressing needed by the organic horticultural sector to produce vegetable transplants within an organically acceptable production system. This project was successful in developing protocols for the production of a range of vegetable transplants including brassica, allium, lettuce and others. However, these protocols were for production during the spring, a relatively undemanding period for transplant production. There were continuing concerns about the production of transplants during the more demanding late autumn, winter and early spring period where conditions for production would be more difficult and the threat from disease greater.

The overall objective of this project was to develop and evaluate protocols for organic transplant production during autumn, winter and early spring, taking particular account of nutrient supply, cell size and disease (particularly mildew) control for brassicas, allium and lettuce. The objectives of the project were;

1. Identify organic acceptable fungicide products to control mildew in transplant production systems for brassicas, alliums and lettuce.

2. Produce integrated organic transplant production systems for brassica, allium and lettuce over the autumn and winter period by identifying optimum cell/block size(s) in relation to nutrient requirements, sources, growing media formulation, supplementary feeding and watering during plant raising; and by assessing risks and opportunities for control of mildew in the light of products evaluated under objective 1.

3. Evaluate developed transplant production protocols during 'winter' period for early production in replicated trials and commercial situations.

4. Facilitate and undertake technology transfer and dissemination of results to technology users (organic growers and plant raisers).

The project was led and project managed by EFRC with the production and commercial trials being undertaken by Horticulture Research International (Wellesbourne) and The Henry Doubleday Research Association respectively.

Objective 1: Identify organic acceptable fungicide products to control mildew in transplant production systems for brassicas, alliums and lettuce.

Specific organically acceptable products were identified and sourced from the UK and other EU countries and permission gained to use in experimental trials to evaluate efficacy for control of *Peronospora parasitica* on cabbage, *Peronospora destructor* on onion and *Bremia lactuacae* on lettuce. Not all biocides were used on all pathogen/crop complexes. Table 1 lists the biocides used within the project.

Table 1: Products tested for their biocidal activity (1997 – 2000).

Product name	Active ingredient
Clove oil	Not available
Cuprokylt FL	Copper Oxychloride
Fennel oil	Not available
Guard B4	Garlic extract
Jet-5	Peroxyacetic acid
Maxicrop Triple	Seaweed extract
Mint extract	L-Carvone (30% AI)
Mycosin	Aluminium sulphate, Horsetail (*Equisetum*) extract
Tea tree oil	Not available
Top Cop with sulphur	Tribasic copper sulphur & sulphur
Bion	Not available
Salicyclic acid	Not available

Biocide efficacy I.

Experiments were designed to determine whether selected biocides (Table 1) would prevent the infection of cabbage seedlings exposed to artificial inoculation. Experiments were also undertaken to develop the method for the laboratory testing of the *in vitro* activity of each chemical to conidia of *Peronospora parasitica.* Other factors were also investigated including the effects of compost and cell size of the propagation unit as well as the interaction of factors ie plant spacing and chemical treatment.

Methods: Cabbage cv. Castello seeds were sown in Sinclair Organic compost in 16-cell hassey module (20x20x40mm) 2½ - 3 weeks prior to first chemical application (3½ - 4 weeks prior to inoculation) or into 84 unit propagation units (40x40x50mm) filled with Bullrush planting medium. In all experiments seedlings were at development stage 1.7 (cotyledons unfolded) at commencement of each experiment (Everaarts, 1994).

Treatments were arranged in a random split-block configuration. Each bench housed 14 hassey trays each with 12, sixteen cell modules equally spaced. Each chemical was represented by 3 trays and each treatment by 6 modules (except the untreated treatment which was applied to 24 modules and 12 modules for the 1 day post-inoculation treatment). Each treatment was repeated twice on different occasions.

Chemicals were applied to the seedlings at the cotyledon stage, both pre- and post-inoculation with downy mildew. Inoculum (*P. parasitica* isolate p005) was raised and bulked up on kale. Inoculation was achieved by suspending conidia in sterile distilled water. The suspension was then diluted to the required concentration and volume. As the experiments progressed the concentration and volume of inoculum was reduced. The inoculum suspension was applied to the seedlings using a Revell airbrush at the calculated rate. In the treatments 'sprayed at inoculation' plants were inoculated three hours after chemical application of the modules and misted with a humidifier for 16 hours.

Application of chemical treatments: 7 days pre-inoculation; 3 days pre-inoculation; 1 days pre-inoculation; same day as inoculation; 1 day post-inoculation.

Six different experiments were carried out using a range of chemicals (Table 2) and treatment times.

Table 2: Chemicals used in Year 1

Chemical	Concentration	Rate
Control (water)	Tap water	3.5ml per module
Conventional industry standard (Aliette)	0.5%	3.5ml per module
Maxicrop Triple	1.0%	3.5ml per module
Mycosin	1.0%	3.5ml per module
Top Cop	1.0%	3.5ml per module
Jet-5	2.0%	3.5ml per module
Cuprokylt	0.5%	3.5ml per module
Garlic Oil (Guard B4)	1.0%	3.5ml per module
Mint Oil	1.0%	3.5ml per module

Assessment: Seedlings were assessed for the presence of disease once a majority of the untreated seedlings had become infected ie 5 – 6 days post-inoculation. Seedlings were assessed for the presence/absence of infection and whether or not there was sporulation.

Statistical analysis: Results were analysed by ANOVA to determine the statistical difference between treatments.

Results: The very high level of infection in the untreated control (90 – 100%) indicating that the conditions under which the tests were conducted were favourable for infection.

The conventional industry standard, Aliette, gave a good control of the level of downy mildew when applied at or one day post-inoculation but was less successful at other times. There was inconsistent control of mildew on seedlings treated with Maxicrop Triple, Jet 5, Cuprokylt and garlic oil (Guard B4) but control was generally poor. Pre-inoculation applications of Top Cop gave good control, comparable to Aliette (Figure 1). Other experiments within this series supported this with Top Cop applied pre-inoculation giving increasing levels of control of downy mildew. L-Carvone also showed some fungicidal activity with a reduced infection of downy mildew on seedlings by approximately 30-40% when applied 3 and 1 day pre-inoculation.

A combination of biocides were also tested (Table 3) which did not improve the control of the disease. Approximately 10 – 20% of inoculated seedlings remained uninfected when combinations of Top Cop was applied 7 days pre-inoculation followed by either Cuprokylt or L-Carvone 3 days pre-inoculation. Applying Mycosin at one day pre-inoculation in combination with Top Cop and L-Carvone applied 7 and 3 days pre-inoculation respectively did not significantly improve control.

A complimentary test was also carried out comparing Aliette with Top Cop alone or applied in combination with L-Carvone. The conditions in the glasshouse became unfavourable for downy mildew infection so the results need to be

taken with some caution. However, Top Cop applied alone or in a mixture with L-Carvone controlled infection as well as Aliette.

The data was fully analysed and is presented in Table 4.

Figure 1: Example of disease control (*P. parasitica*) using biocides application pre- and post-inoculation.

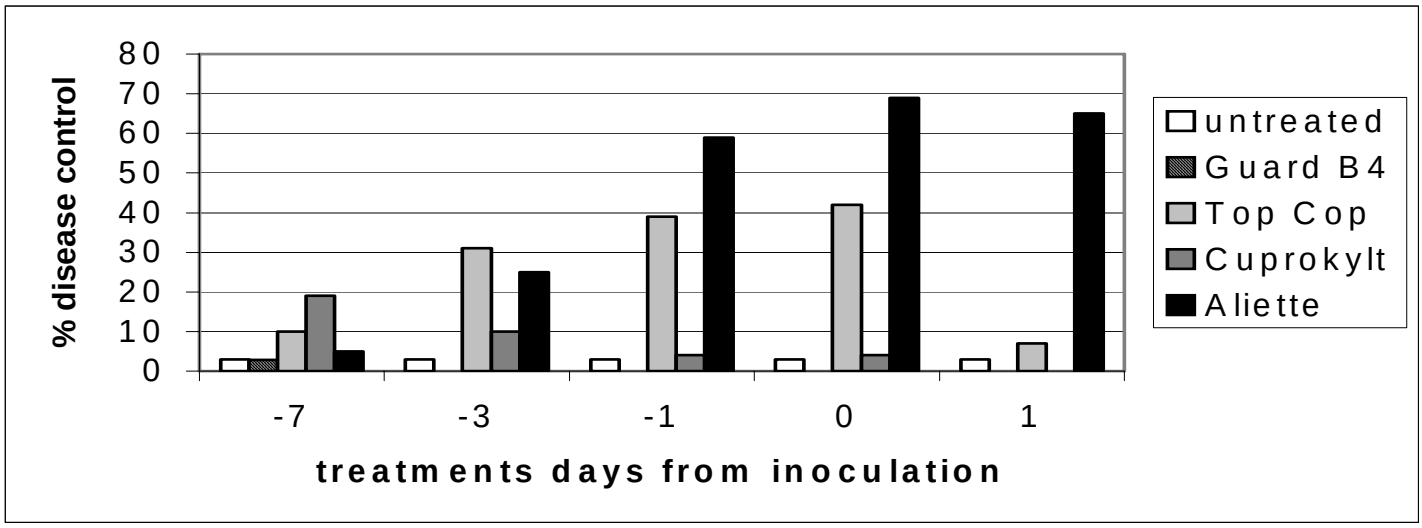


Table 3: Chemical concentrations and rates for combination tests.

Chemical	Concentration	Rate
Untreated	Tap water	3.5ml per module
Combination 1: Top Cop 7 days pre, + Cuprokylt 3 days pre	1% and 1%	3.5ml per module
Combination 2: Top Cop 7 days pre, + L-Carvone 3 days pre	1% and 1%	3.5ml per module
Combination 3: Top Cop 7 days pre, + L-Carvone 3 days pre + Mycosin 1 day pre	1%, 1% and 1%	3.5ml per module
L-Carvone	1%	3.5ml per module

Table 4: Statistical differences between treatment means for all application dates combined.

Experiment No.	Chemical	Significantly more healthy seedlings than control at <P 0.001?	Significantly > or = to No. of healthy seedlings for Aliette <P 0.001?
1	Maxicrop Triple	No	No
SED = 2.779	Mycosin	No	No
Df = 480	Jet-5	Yes	No
	Aliette	Yes	-
2	Top Cop	Yes	No
SED = 2.62	Mycosin	Yes	No
Df = 480	Jet-5	Yes	No
	Aliette	Yes	-
3	Top Cop	Yes	No
SED = 2.414	Guard B4	No	No
Df = 480	Cuprokylt	No	No
	Aliette	Yes	-
4	L-Carvone	Yes	No
SED = 2.86	Guard B4	No	No
Df = 480	Cuprokylt	Yes	No
	Aliette	Yes	-

These results show that only Top Cop, L-Carvone and Jet-5 were consistent in producing significantly (P=<0.001) more healthy seedlings that the untreated control. However, Jet-5 produced phytotoxicity symptoms on cotyledons and was not used further in the experiments. When compared to the industry standard, Aliette, only Top Cop applied 7 or 3 days pre-inoculation performed as well as Aliette.

Biocide efficacy II.

Due to the high resource requirements needed for the glasshouse experiments reported on above other assays for the efficacy of biocides were developed.

Detached cotyledon assay:

Methods: A detached cotyledon assay was developed. Clear plastic boxes (228 x 121 x 86 mm) were prepared by lining the lids with cellulose wadding soaked in benzyl amino purine to delay leaf senescence. The wadding was stretched out to ensure the maximum contact with the detached cotyledon. Three or four week old cabbage seedlings, with the growing tip removed, were used in all experiments with the adaxial surface placed on the wadding. Compounds were applied as two 10µl drops on each of the two cotyledons of the seedling. A spore suspension of *P. parasitica* (1.2×10^4spores/ml) was then applied on top as two 10µl drops on one cotyledon only. This allowed any symptoms of compound phytotoxicity to be observed on the other uninoculated cotyledon. This method was used to assess a number of compounds for efficacy at inoculation and three application times (3 and 1 pre-inoculation, at inoculation or 1 day post-inoculation) and at different doses.

The detached cotyledon assay was useful in identifying compounds that suppress downy mildew infection and eliminating those that showed no activity. A range of compounds and doses were tested (Table 5).

Table 5: Treatments in detached cotyledon experiments carried out to test the efficacy of different compounds for control of downy mildew

Treatment	Application dose	Application timing
Aliette (industry standard)	✓	✓
Fennel oil	✓	✓
Guard B4		✓
L-Carvone	✓	✓
Mycosin	✓	✓
Tea Tree Oil	✓	✓
Top Cop	✓	✓

Results: Guard B4 and Fennel Oil applied at the recommended doses of 1% and 0.4% showed little activity whereas Top Cop, L-Carvone and Mycosin at the recommended doses reduced infection to 10% or below (Figure 2a and b). However, Mycosin resulted in some leaf spotting on uninoculated cotyledons and therefore was not included in subsequent application timing tests. Tea tree oil was extremely phytotoxic at 1% dose tested and was also excluded.

Further work was undertaken to study the effect of timing of compound application. These tests showed that suppression of infection by all the compounds was optimum when applications were made either one day before or at inoculation with *P. parasitica*. Application of any compound one day post-inoculation resulted in higher levels of infection (Figure 3).

Germination of *P. parasitica* assays:

Methods: Experiments were carried out to investigate the effect of the compounds on spore germination reflecting the activity observed in the detached cotyledon tests. A spore suspension of *P. parasitica* (8×10^4 spores/ml) was mixed with each compound concentration (1:1 v/v) and 20 µl pipetted onto microscope slides. Slides were then placed in petri-dishes within clear plastic boxes lined with damp tissue paper to retain moisture. There were three slides per treatment and a water control was included. After incubation overnight in the dark at 15C, 10 µl aniline blue in lactic acid was added (0.1 g/l) and 50 spores per slide assessed for germination under the microscope.

Results: The results from this experiment (Table 6) reflect those on the detached cotyledon assays. Top Cop, Mycosin and L-Carvone all reduced germination to less than 9% at doses > 1%. In contrast Fennel oil, even at the highest dose of 2% only reduced germination to 50%.

Figure 2a and 2b: Effect of different doses of compounds on infection of *P. parasitica* in detached cotyledon test.

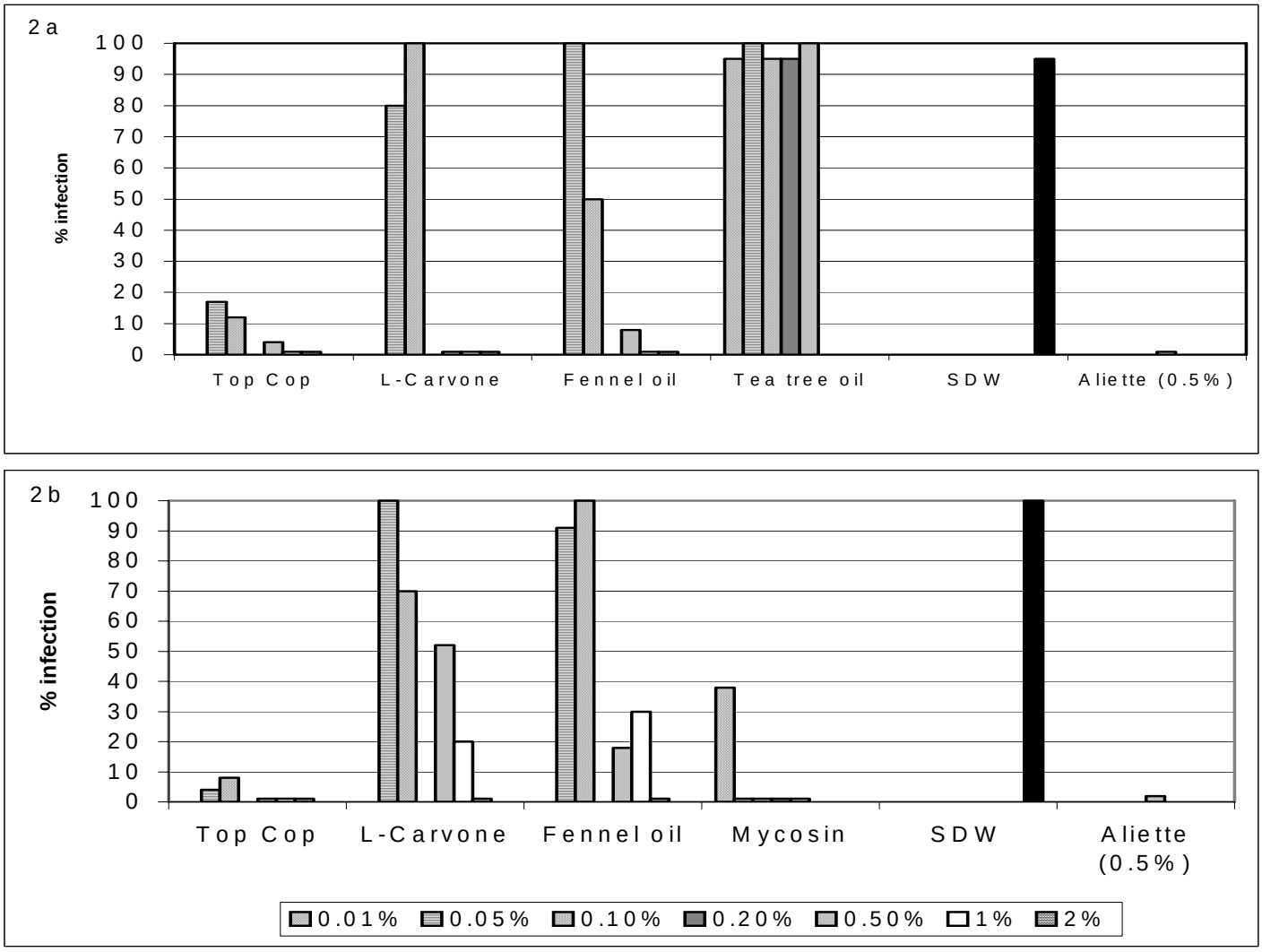


Figure 3. Effect of timing of different compounds application on infection of *P. parasitica* in a detached cotyledon test.

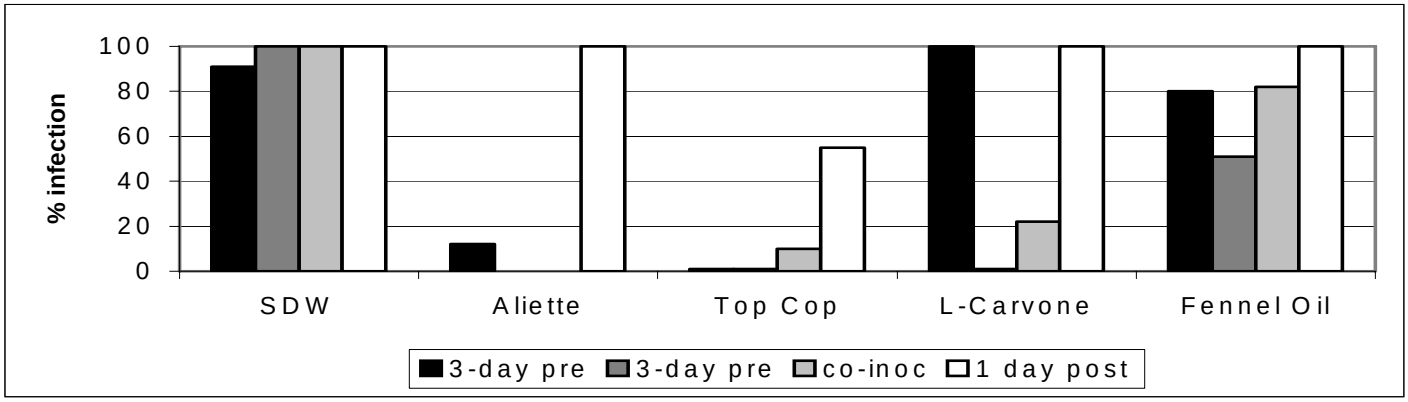


Table 6: Effect of compound doses on per cent germination of *P. parasitica* spores.

Compound	0.1%	0.5%	1%	2%
Sterile Distilled Water	76.7	-	-	-
Aliette	-	25.0	-	-
Top Cop	50.8	33.3	5.0	3.3
Mycosin	49.2	29.2	8.3	3.3
L-Carvone	56.7	65.8	8.3	9.2
Fennel oil	70.0	60.8	58.7	51.7

Least significant difference (LSD) = 9.8

Glasshouse tests:

Methods: The most successful compounds from the cotyledon assays (Top Cop, L-Carvone and Fennel oil) were further tested in the glasshouse. Three week old cabbage seedlings were used in the experiments. Test compounds were applied using a spray gun. Seedlings were then inoculated with 1.5 x 10^4 spores/ml of *P. parasitica* and misted overnight in a polythene tent to allow infection. Plants stayed it the tent for approximately one week before disease assessments were made. There were 5 or 6 replicates 16 cell modules per treatment. A number of experiments were carried out to determine the efficacy of the compounds at three different application times (3 days pre, 1 day pre, or coinoculation), using different doses and a treatment combination. Aliette and a water control were included in each experiment.

The effect of Top Cop, L-Carvone and Mycosin were also tested on onion downy mildew (*Peronospora destructor*). Bulb onions were raised in the glasshouse. When the plants had four fully expanded leaves each pot of four plants was sprayed with 6ml of each compound at doses of 0.5%, 1% and 2%. Control treatments were a standard treatment for onion downy mildew (Folio at 1 g/l; metalaxyl + chlorothalonil) and water only. Once the compound had dried, 5 ml of spore suspension of *P. destructor* (1 x 10^4 spores/ml) was sprayed onto each pot. There were three pots per treatment and plants were misted in a polythene tent for 12 hours to allow infection and then moved to the glasshouse. After two weeks the plants were misted again to promote sporulation and assessed for the numbers of sporulating plants and percentage of leaf length with sporulation.

The effect of a range of biocides was also tested against *Bremia lactucae* (downy mildew) on lettuce. Three week old glasshouse raised lettuce seedlings were sprayed with Clove oil, L-Carvone, Fennel oil (and Aliette) at a range of concentrations (2, 1, 0.5 and 0.1%) immediately prior to inoculation with *B. lactucae* or at 1% 3 days re, 1 day pre-, co-inoculation and 1 day post-inoculation.

Results: As demonstrated previously the timing experiments showed that the optimum suppression of *P. parasitica* occurred when applications were made at the same time as inoculation. The level of infection was much higher than in the cotyledon tests and Top Cop and Mycosin gave the best results with 50-60% plant infection when applied at inoculation. L-Carvone reduced infection to 80-90% and Aliette to 70-80%.

Results for the dose experiments also confirmed the cotyledon assay. Disease levels were much reduced at doses above the recommendations for each compound with Mycosin and Top Cop resulting in 50-70% infection when applied at doses >0.5%. The activity of L-Carvone was particularly enhanced when applied at 2% where infection was 60-70%. Fennel oil showed little activity in these tests and Aliette resulted in approximately 80% infection.

A combination of Mycosin and L-Carvone was also tested at three different doses. This showed little or no advantage when compared to using the different compounds alone. Infection was between 40 and 60% for compounds alone or in combination at 2% dose.

Mycosin and L-Carvone suppressed infection of onion plants resulting in less than 30% plant infection at all three doses tested. Top cop was not as effective and resulted in 80-100% plant infection. The percentage leaf length sporulating showed a similar pattern.

In the lettuce experiments the concentration of L-Carvone was reduced to 2% to avoid possible phytotoxicity problems. Of the three compounds tested clove oil was the most effective in reducing lettuce downy mildew (Table 7). The second experiment investigating the application of compounds pre- and post-inoculation failed due to unfavourable conditions and no observable infection by the lettuce downy mildew was observed.

Table 7: Effect of clove oil, L-Carvone and fennel oil on infection of downy mildew of lettuce.

	Percentage leaf infection				
Compound	**2% dose**	**1% dose**	**0.5% dose**	**0.1% dose**	**Control values**
Clove	1.2	0.9	5.3	5.9	
L-Carvone	6.6	5.2	7.5	8.2	
Fennel	1.0	2.9	6.3	11.7	
Water					14.2
Aliette			3.2		

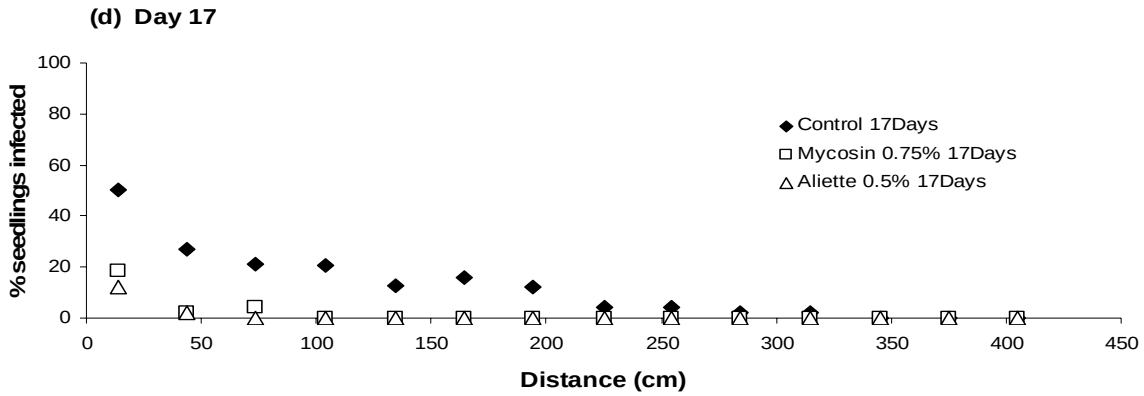
Effect of compounds on the spread of disease:

Methods: Cabbage and *P. parasitica* were again used as the model to ascertain the efficacy of the most successful compounds (L-Carvone and Mycosin) on the spread of the disease. Each experiment was undertaken in a research glasshouse using 30 308 hassey module trays, 10 each for the test compound, Aliette and a water control. The trays for

each treatment were positioned in a single row (1x 10 trays) on the benches of the glasshouse. Sporulating seedlings were introduced into the first row in each set of the 10 hassey trays. Test compounds (0.75% Mycosin, 1% and 0.5% L-Carvone) were applied through the overhead irrigation water using an electric pump. Irrigation was conducted twice weekly in the afternoon to increase the humidity levels. Plants were assessed in a standardised method; 70 plants were assessed in each 308 hassey tray, evenly spread through the tray. Assessments commenced one week after the first irrigation and then were repeated twice weekly for a further three weeks. Assessments were taken on the spread of the disease from the infected plants along the length of the hassey trays. The incidence of disease and the presence or absence of sporulation on the plants was also recorded.

Results: Mycosin applied at 0.75% showed signs of phytotoxicity, however, the symptoms were variable between experiments. Mycosin at 0.75% reduced the spread and level of infection in comparison with the untreated control (Figure 4) but was not as good as the industry standard Aliette. The spread over time was also reduced.

Figure 4: The effect of 0.75% Mycosin on the spread of downy mildew (*P. parasitica)* of brassica.



Phytotoxicity symptoms were also observed with 1% L-Carvone which were expressed as a slight stunting of the plant and a white scorching on the lead surface. However, infection remained at a lower level than for the untreated control and for Aliette. The spread of infection was also slower with reduced severity. Phytotoxicity symptoms were also seen when L-Carvone was applied at 0.5%. However, the level of leaf scorch was reduced but the levels of plant stunting was greater. L-Carvone at 0.5% reduced the level and spread of infection to levels much lower that the plants treated with Aliette or the untreated control. Disease progression was lower than that found for 1% L-Carvone used in the previous experiment (Table 8). However, the progression of the disease in the control was much lower in this experiment and so it is likely that these differences resulted from differences in environmental conditions in the glasshouse.

Table 8: Transmission of downy mildew after 14 days.

	Distance infection travelled (cm)		
	0.75%v/v Mycosin expt	**1.0% v/v L-Carvone expt**	**0.5% v/v L-Carvone expt**
Water control	219.0	278.4	104.0
Test compound	25.2	67.4	2.8
Aliette	8.4	78.6	135.0

Inducers of systemic acquired resistance:

Methods: Systemic acquired resistance (SAR), induced by application of salicylic acid was shown to provide immunity to *P. parasitica* in oilseed rape seedlings (Doughty *et al*., 1995). Similarly Bion, a SAR activator has also been shown to protect brassica seedlings against downy mildew (Jensen *et al*., 1998). To investigate whether SAR could be used in organic transplant production an experiment was set up. One week old cabbage seedlings were used in the experiment. The seedling propagation cells were drenched with salicylic acid (0.5mM, 2 mM and 4mM) or Bion was sprayed onto the seedlings at the recommended dose of 0.05 g/l until run-off. A control treatment was sprayed with water only. After a further weeks growth to allow resistance induction, the plants were inoculated with spores of *P. parasitica* (1.5×10^4 spores/ml) and plant infection/sporulation assessed one week later. The cotyledon diameter of ten plants at their widest point was also measured for each treatment.

Results: Salicylic acid had little effect as an inducer of SAR but Bion completely suppressed infection with only a few dark flecks seen on the cotyledons (Table 9). Increasing concentration of salicylic acid also reduced cotyledon size.

Table 9: The Effect of SAR inducers on infection and sporulation of *P. parasitica* and cotyledon size.

Treatment	% seedlings infected	% seedlings sporulating	Mean cotyledon diameter (mm)
Control	100	100	1.89
Salicyclic acid 0.5 mM	100	100	2.07
Salicyclic acid 2.0 mM	100	100	1.51
Salicyclic acid 4.0 mM	100	87	1.18
Bion 0.05 g/l	0	0	1.72

Spectral filters:

Methods: Spectral filters have been found to reduce downy mildew through inhibition of sporulation in glasshouse grown cucumber (Reuveni & Raviv, 1997). To investigate whether this could be of use in organic transplant production an experiment using a range of spectral filters was set up. Clear plastic boxes were covered with each of four filters; Sunselector Antivirus Diffused (yellow), Sunselector Diffused (yellow), Sunselector Blue (blue) and Visqueen (U.V. absorber). Thirty cabbage seedlings were sown into dishes of vermiculite and allowed to grow on for a week before being inoculated with *P. parasitica* (2×10^4 spores/ml). After a further week of incubation each seedling was assessed for infection or sporulation of *P. parasitica*. In addition the seedlings from each dish were suspended and agitated in 5 ml distilled water and the number of spores assessed using a haemocytometer.

Results: None of the spectral filters tested reduced sporulation of *P. parasitica* (Table 10) and in some cases sporulation was actually increased compared to the control, although not statistically significant.

Table 10: Effect of spectral filters on sporulation of *P. parasitica.*

	% plants with sporulation	Spores/plant ($x10^4$)
Sunselector Antivirus	98.9	2.89
Sunselector Diffused	97.7	1.53
Sunselector Blue	94.1	1.50
Visqueen	97.8	2.37
Control	94.2	0.93

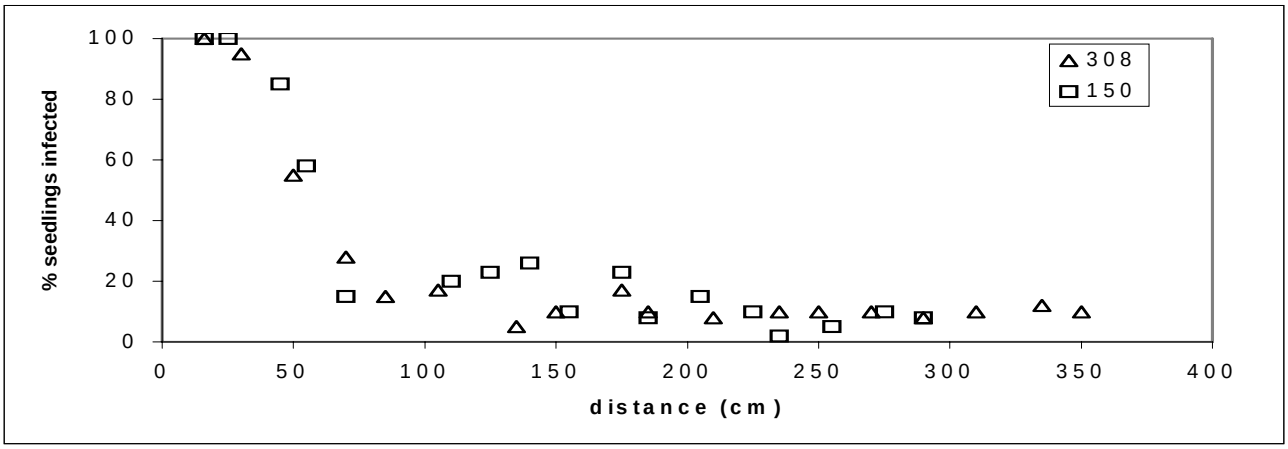
Effect of module size on spread of downy mildew in the glasshouse:

Methods: The size of plant raising modules was identified in the previous project as a potential factor in the spread of downy mildew in the glasshouse. Cabbage was again used as the model crop and seedlings were raised either in 150 (48 x 32 cm, and 15 x 10 cells) or 308 (60 x 30 cm, 22 x 14 cells) module trays. Each module size (9 trays per cell size) was arranged side by side long ways in the glasshouse with a splash barrier separating them. When the seedlings were approximately three weeks old and the first leaf was just appearing, fifteen infected cabbage seedlings with sporulating downy mildew were transplanted into one row at the end of the first tray of each cell size. Seedlings were then watered with an overhead gantry approximately every other day. The number of infected plants were assessed at regular intervals beginning one week after inoculation. Whole trays were assessed in the 150s and the middle block of 10 cells in each row in the 308s (140-150 plants per tray at each assessment). The disease levels at different distances 14 days after inoculation were analysed. Two consecutive experiments were carried out.

Results: Disease assessments made every few days suggested that there were small differences in the levels of disease with distances over time for the 150 and 308 module sizes (Figure 5). Downy mildew was observed in the last tray of the 150 (296 cm from inoculum source) and in the last tray of the 308 (358 cm from inoculum) after 12 – 14 days. Analysis of the data at 14 days showed that there was a small but significant difference ($p>0.05$) in infection levels between the two tray sizes with the 350 having lower levels of infection.

Conclusions: Although there was a small but significant difference on the spread of mildew due to module size this is unlikely to be of a benefit in a commercial plant raising situation. The level of significance was low and the amount of variability and control that can be expected in a commercial glasshouse would soon cancel out any effect. Therefore, as a control measure for the spread of mildew module size would be of little use.

Figure 5: Effect of 150 and 308 module on spread of downy mildew 14 days after inoculation.



Discussion & Conclusions:

The objective was to identify organically acceptable fungicidal products. This objective has been met in full. The products Top Cop, L-Carvone, Mycosin, Fennel and Clove oils all showed potential in controlling mildew on a range of crop species. However, Top Cop was disregarded from further experiments as it fell outside of revised organic regulations. When studies were carried out looking at combinations of the compounds there appeared to be no advantage. Spread experiments encountered phytotoxicity problems that had not been experienced in the previous years work. The problem was encountered with both Mycosin and L-Carvone. The phytotoxicity with Mycosin was eradicated when the concentration was reduced from 2% (used at the beginning of the experiment) to 0.75%. It would be recommended to use Mycosin at levels below 1% where there is a significant reduction of the levels of mildew when compared to the water control. L-Carvone performed well at both concentrations tested, however, subsequent investigations suggest that it is not the active ingredient of L-Carvone that is producing this phytotoxicity effect, but the agent used to make the L-Carvone more soluble in oil. Therefore an alternative application method ie vaporisation, could be used with no phytotoxicity effects being seen. Further work will need to be undertaken to confirm this.

Products that induced SAR showed some potential. Salicyclic acid produced no effect but Bion successful protected the plants from mildew infection. However, there has been on going discussions of the acceptability of such compounds in organic production and therefore work on SAR inducing compounds was not continued within the project. However, this could be a further area of research if an integrated approach to disease is to be developed for organic transplant production.

The work on spectral filters was disappointing with no benefits being found. This was preliminary work and should not be taken as proof that spectral filters could not be used in as part of an integrated control programme within organic production systems.

The effect of cell size on disease spread was minimal with both the cell sizes tested having similar spread of disease over 12 – 14 days. This would suggest that cell size is not a suitable method to control the spread of disease in organic transplant production systems.

Objective 2: Produce integrated organic transplant production systems for brassica, allium and lettuce over the autumn and winter period by identifying optimum cell/block size(s) in relation to nutrient requirements, sources, growing media formulation, supplementary feeding and watering during plant raising; and by assessing risks and opportunities for control of mildew in the light of products evaluated under objective 1.

Work within research and commercial glasshouses was undertaken to develop integrated production systems. This was to draw on the most successful fungicidal compounds from Objective 1 (Mycosin and L-Carvone) as well as introducing new factors such as module size, growing media, feeding regime and variety etc. However, disease levels were believed to be so low within these conditions that the biocides were not included in the initial phases of the work within the objective and protocols were developed using the new factors listed above. Subsequently the commercially trialled protocols (objective 3) did not include biocides.

Development of Protocols

A number of protocols were tested developed and tested under semi-commercial conditions (Table 11).

Table 11: Propagation trial protocols tested under semi-commercial conditions.

Species	Variety	Media	Block/cell size	Supplementary feeding
Lettuce	*Little Gem* *Ferro*	Sinclair blocking Levington B2 (C)	$3.2cm^3$ $4.3cm^3$	-
Cabbage	*Castello*	Sinclair modular Bulrush peat-free	308 150	None Nu-Gro Fish emulsion Conventional
Cauliflower	*Nautilus* *Mayflower* *Gipsy* *Fremont*	Sinclair Organic Module Compost Sinclair Organic Low Nutrient	126 216 324	None Nu-Gro

All composts are acceptable for organic production unless marked (C).

Lettuce

Methods: The growing media were homogenised and 'wetted-up' prior to blocks being made using a commercial blocking machine. The blocks were made two days prior to sowing. A single seed was placed in the indentation of each block and the blocks were then covered with a double sheet of paper to prevent media falling on the seed during watering. The trays were placed in the glasshouse and left covered with paper until most germination had occurred. Once the seedlings emerged the germination rate was assessed on a daily basis. Germination was considered to have taken place when the seed cracked and a shoot had begun to emerge. During the trial the trays were watered as required with overhead mist irrigation. The trays were kept on wire mesh tables to allow for air pruning and free drainage of excess water. During the entire propagation period the transplants were raised in an unheated, frost-free section of the glasshouse with no supplementary illumination. Maximum glasshouse temperature was controlled by automatic venting.

At sowing, samples of homogenised growing media were taken and sent to ADAS for analysis. Assessed plants were taken from an area the middle of the tray. All plants in this area were taken regardless of size although where a seed had not germinated a plant adjacent to the area was taken. The assessments criteria for the trials can be found in Appendix 1. In all trials, assessment of colour, uniformity and weed incidence were carried out on an overall tray basis. The trial was carried out in a fully factorial randomised block design with four replicates. 'Balanced analysis of variance ' analysis was used to analysis the results statistically. The LSDs for the treatment means were calculated according with the Tukey method at the 5% level (Fowler & Cohen (1990)).

Results: Germination was excellent and was similar for seedlings in both growing media. The transplants raised in the Sinclair compost were slightly lighter green than those raised in Levington but all transplants were of acceptable colour. Statistical analysis (Table 12) showed there was no effect on blocking on the parameters measured (height, growth stage, fresh and dry weight and uniformity). Block size was significant on all parameters other than height. With the larger size producing a larger and heavier plant. The effect due to media was highly significant in all measurements with the conventional compost producing larger and heavier plants. However, both media and block sizes produced acceptable transplants but the Levington (conventional) produced the better transplant. There were no pest and disease nor weed problems encountered within the trial.

Table 12: Statistics for lettuce trial.

Effect	Height	Growth Stage	Fresh Weight	Dry Weight	Uniformity
Blocking	ns	ns	ns	ns	ns
Block size	ns	*	*	***	**
Media	***	***	***	***	***
Media*Block	ns	ns	ns	*	ns

ns = not significant, * = significant at P = 0.05, ** = significant at P = 0.01, *** = significant at P = 0.001

Conclusions: Early sowing (6 Feb 98) in Sinclair organic and Levington conventional growing media produced transplants which were considered to be of acceptable quality, although the plants were 'leggy' and elongated compared with the plants produced during main season conditions. The propagation period of 38 days was longer than that required for

plants raised in the main season conditions. Plants raised in both block sizes were of acceptable quality, though at the time of assessment, plants raised in the larger block size had greater fresh and dry weights, a more advanced growth stage and were of greater uniformity. Blocks made with the Sinclair growing medium appeared to dry out more readily and thus plants grown in Sinclair require close attention with regard to watering.

Cabbage

Methods: Sterilised trays were filled with growing medium, sieved over a 6mm mesh, that had been homogenised prior to sowing. An empty tray was then used to lightly press down the medium in the filled trays to create an indentation. A single seed was placed in each indentation and lightly covered with finely sieved medium with any excess medium scraped off. The trays were placed in the glasshouse to germinate. They were not covered nor put in a germination chamber. Once the seedlings emerged the germination rate was assessed on a daily basis. Germination was considered to have taken place as soon as any part of the seedling emerged through the surface. During the trial the trays were watered as required by hand. The trays were kept on wire mesh tables to allow for air pruning and free drainage of excess water. During the entire propagation period the transplants were raised in an unheated, frost-free section of the glasshouse with no supplementary illumination. Maximum glasshouse temperature was controlled by automatic venting.

The cabbage plants were fed during the propagation period. Three feeds were used (details Table 13 and Appendix 2).

Table 13: Feeding regimes for the production of cabbage propagation protocols.

Feed	Concentration of total N	Amount of liquid feed supplied	N supplied/ feed	No. of feeds	Total N supplied
Conventional	100mg/l	0.5 l solution	50mg	12	600 mg N
Nu-Gro	96mg/ml*	11ml	1056mg	2	2112 mg N*
Fish emulsion	45.5mg/ml*	15ml	682.5mg	2	1365 mg N*

* - based on N content given by manufacturer on product label.

The propagation trial was carried out as a split plot multi-factorial randomised block design. There were four replicates of each treatment and all treatments were randomised within the four blocks. A quadrant containing 50 plants was used for assessment at harvest of the transplants. Due to space limitations the trial was not fully factorial and the following 15 treatments were selected. (Table 14).

Table 14: Treatments used in cabbage experiments.

Treatment	Feeding regime	Medium	Cells/Tray	Treatment	Feeding regime	Medium	Cells/Tray
1	None	Sinclair	308	9	Fish	Sinclair	308
2	None	Sinclair	150	10	Fish	Sinclair	150
3	None	Bulrush	308	11	Fish	Bulrush	308
4	None	Bulrush	150	12	Fish	Bulrush	150
5	Nu-Gro	Sinclair	308	13	Conventional	Bulrush	308
6	Nu-Gro	Sinclair	150	14	Conventional	Bulrush	150
7	Nu-Gro	Bulrush	308	15	Conventional	Shamrock	308
8	Nu-Gro	Bulrush	150				

Assessments were carried out as described in the section on lettuce above and Appendix 1. Results were analysed using balanced analysis of variance and one-way analysis of variance. The LSDs for the treatment means were calculated according with the Tukey method at the 5% level (Fowler & Cohen (1990)).

Results: Germination was excellent and similar for seedlings raised in all growing media.

Statistical analysis of the assessments (Table 15) showed significant effects due to the position of the block, feeding, tray size and media. Plants fed with Nu-Gro were significantly better than those fed with the other feeds or not fed. They were of good quality showing little purple colouration. Plants fed conventionally and with fish emulsion were also of an acceptable quality in terms of purple colouration, though they showed a fair amount of purple. Plants that were not fed were of an unacceptable standard, as they were considered to be too purple.

Cell size was also highly significant in all assessments. Although plants raised in both cell sizes were of an acceptable quality, plants raised in 150s (the larger cell size) were significantly taller, had a greater petiole length, more advanced growth stage, of greater fresh and dry weights and had more developed root structures than those raised in 308s. Transplants raised in both Sinclair and Bulrush media were considered to be of acceptable quality, irrespective of the feeding regime. Plants raised in the Sinclair growing medium were significantly taller, had a greater petiole length, more advanced growth stage, of greater weight and had more developed root structures than those raised in Bulrush medium. No pest, disease nor weed problems were encountered in the trial.

Conclusions: In this trial plants raised in all treatments were considered to be of acceptable quality, apart from those which had been given no feed.

Early sowing of cabbage (25 Feb 98) in Sinclair Organic Growing Medium or Bulrush Organic Growing Medium, in 308 or 150 cells, and with the Nu-Gro or fish emulsion feeding regimes produced transplants of acceptable quality. The propagation period of 55 days was slightly longer than for plants raised in previous trials during the main season.

Table 15: Statistics for the cabbage trials.

Effect	Height	Petiole length	Growth Stage	Fresh Weight	Dry Weight	Root index
Blocking	*	**	*	**	***	ns
Feed	***	***	***	***	***	***
Tray	***	***	***	***	***	***
Media	**	***	***	***	***	*
Feed * Media	***	***	***	ns	***	ns
Feed * Tray	ns	ns	ns	***	**	*
Media * Tray	ns	***	***	***	*	ns

ns = not significant, * = significant at P = 0.05, ** = significant at P = 0.01, *** = significant at P = 0.001

The Bulrush medium consistently produced smaller transplants that were of acceptable quality for transplanting given a suitable feeding regime. An additional point to note was that the Bulrush growing media was found to be very coarse and needed to be sieved prior to filling trays. This medium was also more difficult to keep moist, which is a common problem for many non-peat based growing media, and the plants had to be carefully monitored and the watering regime adapted accordingly.

Plants raised in the Sinclair medium in 308 cells with the fish emulsion feeding regime were considered to be the best transplants with the best quality characteristics in the trial. They were compact (not too 'leggy') and had moderate purple colouration.

Cauliflower

Methods: Sterilised trays were filled with growing medium, sieved over a 6mm mesh, which had been homogenised prior to sowing. An empty tray was then used to lightly press down the medium in the filled trays to create an indentation. A single seed was placed in each indentation and lightly covered with finely sieved medium with any excess medium scraped off. The trays were placed in the cold bay of the glasshouse to germinate. They were not covered nor put in a germination chamber. Once the seedlings emerged the germination rate was assessed on a daily basis. Germination was considered to have taken place as soon as any part of the seedling emerged through the surface. During the trial the trays were watered as required by hand. The trays were kept on wire mesh tables to allow for air pruning and free drainage of excess water. During the entire propagation period the transplants were raised in an unheated, frost-free section of the glasshouse with no supplementary illumination. Automatic venting controlled the maximum glasshouse temperature.

Plant assessments were the same as those used for the cabbage experiments.

The trial was carried out as a multi-factorial randomised block design. There were four replicates of each treatment and all treatments were randomised within the four blocks. Due to space limitations the trial was not fully factorial and 16 treatments were selected (Table 16). This allowed all varieties to be tested in all cell sizes using the full nutrient growing medium but only one variety was tested using the low nutrient medium. However, at the time when the feed was to due to be applied to the fed treatments the plants were considered to be too large to warrant any feeding so the application of Nu-Gro was omitted.

Table 16: Selected treatments used in cauliflower experiments.

Treatment	Feed	Media	Variety	Tray
1	None	100%	Nautilus	126
2	None	100%	Nautilus	216
3	None	100%	Nautilus	345
4	None	100%	Mayflower	126
5	None	100%	Mayflower	216
6	None	100%	Mayflower	345
7	None	100%	Gipsy	126
8	None	100%	Gipsy	216
9	None	100%	Gipsy	345
10	None	100%	Fremont	126
11	None	100%	Fremont	216
12	None	100%	Fremont	345
13	None	Low	Nautilus	126
14	None	Low	Nautilus	216
15	None	Low	Nautilus	345
16	Nu-Gro	100%	Nautilus	126

Balanced Analysis of Variance (ANOVA) using MINITAB computer statistical package was used to determine whether differences due to treatments were significant. The LSDs for the treatment means were calculated according with the Tukey method at the 5% level (Fowler & Cohen (1990)). As the trial was not fully factorial, two separate balanced ANOVAs were carried out. The first analysis (A) was used to analyse those treatments which had used the same growing media and the second analysis (B) was used to compare treatments that had used the same variety.

Results: Germination was excellent and was similar for seedlings raised in both growing media.

The first analysis (Analysis A) was used to analyse those treatments which had used the same media and the second analysis (Analysis B) was used to compare treatments that had used the same variety (Table 17).

Plants raised in the low nutrient medium had high purple colouration and were considered too purple to be acceptable quality. All plants were considered to be acceptable in terms of rigidity, brittleness and twisting except for those grown in the low nutrient medium in the 345 cells, which were considered to be too brittle.

Acceptable transplants were produced for all four varieties. The *Gipsy* transplants were the largest with a significantly greater fresh weight (P=0.01) than other varieties and were significantly taller and of a greater dry weight (P=0.05) than *Mayflower*. Whilst *Nautilus* was almost as tall as *Gipsy*, it had a significantly shorter petiole length (P=0.05). *Mayflower* was not as uniform as *Nautilus* or *Fremont* (P=0.05).

Nautilus grown in full nutrient medium were significantly (P=0.001) taller, more advanced in growth stage and of greater fresh and dry weight than those grown in the low nutrient medium. Although, plants grown in the low nutrient medium were of an acceptable size, the overall quality of these were still considered to be unacceptable for transplanting as the plants were very purple.

Plants grown in full nutrient medium in 345 trays were considered to be of acceptable quality, whilst those grown in the 216 and 126 trays were considered to be too large to be of acceptable quality (especially if they were to be transplanted by machine). According to both analysis A and B plants grown in 345 cells were significantly (P=0.001) shorter and of less fresh and dry weights than those grown in 126 and 216 cells. Plants grown in 216 cells were significantly (P=0.001) of less fresh and dry weights than those grown in 126 cells.

No pest, disease or weed problems were encountered in the trial.

Table 17: Statistics for cauliflower trial

Analysis A

Factor	Rep	Var	Cell	Var*Cell
Height	ns	*	***	ns
Petiole	*	*	**	ns
Growth Stage	ns	ns	ns	***
Rooting Index	ns	ns	*	ns
Fresh Weight	ns	**	***	*
Dry Weight	*	*	***	ns
Rigidity	ns	**	***	***
Brittleness	ns	ns	**	**
Twisting	ns	***	ns	***
Uniformity	ns	*	ns	ns

Analysis B

Factor	Rep	Media	Cell	Media*Cell
Height	ns	***	***	ns
Petiole	ns	***	ns	ns
Growth Stage	ns	***	***	*
Rooting	ns	*	ns	ns
Fresh Weight	ns	***	***	***
Dry Weight	ns	***	***	*
Rigidity	ns	ns	ns	ns
Brittleness	ns	*	ns	***
Twisting	ns	**	ns	ns

ns = not significant, * = significant at P = 0.05, ** =significant at P = 0.01, *** = significant at P = 0.001

Conclusions: The Sinclair Organic Compost (full nutrient) used in this trial had unusually high nitrogen content. This, together with comparatively warm glasshouse conditions (frost free conditions), resulted in very vigorous growth and many of the transplants were considered to be too big to be of acceptable quality at the final assessment (date at which time they were due for transplanting).

Plants of all varieties grown in the full nutrient medium in 345 cell size were considered to be of acceptable quality, however, plants of all varieties grown in the full nutrient medium in 126 and 216 cell size were considered to be too large to be of acceptable quality for transplanting.

Plants grown in the low-nutrient medium (without additional feed) were considered to be too purple to be of acceptable for transplanting, although the size of these plants was acceptable.

Discussions & conclusions:

Information from previous experiments on crop types and varieties, growing media, block and cell size and feeding regimes were brought together to develop protocols for overwinter transplant production. The use of biocides was not included in the protocols as disease levels were relatively low and plants grew out of the infection with little effect.

The overall findings of this objective was that production protocols could relatively easily produced and tested successfully on a range of crops in a research scale situation. Production time for overwinter production was longer than for production in the spring. Lettuce was relatively easy to produce with acceptable plants being raised in a range of media and block sizes; no feed is needed for lettuce. Cabbage transplants were also relatively easy to produce in a range of media, and cell sizes. However, feeding was needed for cabbage. The second brassica tested – Cauliflower – may have been affected by improving conditions in the glasshouse and high levels of nutrition in one of the media (Sinclair organic). Acceptable transplants were produced for cauliflower using smaller a cell size (345) and full nutrient compost.

The objective was met in full using with protocols being developed and tested. The knowledge gained under this objective was used to further test the protocols under commercial conditions in objective 3.

Objective 3: Evaluate developed transplant production protocols during 'winter' period for early production in replicated trials and commercial situations.

The information gained from the experiments under objective 2 and from the previous project on main season production were used to develop and test protocols for cauliflower, calabrese, lettuce and leek under commercial conditions. The work was undertaken within commercial glasshouses situated in Lincolnshire and Cambridgeshire. The protocols tested are listed in Table 18.

Table 18: Propagation protocols tested under commercial conditions.

Species	Variety	Media	Block/ cell size	Supplementary feeding
Cauliflower 1	*Nautilus*	Sinclair Organic Module Compost	126 216 345	Nu-Gro
Cauliflower 2	*Nautilus* *Gipsy* *Fremont*	Sinclair Organic Module Compost Sinclair Organic Low Nutrient	216 345	Nu-Gro
Calabrese	*Marathon*	Sinclair Organic Low Nutrient Klasmann Organic Low Nutrient Compost Vapo-Gro Low Nutrient Compost	216	Nu-Gro Rate 1 = 5ml/tray over one feed Rate 2 = 10ml/tray over two feeds No feed
Lettuce	*Set* *Little Gem*	Sinclair Organic Blocking Compost Klasmann Organic Blocking Compost	4.3cm^3	None
Leek	*Pancho*	Sinclair Organic Module Compost Klasmann Organic Module Compost Vapo-Gro Organic Prop Mix Vapo-Gro Organic Veg-based Compost	216	Nu-Gro Rate 1 = 18ml/tray over two feeds Rate 2 = 28ml/tray over three feeds

Cauliflower 1

Methods: See Table 16 for factors. A full factorial randomised block design, two replicates per treatment were established, with 99 trays per replicate making a total of 594 trays. Downy mildew disease occurred through natural infection only.

Sowing took place on 17 October 98 and the trays were watered to requirements throughout the propagation period by site staff. Research staff made visits to the site to monitor and assess the plants on 3 Nov 98, 4 Dec 98, 11 Jan 99, 11 Feb 99 and 17 Mar 99. Feeding took place on 20 Feb and was applied by site staff. Research staff monitored symptoms of downy mildew attack at approximately 30-day intervals from the time of sowing. On each occasion the severity of disease for the plants in each replicate block was scored by estimating number of trays with infected plants, the number of infected plants per tray and the number of dead plants per tray. The height and growth stage were also recorded.

During the trial the trays were watered as required by the use of overhead irrigation. The propagation bay floor was covered with 'Mypex' and the trays were placed on upturned plastic plant pots at each corner to allow for air pruning and free drainage of excess water. During the entire propagation period the transplants were raised in an unheated, frost-free section of the glasshouse with no supplementary illumination.

Statistical analysis of the data was undertaken using balanced ANOVA on all treatments.

Results: The trial was first assessed 17 days after sowing. Germination was very good and no disease problems were apparent. The second assessment was carried out 48 days after sowing and some downy mildew was apparent. Plants grown in the 345 trays were worst affected although the numbers of dead plants per tray was similar across all cell sizes. The third assessment was carried out 86 days after sowing. Disease incidence was high with the dicotyledons of the plants in all treatment either dead or severely infected. The numbers of dead plants per tray due to downy mildew was slightly greater in the 126 trays (though not detectable with the assessment scale used) than in 216 or 345 trays. However, according to the assessments made of the proportion of plants affected per replicate and per tray, the incidence of downy mildew appeared to be slightly greater in the 345 trays. The forth assessment was carried out 117 days after sowing. At this stage there were no detectable differences between the treatments; all plants in all cell sizes showed symptom of that downy mildew had been present, but at this time infection was much less severe than on the previous visit. The number of dead plants per tray had not risen. In general, the first true leaves were yellow or necrotic and the younger leaves were green with spots of necrosis. The last assessment was carried out 151 days after sowing. At this stage there were no detectable differences between the treatments; all plants in all cell sizes showed symptoms that downy mildew had been present, but the disease appeared to have disappeared. In general, the transplants appeared healthy and vigorous with only the first true leaves yellow or necrotic whilst the younger leaves were green with only minor spots of necrosis.

No pest or weed problems were encountered in the trial and all plants in all treatments were considered acceptable in respect of brittleness, rigidity and twisting. When the data was analysed by a balanced ANOVA there were in general terms no significant differences due to the position of the block.

All of the transplants were considered to be of acceptable quality for transplanting, as judged both by the on-site staff and researchers. In agreement with results from previous trials, the plants tended to grow bigger the bigger the cell size was. Plants grown in 126 cells had significantly (P=0.01) greater fresh and dry weights than those grown in 216 and 345 cells. The on-site staff were of the opinion that plants grown in the 126 trays were of the highest quality.

Conclusions: The incidence of downy mildew was high and all plants became infected. There were some indications that the incidence of the disease at the early stage of infection was higher on plants grown in 345 trays than on plants grown in the other cell sizes. However, despite the early occurrence of downy mildew, all of the transplants were considered to be of acceptable quality at the time they were due for transplanting.

All of the transplants were considered to be of acceptable quality, irrespective of the cell size in which they had been grown. On-site staff were of the opinion that plants grown in the 126 trays were of the most superior quality.

On-site staff were of the opinion that the lack of options available to them for the control and prevention of downy mildew means that the risk of failure for organic transplant productions is extremely high.

Cauliflower 2

An aim of this trial was to establish whether or not the performance of the Sinclair medium for the purpose of over winter cauliflower production could be improved by lowering its nutrient content. For the purpose of this trial Sinclair produced a batch of medium with a lower nutrient (referred to as Low Nutrient). Furthermore, the aim of this trial was to establish whether some varieties of cauliflower were more suitable than others for organic production. The propagation protocol included the use of a feed (Nu-Gro) to all treatments if this was considered necessary.

Methods: See Table 16 for factors. It was intended to establish a multi factorial randomised block design with two replicates with 20 trays per treatment making 320 trays in total. Due to space limitations the trial was not fully factorial and the 8 treatments were selected. This allowed all varieties to be tested in both cell sizes in the normal medium and one variety to be tested in both cell sizes in the lower nutrient medium. However, through the action of on-site staff a subsequent factor was included in the trial; sulphur was applied as a foliar application to prevent downy mildew to half of the trays in each replicate. As a result the trial included a total of 16 treatments with 10 trays per replicate.

Sowing took place on 3 Nov 98 and the trays were watered to requirements throughout the propagation period by site staff. Research staff made visits to the site to monitor the trial on 4 Dec 98, 11 Jan 99, 11 Feb 99 and 17 Mar 99. Feeding took place on 18 Feb 99 and 22 Mar 99 and was applied by site staff.

During the trial the trays were watered as required by hand by the use of a hand lance. The propagation bay floor was covered with black polythene and the trays were placed on upturned plastic plant pots at each corner to allow for air pruning and free drainage of excess water. During the entire propagation period the transplants were raised in an unheated, frost-free section of the glasshouse with no supplementary illumination.

As the trial was not fully factorial, two separate balanced ANOVAs were carried out. The first analysis (Analysis A) was used to analyse those treatments which had used the same growing media and the second analysis (Analysis B) was used to compare treatments that had used the same variety.

Results: The first assessment was carried out 31 days after sowing. Germination was good and plants were just beginning to shows signs of the first true leaf forming. No downy mildew was apparent. The second assessment was carried out 69 days after sowing. Disease incidence was high with the dicotyledons of the plants in all treatment either dead or severely infected. The numbers of dead plants per tray was similar in all treatments (3-10 plants/tray) although there was a very high incidence of disease (in terms of incidence within trays) in two treatments where water had dripped in through vents. The third assessment was carried out 100 days after sowing. The sulphur had been applied by this visit and there were now 16 treatments. However, there were no detectable difference in the level of disease incidence in any of replicates and therefore each replicate (ie 20 trays) were assessed. All plants in all cell sizes showed symptoms that the disease had been present but the infection appeared to be much less severe than on the previous visit (11 Jan 99). The number of dead plants per tray had not risen. In general, the first true leaves were yellow or necrotic and the newer leaves were green with spots of necrosis. The last assessment was carried out 139 days after sowing. All plants in all cell sizes showed symptoms that the disease had been present but at this stage the disease appeared to have disappeared.

In general, the transplants appeared healthy and vigorous with only the first true leaves yellow or necrotic and the newer leaves were green with spots of necrosis. All plants showed signs of purpling on true leaves.

No pest or weed problems were encountered in the trial. At the date of harvest (date when the plants were due for transplanting) an overall assessment was made of their quality. This assessment was done jointly between on-site and research staff. Plants grown in the 100% medium in 216 trays were considered to be ideal for transplanting. Plants grown in 345 trays and 100% medium were considered to be acceptable for transplanting but would have benefited from one week more in the glasshouse. Those grown in the low nutrient medium were considered to be a little too small and could have benefited from more feed.

The addition of the extra treatment into the trial protocol (sulphur) made the statistical analysis difficult to interpret, particularly due to the complex interaction effects. Interaction effects have therefore no been interpreted. However, plants of acceptable quality were produced for all of the varieties. *Fremont* was significantly shorter than *Nautilus* and *Gipsy* although it had a significantly greater dry weight. All of the plants raised in the 100% medium were of acceptable quality, and these were significantly taller and a greater fresh weight than those grown in the low nutrient medium. Plants grown in the low nutrient medium were considered to be too small and too purple. Plants grown in both of the cell sizes were considered to be of acceptable quality, though those grown in 216 trays were considered to be superior. Plants grown in the 216 trays were significantly taller and had greater fresh and dry weights than those grown in 345 trays.

According to the statistical analysis the application of sulphur was found to have influenced the growth of the plants (petiole, growth stage) and to have resulted in a slight reduction in the in the presence of symptoms of disease attack at the time of harvest. This effect of the sulphur was not detected in the disease assessments carried out during the growth of the plants.

Conclusions: The incidence of downy mildew was high and all plants became infected. However, despite the early occurrence of downy mildew, all of the transplants were considered to be of acceptable quality at the time they were due for transplanting. The single application of sulphur did not appear to significantly influence the incidence of disease.

All of the plants, irrespective of the variety, grown in the 100% medium in 216 and 345 trays were of acceptable quality, though those grown in the 216 trays were considered to be superior. Plants grown in the low nutrient formulation of the Sinclair medium were considered to be slightly small and too purple to be of acceptable quality.

On-site staff were of the opinion that the lack of options available to them for the control and prevention of downy mildew means that the risk of failure for organic transplant productions is extremely high.

Calabrese

The overall aim of this on-site trial was to assess the performance of calabrese transplants produced under commercial conditions over winter for transplanting in spring (late March/early April). The protocol was based on those developed for main season production of brassica transplants in previous trials. Originally the plan was to test three low nutrient growing media in combination with two feeding regimes (Rate 1 = 5ml/tray as 1 feed, Rate 2 = 10ml/tray split into 2 feeds). However, the nitrogen content of the Klasmann Low Nutrient Compost was found to be as high as that which would normally be found in a standard nutrient level compost (118 mg/l total N) and the feeding regimes for this media were therefore amended to reflect this (no additional feed was used).

Nu-Gro is distributed by William Sinclair Holdings Ltd. This liquid fertiliser contains material derived from fish residues. The product has changed formulation since it was used in previous trials when it contained blood and bone meal. It is approved for restricted use in organic systems and is certified by the Soil Association.

Methods: See Table 16 for factors. The propagation trial was carried out in a commercial plant raising glasshouse as a multi-factorial randomised block design. There were four replicates of each treatment, with 6 trays per treatment and all treatments were randomised within the four blocks. Giving a total of 166 trays.

During this trial (and the lettuce and leek trials to follow) the trays were watered as required by hand using a hand lance. The floor of the propagation bay was covered with black polythene (calabrese and lettuce) or concrete (leek). Module trays (calabrese and lettuce) were placed on upturned plastic plant pots at each corner to allow for air pruning and free drainage of excess water whilst block trays (leek) were placed directly on the polythene. During the entire propagation period the calabrese and lettuce transplants were raised in an unheated, frost-free section of the glasshouse with no supplementary illumination. The glasshouse bay used for leek was heated to maintain a minimum temperature of 18ºC and a maximum glasshouse temperature of 23ºC was controlled through automatic venting.

Sowing took place on 14 Oct 99. Interim assessments were carried out on 11 Nov 99, 16 Dec 99 and 20 Jan 00 to record levels of downy mildew (*Peronospora parasitica*). The transplants had been grown for 132 days when the final transplant assessment took place. Assessments at harvest were: colour, height, petiole length, growth stage, root index, mildew, fresh weight, dry weight and uniformity (Appendix 1).

A General Linear Model (GLM), using Systat 8.0 for Windows, was used to carry out analysis of variance for the data from each trial within this, the lettuce and leek trials (see below). Least Significant Differences (LSD) for the treatment means were calculated according to the Tukey method at the 5% level (Fowler, J. & Cohen, L. (1990)).

Results: Germination was excellent and was similar for seedlings raised in all growing media. The trial was monitored at approximately 31-day intervals by research staff and levels of mildew were recorded. Mildew levels were generally very low despite potential disease pressure from surrounding infected plants in the glasshouse. By the time of the final assessment (23 Feb 00) there was barely any mildew on the transplants. Statistical analysis showed there were no significant differences in the level of mildew infection between treatments. All plants were of acceptable quality with regards to purple colouration; plants that were fed the most were the least purple. Despite its initial high nutrient level plant raised in Klasmann media showed signs of purple colouration.

Due to the unbalanced nature of the trial, the effects of feeding and the growing media could not be statistically analysed individually. However analysis of variance for both block effect and treatment effect were undertaken. Apart from the assessment of rooting index, there was no significant effect due to blocking. No insect pests or weed problems were encountered in the trial. All of the plants were considered to be of acceptable quality for transplanting, as judged by both on-site and research staff. In agreement with results from previous trials, the application of liquid feed appeared to improve the overall quality of the transplants (although the measured differences were not always statistically significant). The Klasmann media produced the largest and most advanced transplants. Comparing treatments given the same feed rate (Rate 1), the transplants grown in Klasmann were significantly taller, with greater petiole length, most advanced growth stage and with greater fresh weight than those grown in the other media. However, the dry weight of these plants was lower than that for the others. There were no significant differences between transplants grown in the Sinclair and the Vapo-Gro media (comparing treatments given the same feed rate), although those grown in Vapo-Gro were slightly smaller.

The on-site staff were of the opinion that the transplants grown in the Sinclair Low Nutrient media with the higher rate of feed were plants with the highest quality, considering both the size of the plants and the degree of purple colouration.

Conclusions: All of the calabrese transplants produced in this trial were considered to be of acceptable quality. The application of the liquid feed was considered to improve the overall quality of the transplants, although the differences were not always statistically significant.

Plants grown in the Sinclair Low Nutrient medium with the higher level of feed (Rate 2) were judged to be the highest quality within this trial.

The nitrogen content of the Klasmann medium was considered to be too high for over-winter brassica production, but despite this the transplants raised in this medium were of acceptable quality (though with some signs of purple colouration) and they were the largest in the trial. Notably, the dry matter content of these transplants was lower than the other plants and the suitability for transplanting in the field of such plants is questionable.

The Vapo-Gro Low Nutrient medium, which had not previously been used in this research programme, produced transplants of very similar quality to those grown in the Sinclair Lower Nutrient medium.

Although small pockets of downy mildew infection (*Peronospora parasitica*) were recorded within the trial at the time of the interim assessments, the disease did not appear to spread and at the time of harvest the level of infection was considered to be negligible.

Lettuce

The overall aim of this trial was to assess the performance of lettuce transplants grown under commercial conditions over winter for transplanting in early spring. The protocol was based on that developed for early season production in previous trials.

Methods: See Table 16 for factors. The propagation trial was carried out in a commercial plant raising glasshouse as a fully factorial randomised block design. There were three replicates of each treatment, with 24 trays per treatment and all

treatments were randomised within the three blocks. Giving a total of 288 trays. See the above calabrese section for glasshouse and propagation conditions.

Sowing took place on 16 Dec 99 and the blocks were watered to requirements throughout the propagation period by site staff. Research staff made one visit to the site to monitor the trial on 11 Jan 00 and another to collect transplants for final harvest assessments on 23 Feb 00. Assessments were made of height, petiole length, growth stage, rooting, mildew, fresh weight, dry weight and uniformity (Appendix 1).

Results: There was no mildew apparent on any of the plants when they were assessed on 11 Jan 00. No pest or weed problems were encountered in the trial.

For most of the parameters of assessment, with the exception for growth stage, fresh and dry weight, there were no significant differences due to the position of the block. Both growing media produced transplants of acceptable quality, although in both of the media the degree of rooting was considered to be less than optimal. For both varieties, transplants grown in Klasmann medium were larger than those grown in Sinclair. They were significant taller (p=0.01), they had a greater petiole length, rooting index, fresh weight and dry weight (p=0.001)

Both varieties produced transplants of acceptable quality, although for both varieties the degree of rooting was considered to be less than optimal. The transplants of variety Set were significantly larger (height, petiole length, fresh and dry weight) and at a more advanced growth stage (p=0.001) than those of Little Gem. The Set plants were also significantly more uniform and with less mildew (p=0.05).

Variety Set reached a significantly more advanced growth stage when grown in the Sinclair medium (p=0.05). Variety Little Gem scored significantly better root structure when grown in the Sinclair medium (p=0.001).

Conclusions: This was a large-scale trial testing two varieties of lettuce in two organic blocking media. All of the lettuce transplants produced in this trial were considered to be of acceptable quality, although the degree of rooting (as assessed by rooting index) was considered to be less than optimal. *Little Gem* grown in the Sinclair medium was significantly better in terms of degree of rooting than the plants grown in the other treatments but even for these plants the rooting was considered to be less than optimal. At the time of the final assessment the Set transplants were larger and at a more advanced growth stage than the Little Gem. Transplants grown in the Klasmann medium were larger than those grown in Sinclair medium. In both varieties infection by disease was recorded to be at negligible levels both during the growth of the plants and at the time of harvest (looking particularly for infection by *Bremia lactucae*).

Leek

The overall aim of this trial was to assess the performance of leek transplants grown under commercial conditions over winter for transplanting in spring. The protocol was based on that developed for main season production in previous trials. Four growing media, including one with vegetable-based nutrient source, were used with two rates of feed.

Methods: See Table 16 for factors. The propagation trial was carried out in a commercial plant raising glasshouse as a fully factorial randomised block design. There were three replicates of each treatment, with 6 trays per treatment. Giving a total of 144 trays. The trays requiring different feed levels were grouped within each replicate and randomised within this sub-group. See the above calabrese section for glasshouse and propagation conditions.

Sowing took place on 20 Jan 00 and the trays were watered to requirements throughout the propagation period by site staff. Research staff made visits to the site to monitor the trial on 23 Feb 00. Assessments were made of height, growth stage, rooting index and fresh and dry weight (Appendix 1).

Results: No symptoms of disease infection were apparent within the trial when plants were monitored on 23 Feb 00. At the time of the final assessment a large number of trays contained a range of species of weeds. All weeds were collected and identified. The results of the weed analysis were not analysed and within the scope of this trial it was not possible to determine the source of the weed seeds i.e. whether they were present in the media or through airborne contamination.

Apart from for the assessment of dry weight, there were no significant effects due to the positioning of the blocks. The height of transplants grown in the Sinclair medium was significantly greater than those grown in the Vapo-Gro vegetable-based medium (p=0.05). The fresh weight of transplants grown in the Sinclair and Klasmann media was significantly greater than those grown in the Vapo-Gro media (p=0.001). The dry weight of the transplants grown in the Klasmann medium was significantly greater than those grown in the Vapo-Gro Standard medium (p=0.05). Transplants given the higher rate of feed were more advanced in growth stage, had a greater rooting index score (p=0.05) and had greater fresh weight (p=0.01). All of the transplants raised in this trial were considered to be of acceptable, though less than

optimal, quality. Transplants grown in the Sinclair and the Klasmann media with the higher level of feed were judged by on-site staff to be the best transplants. Transplants grown in the Vapo-Gro veg-based medium with lower level of feed were judged to be the poorest. On-site staff were of the opinion that it would be recommendable to use higher feeding rates for leeks for all of the media used in this trial.

Conclusions: This was a large-scale trial carried out under commercial conditions testing four growing media and two levels of feed. All of the transplants raised in this trial were considered to be of acceptable, although less than optimal, quality at the time they were due for transplanting. The plants were considered to have been short of nutrients resulting in somewhat small and weak plants with too much yellowing of the tips of the leaves. In all of the media, the higher rate of feed resulted in improved growth of the plants (size and colour). In the opinion of the on-site staff it would be recommendable to increase the supply of feed (rates and/or frequency of application) for leeks grown in these media. Transplants grown in the Sinclair and the Klasmann media with the higher level of feed were considered to be the best. No symptoms of disease infection were noted on the leeks grown in this trial.

Discussions & conclusions:

Protocols were tested for a range of crop species and varieties, growing media, block or cell size and feeding regimes over three seasons under commercial conditions (Table 18). It was considerably easier than initially feared to produce organic transplants of suitable quality during the overwinter period. However, propagation time was generally longer than would be needed to produce comparable transplants at more favourable times of the year. Overall conclusions are shown in Table 17.

Table 19: Overwinter organic transplant propagation systems – conclusions of trials 1997 – 2000.

	Brassica				
	Cabbage	Cauliflower	Calabrese	Leek	Lettuce
Cell/block sizes	308, 150	126, 216, 345	216	216	3.2cm^3 4.3cm^3
Growing medium[1]	S, B	S,	SLow, VLow	S, K, V, VVeg	S, K
Feeding	Nu-Gro , Fish emulsion	Nu-Gro	Nu-Gro	Nu-Gro	Not required
Species/variety	Only 1 variety tested	Similar requirements	Only one variety tested	Only 1 variety tested	Set & Little Gem similar
Propagation period (days)	55	123 -159	132	68	24-38

[1]Growing media: B = Bullrush Peat Free, K = Klasmann Organic; S = Sinclair Organic; SLow = Sinclair Low Nutrient; V = Vapo-Gro Organic; VLow = Vapo-Gro Low nutrient; VVeg = Vapo-Gro Organic Veg-based.

Objective 4. Facilitate and undertake technology transfer and dissemination of results to technology users (organic growers and plant raisers).

A range of technology transfer and dissemination events have occurred during the project. The events were aimed at organic growers, plant raisers, scientists and the organic sector as a whole. Below is a list of the events/publications.

Publications and conferences

Clarkson, J., Fox, S., Kennedy, R. and Stopes, C. (1999). On top of mildew organically. The Grower, August 19, 1999, p24.

Elm Farm Research Centre Bulletin No. (May 1998). Organic transplants over winter.

Elm Farm Research Centre Bulletin No. (October 2000). Transplant Update.

Kennedy, R. (2000). Organically acceptable active ingredients. HRIA Vegetable Propagation Meeting. Horticulture Research International Wellesbourne, 9 November 2000.

Lawson, M. and Kennedy, R. (1998). Evaluation of garlic oil and other chemicals for control of downy mildew (*Peronospora parasitica*) in organic production of brassicas Tests of Agrochemicals and Cultivars No 19 (Annals of Applied Biology, Supplement 132) pp14-15.

Mowat H. 1999. Healthy vegetable transplants. Organic Farming 64:22-23

Pearce, B., Stopes, C., Lennartsson, M., Manchett, R., Kennedy, R. and Clarkson, J. (2000). Organic vegetable transplants: Evaluation and development of production techniques. Proceedings 13th IFOAM Scientific Conference. p 198.

Stopes, C. (1999). Organic vegetable transplant production. Soil Association 11th National Conference. Cirencester, January 1999.

Stopes, C., Pearce, B., Clarkson, J. and Kennedy, R. (2000). What scope for using organic acceptable biocides in organic plant production? Proceedings 13th IFOAM Scientific Conference. pp 602 – 605.

Stopes C., Pearce B., Clarkson J. and Kennedy R. (2000). What is the scope for using organic acceptable biocides in organic plant production. Proceedings of the 2000 Brighton Crop Protection Conference - Pests and Diseases. pp177-182.

Soil Association technical leaflet on organic transplant production (in-press).

Information on the project is also available on www.efrc.com

Technology transfer / Dissemination events

A plant raisers meeting was held at HDRA Ryton Organic Gardens on 26 October 2001. The meeting was advertised in the Grower and the EFRC bulletin and it is believed that plant raisers representing over 90% of the UK production of organic transplants were represented at this meeting. The findings of the project were presented to an audience of plant raisers, advisors, sector bodies, levy boards, supermarkets and scientists. The EFRC Bulletin, Transplant Update was distributed to all who attended this meeting and to others who were unable to attend but sort information. There were advisors at this meeting from EFRC Organic Advisory Service and ADAS. This ensured that the majority of organic horticultural advisors in the UK now have the information.

The project was presented at an HRI Association propagation day at HRI Wellesbourne in November 2000.

The project was to be presented at a Soil Association horticultural technical day. However, the meeting was cancelled due to foot and mouth and will be rescheduled.

Information from the project will be presented at an EFRC Horticulture Group meeting in 2001.

OVERALL DISCUSSION AND CONCLUSION.

The project has full met its overall objective to develop and evaluate protocols for organic transplant production during autumn, winter and early spring, taking particular account of nutrient supply, cell size and disease (particularly mildew) control for brassicas, allium and lettuce.

The testing of biocides has shown that there are candidates that are acceptable for organic production. However, with current pesticide laws it is unlikely that any of these will become available to the organic (or to that matter the conventional) plant raiser due to the complexity and expense of pesticide registration. There is also the issue of whether biocides have place in organic production. Results from these experiments showed that although mildew does appear under commercial organic transplant conditions but if left untreated the plants grow out of the disease and produce healthy acceptable transplants. However, there is a feeling amongst organic plant raisers that they want a ‘safety net’ of a chemical. This may be dissipated if mildew continues not to be a major problem in organic production.

Overall it was considerably easier than initially feared to produce organic transplants of suitable quality during the overwinter period. However, propagation time was generally longer than would be needed to produce comparable transplants at more favourable times of the year. For overwinter production a number of the composts were believed to

have too high nitrogen content. A clear picture has not appeared from these trials however, as there was evidence on both sides.

Of the crop species tested leeks continue to be more difficult than other species worked on. The trial carried out, although using two feeding regimes, still did not supply enough nutrients to the growing plants. The commercial plant raisers who worked on this trial felt that the supply of feed needed to be higher than the maximum rate given (28ml/tray of Nu-Gro). Further development work is still needed on leek (and other allium species) before there is high level of confidence in their production.

Although the transplants produced under the protocols in this project are labelled as 'organic' there are being produced using products that are acceptable under Annex 2 of the EU regulation 2092/91 (EC 1991) and are not in themselves organic. Currently this is not an issue but to develop a truly closed organic system they will need to be able to produce growing media using from recycled organic products with less or no peat. The issue of using animal waste as a feed is also contentious with a small but significant move towards a 'vegan' organic horticulture production system. This would mean that the use of the fishmeal feeds and hoof and horn additions to media would become unacceptable and a plant based feed would need to be identified or developed. However the issue of a truly organic media and feed as well as an animal free feed is still some way off with a considerable amount of research still needs to be undertaken.

FUTURE WORK.

Development of a full range of protocols
Generally prototype protocols for transplant production for most crop groups are now available. However, further development work is still needed on allium and the range of minor horticulture crops that make up a significant part of horticultural production. Work should initially concentrate on investigating how transferable the protocols that have been developed are to other crops.

Establishment and performance trials.
There is little hard information available on the subsequent performance of these transplants once they have left the nursery. A small amount of work was undertaken in the previous transplant project but this work was far from conclusive. Many subsequent problems (ie blindness in calabrese) can be traced back to plant raising and there is a need to follow plants from a range of plant raising protocols through to harvest and grading to truly assess the transplant protocols.

Seed health and seed borne diseases.
At the dissemination meeting in October 2000 there was great concern about the effect of organic seed on plant raising. There is a fear that seed borne diseases and general seed health and vigour will have a detrimental effect on plant raising. There is a need to undertake work to investigate the level of disease in organic seed stocks, the vigour of such seeds and to look at seed treatments for the control of seed borne diseases.

Growing media and feeds
The media currently produced and tested within this project area Annex 2 products and therefore in themselves not organic. There is a need to investigate ways of producing organic media. There has recently been reported (McGrath (2001)) work using straw which is looking hopeful. Work on plant based feeds is less developed and there is a need for these to be developed.

Biocides/Pesticide regulation
The completed trials indicate that some of the active ingredients have useful efficacy against the tested diseases. However, they are not currently registered for use in the UK although they may be permitted for use under organic standards. Thus they are not available for use by organic producers in the UK. In view of the need for organic producers to have effective active ingredients that are acceptable under organic standards, further work is needed to enable approval under UK legislation. There are several barriers that must be overcome including the cost of registration; the commercial viability of the substances in use; the data package for efficacy, human toxicity and eco-toxicity. In other EU member states the legislative framework is different and many of these substances are permitted for use. This leads to competitive advantage to organic producers in other member states which must be addressed as a matter of priority. UKROFS should be encouraged to take an active role in this area, working with PSD and with the organic sector in the UK and EU to achieve equivalence.

OTHER ACTIONS.

Technology transfer was included within the project (see objective 4). Other issues that have been developed from the project have been the initiation of the production of organic standards for plant propagation and the use of information

from the project to address pesticide registration issues with PSD.

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Appendix 1: Methods of assessment.

Lettuce

Colour: Only a visual comparison was made.

Pest and Disease Assessment: Each tray was assessed for any signs of pest and disease attack on the overall tray, Score was given in terms of % infestation.

Weed Assessment: If any weeds were present their frequency in each tray was recorded.

Height: A random 10 plants from the centre of each tray were measured. Height was measured from the top of the compost to the tip of the longest leaf.

Growth Stage: A random 10 plants from the centre of each tray were pulled out of the trays and their leaves counted using the following key:-

Index For analysis	Index For recording	Description
1	$2^{3'}$	2 leaves and the 3rd visible but not yet developed into a leaf, (only a bud)
2	2^{3}	2 leaves and the 3rd developed but not yet fully opened, (still cupped)
3	3	3 leaves
4	$3^{4'}$	3 leaves and the 4th visible but not yet developed into a leaf, (only a bud)
5	3^{4}	3 leaves and the 4th developed but not yet fully opened, (still cupped)
6	4	4 leaves
7	$4^{5'}$	4 leaves and the 5th visible but not yet developed into a leaf, (only a bud)
8	4^{5}	4 leaves and the 5th developed but not yet fully opened, (still cupped)
9	5	5 leaves
10	$5^{6'}$	5 leaves and the 6th visible but not yet developed into a leaf, (only a bud)
11	5^{6}	5 leaves and the 6th developed but not yet fully opened, (still cupped)
12	6	6 leaves

Rooting Index: The same 10 plants were assessed using a scale of 1-5, where 1 = worst and 5 = best.

Mildew: The same 10 plants were assessed using a scale of percentage leaf area infected.

Uniformity: Uniformity of each tray was assessed on a scale of 1 (poor) - 9 (very uniform).

Fresh and Dry Weight: In addition to the 10 plants used for other assessments, another 10 plants were pulled out from the centre of each tray. Every cell in a given square was used regardless of the size of the plant, providing a plant was present. The plants were cut off at the top of the compost and weighed before and after drying.

Cabbage/cauliflower/calabrese

Colour Index: RHS colour cards were used to determine the green colour variations between treatments. The score was done on an overall tray appearance. An accurate assessment proved difficult as the RHS cards did not contain any of the green-purple colours typical for the leaves of cabbage transplants suffering from nitrogen deficiency. When ignoring the hints of purple coloration, it was possible to match the green shades with the aid of RHS cards. Often the true colour was made up of a combination of RHS colours. In order to account for the various shades of purple, a colour index of 1 to 7 was given using the following key:

Index	Description
1	Very purple
2	Clearly purple
2.5	Leaves are very purple at the bottom of the leaves and beginning to get quite purple at the front. 30-40% of the leaves appear purple on an overall basis.
3	Leaves are purple at the bottom of the leaves. Only starting to get a hint of redness at the

Index	Description
	top. Approximately 20% of the leaves are purple. Darker green (grey green) than the controls.
3.5	As above (3) but only about 5% of the leaves are purple at the top.
4	Purple at the bottom of some of the leaves, but not at the top. Darker green (grey green) than the controls.
4.5	Some purple (5%) but otherwise the same as below (5).
5	Hardly any purple; only a hint at the bottom of the leaves on some of the plants. The tray as a whole does not appear purple at all. The green colour of the leaves is a bit more yellow than the grey-green shade of 3 and 4.
6	A darker green than any of the above colours. Not as grey-green as 3 and 4 and not as yellow green as 5. Some leaves are purple at the bottom; less than 5%.
7	Dark green without any purple. Less grey-green than 3 and 4.

Rooting Index: A random 10 plants/tray were assessed using a scale of 1-5, where 1 = worst and 5 = best.

Mildew (calabrese): The same 10 plants were assessed using a scale of percentage leaf area infected.

Pest and Disease Assessment (cabbage and cauliflower): Each tray was assessed for any signs of pest and disease attack on the overall tray, Score was given in terms of % infestation.

Weed Assessment: If any weeds were present their frequency in each tray was recorded.

Height: A random 10 plants from the centre of each tray were measured. Height was measured from the top of the compost to the tip of the longest leaf.

Growth Stage: A random 10 plants from the centre of each tray were pulled out of the trays and their leaves counted using the following key:

Index For analysis	Index For recording	Description
1	$2^{'}$	2 leaves and the 3rd visible but not yet developed into a leaf, (only a bud)
2	2^{3}	2 leaves and the 3rd developed but not yet fully opened, (still cupped)
3	3	3 leaves
4	$3^{'}$	3 leaves and the 4th visible but not yet developed into a leaf, (only a bud)
5	3^{4}	3 leaves and the 4th developed but not yet fully opened, (still cupped)
6	4	4 leaves
7	$4^{'}$	4 leaves and the 5th visible but not yet developed into a leaf, (only a bud)
8	4^{5}	4 leaves and the 5th developed but not yet fully opened, (still cupped)
9	5	5 leaves
10	$5^{'}$	5 leaves and the 6th visible but not yet developed into a leaf, (only a bud)
11	5^{6}	5 leaves and the 6th developed but not yet fully opened, (still cupped)
12	6	6 leaves
13	$6^{'}$	6 leaves and the 7th visible but not yet developed into a leaf, (only a bud)

Length of Petiole of the Second True Leaf: The petiole of the second true leaf of 10 plants per tray was measured. The second leaf was used as this was generally the largest leaf on 5-6 weeks old cabbage transplants. This measurement was used as it could provide a good indication of the 'legginess' of the plant.

Fresh and Dry Weight: In addition to the 10 plants used for other assessments, another 40 plants (10 for the sequential harvest trails) were pulled out from the centre of each tray. Every cell in a given square was used regardless of the size of the plant, providing a plant was present. The plants were cut off at the top of the compost and weighed before and after drying.

Rigidity: A random of 10 plants/tray were assessed using a scale of 1-5. The plant should be held half way along the stem and held horizontally. 1 = root ball bends to vertical and 5 = root ball remains horizontal.

Brittleness: A random of 10 plants/tray were assessed using a scale of 1-5, were 1 = very brittle and 5 = supple. The plant should be held by root ball and the stem bent half way along the stem.

Twisting: A random 10 plants/tray were assessed using a scale of 1-5, were 1 = very twisted and 5 = straight.

Uniformity: Each tray was assessed on an overall appearance of uniformity. A scale of 1-5 was used, with 5 representing the most uniform a tray could be.

Leeks

Colour Index: R.H.S cards were used to determine the colour variations between treatments. The colour was scored on an overall tray appearance. An exact colour match was not possible and for most of the treatments several cards were recorded as the real colour of the plants was made up of a combination of card colours.
A second colour key was used to account for the degree of yellowing of the transplants. The key ranged between 1 and 9 where:

Index	Description
1	More yellow than green
2	The second leaf completely to half way yellow. The overall tray appearance is very yellow, approx. 40%
3	The second leaf anything between completely yellow to only yellow at the tip. The overall tray appearance is about 30% yellow
4	The second leaf is half way yellow or yellow at the tip. The overall yellow appearance of the tray is about 25%.
5	The overall yellow appearance of the tray is about 20%
6	The tip of half the second leaf is yellow. The overall tray appearance is about 15% yellowing.
7	The odd tip of the second leaf is yellow. The overall tray appearance is about 10% yellowing.
8	The odd tip of the second leaf is yellow. The overall tray appearance is about 5% yellowing.
9	No yellowing

Pest and Disease Assessment: Each tray was assessed for any signs of pest and disease attack on the overall tray. Score was given in terms of percentage of infestation.

Weed Assessment: If any weeds were present, the species and frequency in each tray was recorded.

Height: A random of 10 plants were taken from each treatment and the length of each recorded. They were measured from the upper edge of the plug to tip of the longest leaf.

Growth Stage: The growth stage of the same 10 plants used for height assessment were scored according to the following key:

Index For analysis	Index For recording	Description
1	1	One leaf fully open (not counting the first not folded leaf)
2	$1^{2'}$	One leaf fully open and the second leaf tip (up to 2 cm long) emerging
3	1^{2}	One leaf fully open and the second leaf longer than 2 cm but not yet open
4	2	Two leaves fully open
5	$2^{3'}$	Two leaves fully open and the third leaf tip (up to 2 cm long) emerging
6	2^{3}	Two leaves fully open and the third leaf longer than 2 cm but not yet open
7	3	Three leaves fully open
8	$3^{4'}$	Three leaves fully open and the fourth leaf tip (up to 2 cm long) emerging

Index For analysis	Index For recording	Description
9	3^4	Three leaves fully open and the fourth leaf longer than 2 cm but not yet open
10	4	etc.

Root Index: The same 10 plants were assessed using a scale of 1-5, where 1 = worst and 5 = best.

Fresh and Dry Weight: In addition to the 10 plants used for height and growth stage assessments, the remaining 38 taken from the trial were used for weight assessments. Every cell in a given square was used regardless of the size of the plant, providing a plant was present. The roots were cut off and the 48 plants were weighed before and after drying.

Appendix 2: Details of feeds used in cabbage experiments.

Feeds and Method of Application

Conventional Nutrient Feed: A stock solution was made of 90g/l potassium nitrate and 20g/l ammonium nitrate. The stock solution was diluted 1:200 to provide a nitrogen concentration of 100:200 mg/kg N:K2O. 0.5l of the suspension was watered on 3 times a week from just after the first true leaf emerged (23 Mar 98) until harvest (21 Apr 98).

Nu-Gro - liquid blood and bone: Nu-Gro is distributed by R & D Formulations (Park Farm, Kettlethorpe, Lincoln LN1 2LD). This product is manufactured in New Zealand. It contains blood and bone meal as well as natural growth promotants (gibberellic acid and Triacontanol). According to the manufacturers, the nitrogen content is 8%; P2O5 is 7.8% and K2O is 7.2%. With a measured density of 1.2 g/ml this gives an N concentration of 96 mg/ml. Previous trials had not used Nu-Gro on cabbage transplants so a feeding regime was chosen that would supply a total amount of nitrogen which had produced beneficial results using dried blood. Trial 2.4 (b) had supplied 2124mg N during the growing period. 11 ml of Nu-Gro was watered on in 0.5l of water twice during the growing period to supply 2112 mg N. The first feed was carried out just after the first true leaf emerged (23 Mar 98) and again 7 days later.

Fish emulsion: Chase Fish Emulsion, distributed by Chase Organics (Coomelands House, Addlestone, Surrey KT15 1HY), was used. Manufacturer's analysis shows the nitrogen content to be 5%, P205 1% and K20 1%. With a measured density of 1.01 g/ml this gives an N concentration of 45.45 mg/ml. A level of 15ml of fish emulsion was chosen on the basis of conclusions drawn from a previous trial with brassicas [2]. It was watered on in 0.5l of water twice during the growing period to supply 1363.5mg N. The first feed was carried out just after the first true leaf emerged (23 Mar 98) and again 7 days later.

Please press enter