



Improving knowledge of pest and weed control in organic crop production in Wales

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A report prepared for Organic Centre Wales on 3 organic grower pest and weed control workshops organised by ADAS Wales

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1. EXECUTIVE SUMMARY

- 1.1 ADAS Pwllpeiran were commissioned by the Farming Connect Organic Development Centre to compile information on pest and weed control and to hold workshops that will be valuable for the development of organic horticulture in Wales.
- 1.2 The project started on 1st October 2002, and three Welsh Organic Grower Workshops were held in 2002 / 2003 at Aberystwyth, Northop and Llanarthne.
- 1.3 The first workshop was held at the Llanbadarn Campus at University of Wales, Aberystwyth with a farm visit to Blaencamel, Cilcennin. There were fifteen delegates including growers, Farming Connect facilitators and researchers.
- 1.4 The second workshop was held at the Welsh College of Horticulture, Northop, Mold, 22 January, 2003. There were seven delegates including growers, consultants, 1 Farming Connect Facilitator and 2 students.
- 1.5 The third workshop was held at the National Botanic Garden of Wales, Llanarthne, Carmarthen. There were 28 delegates, 25 growers and three researchers / consultants.
- 1.6 Technical information has been prepared on 'Pest and Disease Control in Horticultural Crops' and 'Weed Control in Horticultural Crops' for organic growers. The format for publication will be decided by Organic Centre Wales.
- 1.7 The workshops identified 9 areas for action: composting, management of specific pests and diseases, making information on mechanical weed control more available, developing top and soft fruit growing, promoting health benefits of organic food, promoting marketing, support for horticultural businesses, monitoring effects of climate change, collection of information on the performance of organic seed varieties, the need for high quality alternatives to peat based growing media, and a greater focus on non-food crops.
- 1.8 Priorities and action points have been developed for each of these areas and it is proposed that these should be incorporated into a draft Action Plan for Organic Horticulture in Wales.

2. INTRODUCTION

- 2.1 ADAS Pwllpeiran were commissioned by the Farming Connect Organic Development Centre to compile information on pest and weed control that will be valuable for the development of organic horticulture in Wales. The project aim was to bring together growers, advisors and researchers in a series of workshops to share information relating to organic crop production. Through group discussion, the workshops aimed to identify the main technical problems and current knowledge of control methods. Following the workshop a review was undertaken to collate technical information, and to identify areas where further investigation is a priority.
- 2.2 The project started on 1st October 2002, and three Welsh Organic Grower Workshops were held in 2002 / 2003 at Aberystwyth, Northop and Llanarthne.

3. REPORT OF THE WORKSHOPS

- 3.1 **Workshop I - Aberystwyth and Blaencamel, 16th December 2002.** This was the first of three workshops aiming to bring together growers, advisors and researchers to share information on organic crop production, and discuss future directions for research and development. It was held at the Lanbadarn Campus at University of Wales, Aberystwyth with a farm visit to Blaencamel, Cilcennin. There were fifteen delegates including growers, Farming Connect facilitators and researchers.
- 3.2 The first presentation was a review of the current situation for organic horticulture in Wales by David Frost (ADAS Pwllpeiran). This presentation covered the work of the Welsh Agri-Food Partnership's Organic Strategy Group, Horticulture Strategy Group and the Organic Horticulture Sub –Group; the role of Organic Centre Wales and the Farming Connect Organic Development Centre horticulture projects; and a brief introduction to Defra funded horticulture projects. (for details of this presentation, see Appendix 1)
- 3.3 The second presentation was an outline by Roger Hitchings (Elm Farm Research Centre) of the Defra funded project on weed management currently being carried out by the Initiative on Organic Research (IOR) with the collaboration of HDRA, Elm Farm Research Centre, Horticulture Research International (HRI), ADAS and Rulivsys.
- 3.4 The group then went to Blaencamel, an organic horticulture unit, established in 1974, near Aberaeron, managed by Anne Evans. Here, the focus was on a Controlled Microbial Composting (CMC) system that Anne and foreman Gareth Webster operate on farm. By strictly controlling the composting process, CMC systems encourage the rapid growth of aerobic bacteria and fungi to keep support efficient cycling of carbon, nitrogen and other nutrients. It also supports large populations of disease suppressing microorganisms.
- 3.5 Anne Evans led a discussion on CMC composting, the technicalities of producing the compost and its dual role in providing nutrients and suppressing diseases. The production of compost teas was also covered. These are produced by pumping water through a core of CMC compost. The beneficial bacteria in the compost multiply in the

solution, amplifying the nutritional and disease suppressant qualities of the compost. The tea can be used in various ways, including a foliar spray, or as a soil drench in the field. At Blaencamel it is mainly used to improve the biological activity of commercial propagation compost.

3.6 In the afternoon session there was a workshop discussion on pest and disease management and the future direction of research and development for organic horticulture.

3.7 Priorities identified at the first workshop:

- **Composting**

Producing compost to meet specific nutrient requirements

Developing a database of sources of local waste for composting

Developing microbial analysis facilities for CMC and compost tea producers

- **Management of specific pests and diseases**

Biological approaches to management of mildews

Slug management

Production of factsheets on vertebrate pest management

Research into health benefits of organic food over conventional

- **Marketing**

Promotion of fruit & vegetable consumption as a health issue

Value added processing (Salad packs, soups etc.)

Public procurement

- **Support for horticultural businesses**

Development of a labour database (working closely with machinery rings)

Benchmarking for horticultural producers

Making certification costs more affordable to smaller growers

- **Monitoring effects of climate change on plant growth patterns and pest and disease populations.**

- **Ongoing projects to collect information on the performance of varieties available in organic seed**

- **High quality alternatives to peat based growing media**

- **More focus on non-food crops**

3.8 **Workshop II - Welsh College of Horticulture, Northop, Mold, 22 January, 2003.**

At the 2nd workshop there were seven delegates including growers, consultants, 1 Farming Connect Facilitator and 2 students. Following the format established in the first workshop, David Frost of ADAS Wales outlined current developments in horticulture in Wales and Roger Hitchings of OAS presented the latest report on the Initiative on Organic Research's Organic Weed Management project.

3.9 The workshop participants had the opportunity to discuss plans for development of the organic unit at the Welsh College of Horticulture with Leigh Morris, Head of Horticulture and Paul Robertshaw, Project Officer. At this point the 10 ha unit was at an advanced

planning stage, but no crops had yet been established. The aims of the unit were outlined as a demonstration unit for commercial organic growing, showing principles of rotation design and providing a site for variety trials etc.

3.10 The issue of composting was also discussed following a presentation on Controlled Microbial Composting by Anne Evans, and an outline of the wood chip livestock bedding and composting trials at ADAS Pwllpeiran by David Frost. (For details of these presentations, see Appendix 2)

3.11 Tony Little from OCW presented the workshop with results from the survey into growers' experience using organic seed varieties. This is a pressing topic in view of the requirement for growers to use only organic seed, which is due to come fully into force in 2004.

3.12 Priorities identified at the second workshop were:

- **Composting** – *development of composting systems for horticulture and use of regional waste collection and development of controlled composting sites.*
- **Seed varieties** – *need for more trials to establish the most valuable varieties to grown in organic systems, that are available as organically produced and that have appropriate qualities to cope with pest and weed challenge.*

3.13 **Workshop III - National Botanic Garden of Wales, Llanarthne, Carmarthen.**

There were 28 delegates at the third workshop, 25 growers and three researchers / consultants. The morning session started with David Frost's review of the current situation for organic horticulture in Wales and an outline by Roger Hitchings of the Defra funded project on weed management. This led immediately to a preliminary discussion of the need for more information on technical subjects such as weed control, and the particular needs of smaller growers.

3.14 David Frost gave a presentation on *Controlled Microbial Composting for organic vegetable growing* on behalf of Anne Evans who could not be at the workshop.

3.15 Tony Little from OCW brought the workshop up to date with the survey into growers' experience using organic seed varieties and gave an introduction to the organic seeds websites. The morning session closed with a discussion on priorities for organic growers.

3.16 The afternoon session comprised a visit to *Organics to Go* where Roger Hallam described the operation of the box scheme and the origins and development of his vegetable growing enterprise. The operation has been going for four years and boxes are delivered to London as well as in south and west Wales. Roger then took the group on a tour of the *Organics to Go* packhouse, the polytunnels and, briefly the vegetable fields. The lively discussion concluded with Roger appealing for more growers to produce vegetables in Wales to be marketed through *Organics to Go*.

3.18 The priorities identified in the third Grower Workshop were:

- ***On-farm weed control workshop to demonstrate machinery and equipment***
- ***More information for organic growers from R&D projects (better TT & KT)***
- ***Organic growing etc should have a higher profile at shows (including Pembrokeshire Show)***
- ***Study tours, e.g. to Vale of Evesham and abroad***
- ***More information needed on organic top and soft fruit growing relevant to Wales, especially disease control and suitable varieties***
- ***Farm walks for growers***
- ***Database of local organic growers***

4. PREPARATION OF FACTSHEETS / TECHNICAL INFORMATION BULLETINS

4.1 As part of this project, technical information on '*Pest and Disease Control in Horticultural Crops*' and '*Weed Control in Horticultural Crops*' has been collated which will be used in the preparation of technical publications for organic growers. The format for these publications is to be decided by Organic Centre Wales.

5. SUMMARY AND CONCLUSIONS

- 5.1 The workshops were attended by 50 delegates, including growers, researchers, advisors and Farming Connect Facilitators.
- 5.2 It was felt valuable that Farming Connect Facilitators joined these workshops as growers (both organic and conventional) frequently express the view that Farming Connect is directed heavily towards agriculture with little resources devoted to horticulture.
- 5.3 It was particularly noticeable at the third workshop at Middleton, National Botanic Garden of Wales in Pembrokeshire that a significant proportion of delegates were new entrants to organic horticulture. Despite the large number of events organised by Organic Centre Wales, HDRA and Soil Association Producer Services; and the availability of OCIS and Farming Connect Technical Consultancy, many growers felt the need for more information and practical advice on technical issues such as weed, pest and disease control.
- 5.4 Many small-scale growers felt that there is a particular need for many of the advances in mechanical weed control and Controlled Microbial Composting to be developed at scale suitable for the smaller grower.
- 5.5 The workshops provided an opportunity for an exchange of information between growers, researchers and advisors. They also identified areas for priority action.

6. RECOMMENDATIONS

6.1 The workshops identified a number of areas for development. These have been summarised into the following table along with relevant action points:

DEVELOPMENT AREA	PRIORITIES	ACTION POINTS
<i>Information and practical advice on technical issues such as weed, pest and disease control</i>	<ol style="list-style-type: none"> 1. Dissemination of R & D findings 2. Dissemination of sources of information 3. Examples of best practice 	<p><i>Production of technical information bulletins especially aimed at growers in Wales</i></p> <p><i>Programme of events for growers in Wales</i></p>
<i>Composting</i>	<ol style="list-style-type: none"> 4. Producing compost to meet specific nutrient requirements 5. Developing a database of sources of local waste for composting 6. Developing microbial analysis facilities for CMC and compost tea producers 	<p><i>These priorities have been collated into a proposal put to the OCW Management Group for support as a Phase II Farming Connect project</i></p>

<p>Management of specific pests and diseases</p>	<ol style="list-style-type: none"> 1. Biological approaches to management of mildews 2. Slug management 3. Production of factsheets on vertebrate pest management 	<p><i>Collection and assessment of technical information needed for preparation of publications as part of OCW programme</i></p>
<p>Make information on advances in mechanical weed control more available</p>	<ol style="list-style-type: none"> 1. On-farm weed control workshop to demonstrate machinery and equipment 2. More information for organic growers from R&D projects (better TT & KT) 3. Study tours, e.g. to Vale of Evesham and abroad 4. More information needed on organic top and soft fruit growing relevant to Wales, especially disease control and suitable varieties 5. Farm walks for growers 	<p><i>These priorities to be incorporated into the remit of the horticulture component of the Alternative Land Use Development Centre, and to be developed in collaboration with OCW, and the Horticulture and Organic Strategy Groups.</i></p>
<p>Develop top and soft fruit growing in Wales</p>	<ol style="list-style-type: none"> 1. More information needed on organic top and soft fruit growing relevant to Wales, especially disease control and suitable varieties 	<p><i>Technical publications as above, Development Centre work as above</i></p>
<p>Promote health benefits of organic food</p>	<ol style="list-style-type: none"> 1. Organic horticulture should have a higher profile at shows in Wales (eg Pembrokeshire Show) 	<p><i>Addressed under the second phase OCW remit, and to be carried forward by the proposed Interreg project on Public Procurement and Public Information</i></p>
<p>Marketing</p>	<ol style="list-style-type: none"> 1. Promotion of fruit & vegetable consumption as a health issue 2. Value added processing (Salad packs, soups etc.) 3. Public procurement 	<p><i>Addressed under the second phase OCW remit, and to be carried forward by the proposed Interreg project on Public Procurement and Public Information</i></p>

Support for Horticultural businesses	<ol style="list-style-type: none"> 1. Development of a labour database (working closely with machinery rings) 2. Benchmarking for horticultural producers 3. Making certification costs more affordable to smaller growers 4. Produce a database of local organic growers 	<i>Development Centre activities, as above. certification issues to be addressed through Organic Horticulture Sub-Group with recommendations to National Assembly Database to be derived from OCIS database and workshop lists. Data Protection Act issues to be investigated.</i>
Monitoring effects of climate change on plant growth patterns and pest and disease populations		<i>Proposal to be put forward through the Horticulture Strategy Group's Research Task and Finish Group</i>
Ongoing projects to collect information on the performance of varieties available in organic seed		<i>Proposal from WCOH put to the OCW Management Group for support as a Phase II Farming Connect project</i>
Develop high quality alternatives to peat based growing media		<i>Proposal to be put forward through the Horticulture Strategy Group's Research Task and Finish Group</i>
More focus on non-food crops		<i>This will be addressed by incorporation of organic horticulture into the remit of the Alternative Land Use Development Centre, and to be developed in collaboration with OCW, and the Horticulture and Organic Strategy Groups.</i>

6.2 The prime recommendation arising from the workshops is that the priorities identified should be translated into action as detailed in the table. It is also suggested that the points in the table could form the basis for a draft Action Plan for organic horticulture in Wales. This draft would be presented to Organic Centre Wales and the Organic Strategy Group as part of the preparation of the Action Plan II for Organic Agriculture in Wales.

Appendix 1

WELSH ORGANIC GROWERS' WORKSHOP -WHAT'S HAPPENING IN WALES

David Frost, ADAS Wales

WALES AGRI-FOOD PARTNERSHIP

- Organic Strategy Group
- Organic Horticulture Sub Group
- Horticulture Strategy Group

WELSH HORTICULTURE STRATEGY – GOALS

1. Develop a long-term vision for a sustainable Horticultural Sector in Wales
2. Improve the technical, business and management performance of the sector
3. Evaluate existing and develop new marketing initiatives for the horticultural sector in Wales
4. Integrate the support infrastructure to the horticultural sector in Wales
5. Evaluate the education and training needs of the horticultural sector

ORGANIC CENTRE WALES - Partners

ADAS

IGER

Institute of Rural Studies (Lead Body)

Organic Advisory Service – EFRC

Soil Association

FARMING CONNECT ORGANIC DEVELOPMENT CENTRE - HORTICULTURE PROJECTS:

- Organic seeds survey
- Grower Workshops
- Horticultural Discussions Groups
- Technical Training days

DEFRA FUNDED PROJECTS

- The initiative on organic research and the organic weed management project
- Economics study - profitability of organic vegetable production

Appendix 2 – COMPOSTING PRESENTATIONS

CONTROLLED MICROBIAL COMPOSTING

Anne Evans

BENEFITS OF CMC

- improved soil friability & crumb structure
- reduced erosion, nutrient leaching, compaction
- improved C, N & nutrient cycling
- increased beneficial soil bacteria & fungi
- reduced soil pathogens & infections
- healthier crops with greater resistance to pests and diseases

WINDROW COMPOSTING at BLAENCAMEL, CEREDIGION

COMPOSTING MATERIALS

6 x 50m windrows made up in horizontal layers with:
1/3 FYM
1/3 brown material (woodchip / spoiled hay etc)
1/3 green material (vegetable waste / weeding / cut grass-clover
small portion loam or clay

ESSENTIAL EQUIPMENT

compost turner
tractor with creep gear
crop covers
monitoring equipment
starter mix

COMPOST TURNER

windrows, mixes and aerates the pile
operates like an Archimedes screw
promotes biological activity

COVERS

Top Tex
geotextile fabric
gas permeable
repel water
cost £200 sheet
cheaper than erecting a building
applied using fleece roller on the
compost turner

COMPOSTING PROCESS

windrows constructed
starter sprayed from tank on turner
rows covered with Top Tex
aerobic process starts
composting process monitored
piles turned at $>60\text{ C}$ or $> 16\% \text{ CO}_2$
each row turned 6 times
process takes 6 weeks (plus)

MONITORING EQUIPMENT

thermometer with lance
instrument for measuring and reading
 CO_2 levels

CMC IN PROTECTED CROPPING

- reduced inputs - compost only
- strong plant growth
- high yields
- weed control
- disease control

CMC – GRASSLAND

- reduced inputs
- improved grass quality
- earlier silage cuts
- fertility building in cropping rotation

CMC - FIELD CROPS

- reduced inputs
- improved soil quality / soil organic matter
- improved yields
- improved quality

COMPOST TEAS

microbrewer makes a tea multiplying organisms from the original compost used as a drench on transplants to protect against infection (eg *rhizoctonia*, mildew in lettuce) and on crops as foliar spray
soil drench - promising method of controlling fungal diseases but more work needed

USE OF WOODCHIP FOR LIVESTOCK BEDDING AND COMPOSTING

David Frost

WOODCHIP DEMONSTRATIONS AT ADAS PWLLPEIRAN

- Cattle experiment
- Sheep experiment
- Assessments
- Technology Transfer

CATTLE EXPERIMENT

Three treatments:

1. Straw (control treatment)
2. Hardwood chips
3. Softwood chips

Cattle fed ad lib silage

SHEEP EXPERIMENT

Three treatments:

1. Straw (control treatment)
2. Hardwood chips
3. Softwood chips

Sheep fed ad lib silage

COMPOSTING

At the end of the housing period pens mucked out into covered stores.
Manure piles composted according to ADAS protocols

ASSESSMENTS

Assessments – 1

Animal:

Performance (weight gain/loss)
Health (lameness, respiratory problems)
Cleanliness of animals
Feed intake

Assessments – 2

Bedding materials:

How much
How often
Cost
Labour requirement

Assessments – 3

Compost:

Leachate loss
Temperature
End product quality

Appendix 3 –A REVIEW OF PEST AND WEED CONTROL IN ORGANIC CROP PRODUCTION

Pest Control in Horticultural Crops

Pest and disease management in organic production systems is based upon crop rotation, selection of appropriate crop species and cultivars and other cultural and husbandry practices which are regulated by organic standards, national certifying bodies and the EU. Biorational approaches are preferred and the use of active ingredients for pest and disease control is restricted to those situations where there are no alternative approaches (Price and Stopes, 1999).

In Wales, organic crop production faces a number of pest and disease problems inherent to a geographical area characterised by cool ambient temperatures, high rainfall, high humidity and low light levels. Many of the diseases identified in the Defra funded DOVE project (Gladders et al, 2002) are particularly prevalent in Welsh conditions, especially air borne fungal diseases. Crop attacks by molluscs are also particularly pernicious in wet humid conditions and can also be a problem in protected organic crop production. In some cases crops that are suitable for cultivation in Welsh conditions, e.g. root crops, may be attacked by particularly damaging pests such as carrot root fly. Without adequate control of these very specific pests their production under organic conditions is not commercially viable. In the case of other crops suitable for cultivation in Wales the range of potential pests is very wide, making an integrated pest control programme vital. Whereas carrots are vulnerable to 3 pests for example, the number for brassicae is around 50 (Collier, 1999). Some sectors of organic production face particular pest and disease control problems. These include top and soft fruit growers, where the permanent nature of the cropping systems means that crop rotation - standard organic practice to avoid P&D build-up in crops - cannot be implemented. On the other hand the protected cropping sector is able to use effective bio-crop protection methods and bio-control products are being developed for organic field crops.

The situation for organic growers in Wales is confusing since particular P&D control methods used in other European countries, such as herbal based preparations to control potato blight (Marilleau, 2001 reported by Sumption (pers.comm) are not on the UK approved list. According to a 1999 review, almost half of the pest control methods in the UK certification bodies' Recommended or Permitted lists were not approved for use in the UK by the Pesticide Safety Directorate (Labuschagne, 1999). This situation will be addressed by a proposed Welsh Assembly Government project.

The following section concentrates on pest control since diseases of organic vegetables are covered comprehensively by the Dove Report (Gladders et al, 2002). There is also a Pest and Diseases Email Group provided by HDRA. This is a forum for members to discuss issues concerning pests and diseases in organic systems. All opinions expressed are those of the individual participants, and do not represent the views of HDRA. Most of the references cited as personal communications in this review originate from this forum. To subscribe, e-mail a request to gdavies@hdra.org.uk.

Physical Barriers

Physical barriers such as woven fleeces and fine mesh are successfully used to protect some crops from pest attack. At HRI Stockbridge House three physical barriers were tested for pest control (Davies, 1999). The physical barriers tested were: non-woven horticultural fleece, fine mesh e.g. Gro-

net, and fine net - Environmesh (e.g. Agrilan). The benefits of these barriers were found to be control of aerial pests and enhanced yield and quality. The disadvantages associated with them were found to be cost, questionable environmental acceptability, unsuitability for some crops, and that they do not control soil borne pests. Trials were conducted on cauliflower, leek, Chinese cabbage, carrot, swede and lettuce. The conclusions from the Stockbridge trials were that physical barriers produced good results for cauliflower, carrot and swede; moderate results for Chinese cabbage and leeks; and poor results for lettuce.

Farmers in the Pas de Calais region of France using fleeces reported that they interfered with carrot growth and this resulted in lower yields. There were 4 trials over 2 years using trapping and timing fleece application. The conclusion was that fleece should be used against carrot fly but it needs to be applied early. Some level of damage was suffered even under fleece where the fleece had been put on too late and after the flies had started laying eggs (Legrand, 2001 reported by Sumption pers. comm.)

Table 1: Recommendations on the use of physical barriers

- | |
|---|
| <ul style="list-style-type: none">• Decide whether to cover from planting/sowing, or strategically based on pest forecasts.• Decide on single or multiple use• Deal with soil borne pests separately• Note disease risk with crops such as swedes and lettuce• Check crop suitability - avoid fleshy/leafy crops• Calculate cost implications of using physical barriers |
|---|

Source: based on Davies, 1999

Timing Pest Controls and Pest Forecasts

Pest attacks are seasonal and vary with geographical region. Attacks are referred to as generations. Understanding timing can assist pest control in a number of ways (Collier, 1999). Growers can avoid generation peaks, harvest before damage occurs, protect crops by excluding pests (e.g. with covers), kill pests (e.g. using BT for caterpillars, irrigation for cutworms), help plants to tolerate pest damage and use biological controls (e.g. nematodes, predator insect, fungi). Trials at HRI East Malling, part of an organic LINK project, have shown, for example, that rosy apple aphid can be more easily controlled in the autumn using organic insecticides like Savona. Spraying at this time of the year does not induce the leaf curling that happens in the spring which renders non-systemic sprays ineffective (Lovellidge, 2003).

Insect life cycles follow a seasonal pattern and, in general, insects develop more rapidly when it is warm. They usually develop and reproduce in the spring and summer, spending the winter in a state of dormancy. Studies have shown that the relationship between the rate of insect development and temperature is usually consistent within a species and that it can be described by a mathematical equation (Collier, 2003). This has led to the development of 'forecasts' of pest insect development. These computer programs use weather records to predict when pests are likely to colonise a crop or lay their eggs. Regional forecasts of the timing of activity of the cabbage root fly, carrot fly and pollen beetles have been available from HRI in recent years. They were sent to growers each week by post, fax or e-mail and there was a charge to cover the cost of the weather data (supplied by the Met Office) and forecast production. Plans have been announced to amalgamate HRI Wellesbourne within the University of Warwick. Staff hope that pest forecasting will continue (Collier, pers. comm.)

HRI Pest Forecasts include recommendations for particular crops and pest categories.

Box 1: Use of Pest Forecasts for brassica pests

Cabbage root fly

Timing of egg laying in the spring depends on latitude. Egg-laying lasts for about four weeks. Newly-transplanted crops are particularly at risk because the root system is too small to support both the plant and large numbers of cabbage root fly maggots. As the cabbage plants grow and the root system increases in size, the plants become more tolerant to infestation.

Cabbage root fly control Recommendations:

1. Crops transplanted during the risk period should be covered with fleece or fine mesh netting immediately after planting to ensure that cabbage root fly females are excluded from the crop. They can be uncovered once the risk of egg-laying has decreased.
2. Late planting in early June avoids egg-laying by the first generation. The second generation of cabbage root fly is likely to start laying eggs in late June-July (depending on weather conditions).
3. Some cabbage root flies emerge from the soil later in the year. These 'late-emerging' flies are genetically different from 'early-emerging flies'. Significant numbers occur in Devon, South Wales, south-west Lancashire and on Tyneside. In these areas it would be safer to keep crops covered until brassicas are well established.

Some growers use garlic treatments to control cabbage root fly.

Aphids

Research entomologists at Rothamsted produce forecasts of the timing of the spring migration by the peach-potato aphid and cabbage aphid into susceptible crops. These forecasts are based mainly on winter temperatures. Information on aphid activity is available from the Rothamsted Insect Survey, Go to <http://www.rothamsted.bbsrc.ac.uk/insect-survey/>.

Caterpillars

The diamond-back moth and small white butterfly are the most widespread caterpillar pests of brassicas in the UK. The silver Y moth is also common. The cabbage moth and garden pebble moth are localised pests. The large white butterfly occurs rarely in commercial brassica crops. The diamond-back moth is a migrant species (moths fly across the Channel from continental Europe) and the timing of immigration varies from year to year. Pheromone traps are the best way of indicating when the moths have arrived. The eggs are laid almost immediately and caterpillar development is rapid. It is important to monitor this pest regularly if *Bacillus thuringiensis* is used to control caterpillars. In past studies, most of the small white butterfly caterpillars found on plants were the progeny of either the second or third generations. The second generation starts usually in late July - early August.

Source: HRI Pest Forecasts, 2003.

Box 2: Use of Pest Forecasts for carrot pests

Carrot fly

Adult carrot flies emerge from the soil as it warms in spring, emergence starts earlier at warm sites in the south than at cold sites in the north. Once they have emerged, adult flies require a period to feed, mate and mature their eggs before egg-laying begins. In April, when it is cool, the period between egg-laying and emergence is likely to be 1-2 weeks, so that egg-laying is likely to start from early May onwards. Once started, egg-laying is likely to last for at least four weeks.

Strategy for reducing carrot fly damage

1. Partially-resistant carrot cultivars - Some carrot cultivars are partially resistant to carrot fly attack. At present, the most resistant cultivars suffer about half as much damage as susceptible ones.
2. Crop isolation - isolation of new crops from crops infested with carrot fly can reduce carrot fly numbers significantly. Recent DEFRA funded work at HRI showed that very few adult carrot flies reached plots of spring-sown carrots that were more than 1 km away from their overwintering/emergence site.
3. Crop covers - carrots should be covered as soon as possible to ensure that carrot fly adults are excluded from the crop. If seedlings are likely to emerge during the period of egg-laying, then the covers should be applied soon after sowing, before the carrots have emerged.
4. Sowing late - sow late to avoid carrot fly egg-laying. In a trial at Wellesbourne (Collier, 1999) carrot plots were sown at two-weekly intervals from mid-March until mid-June, and became infested by the local carrot fly population. Just before the start of the second fly generation, plots were covered with fine mesh netting and the emerging flies were captured on sticky traps placed inside the net cages. Relatively few flies emerged from plots that were sown after 50% of the eggs had been laid.

Source: HRI Pest Forecasts, 2003.

Box 3: Use of Pest Forecasts for lettuce pests

Lettuce crops may be infested by three species of foliage aphid (peach-potato aphid, currant-lettuce aphid, potato aphid) and by the lettuce root aphid. Timing of the migration by winged currant-lettuce aphids into new crops depends on spring temperatures. Lettuce root aphids usually migrate into lettuce crops during June.

Source: HRI Pest Forecasts, 2003.

Biological Controls

Using Natural Predators

An 'agro-ecosystem' is a growing environment with a balanced population of beneficial and pest insects (Skinner, 2003). In this agro-ecosystem there are three trophic levels. The first is the plant life, the second is the herbivores drawn to the first level by visual and chemical signals emitted by the plants, and the third level is the natural allies which predate on the herbivores and interact with the plants themselves. Using natural allies as a means of control can be lethal (where the allies kill the pests directly) or sub-lethal (where the allies affect the pests so that their reproduction is impaired). Encouraging certain perennials around a commercial crop helps to attract natural allies to a source of pollen and nectar as well as cover. The Soil Association has produced a chart showing five main vegetable pests along with their individual characteristics, life cycle details and natural predators (see Skinner, 2003). These pests and their predators are summarised in table 1

Table 2. Organic Pest Control - Main Vegetable Pests and their Natural Predators

Pests	Natural predators
Aphids	Parasitic wasp <i>Aphidius colemani</i> Gall midge-larva <i>Aphidoletes aphidimyza</i> Parasitic wasp <i>Aphidius ervi</i> Ladybird <i>Hippodamia convergens</i> Lacewing <i>Chrysoperia carnea</i>
Cabbage white and cabbage moth caterpillars	Parasitic wasp <i>Trichogramma brassicae</i> Bacterium <i>Bacillus thuringiensis</i> Predatory bug <i>Podisus maculiventris</i>
Leatherjacket	Ground beetles Rooks and starlings Nemasys H <i>Herterorhaditis megidis</i>
Thrips	Predatory mite <i>Amblyseius cucumeris</i> Predatory mite <i>Amblyseius degenerans</i> Predatory bug <i>Oris laevigatus</i> Predatory bug <i>Oris majusculus</i> Fungus <i>Verticillium lecanii</i>
Carrot root fly	Gall-midge larva <i>Feltiella acarisuga</i> Robber flies <i>Dioctria atricapilla</i> Hoverflies <i>Syrphidae</i>

Source: adapted from Soil Association panels presented in Skinner (2003)

Attracting Natural Predators

Floristically rich hedgerows provide habitats for natural crop pest predators such as anthrocorid a wide ranging predator which is found on many flowering plants. Other predators attracted by flowers like corn marigold, cornflower, corn camomile and phacelia include ladybird (both the beetle and larvae eat aphids) and lacewing (the larva of green lacewing feed on aphids). Beneficial parasitoid wasps are particularly attracted by umbelliferae such as hogweed. Some beneficial insects are effective over a 100-metre range. Windbreak trees are also valuable, especially Alder *spp.* Which attracts the black-kneed capsid. Where natural habitats are lacking, artificial shelters can be introduced e.g. corrugated cardboard in rolls hung in an upturned plastic bottle with bottom cut out, flower pots and boxes stuffed with straw for lacewings. Log or rock piles can provide over-wintering sites for many predators that will then be active in the field early in the season, helping to slow down, or prevent, the build up of pest populations in the crop.

At HRI East Malling, work was undertaken to encourage anthrocorid (Soloman, 1999). In the East Malling orchards the 'herbicide strip' was replaced with an undersowing of a flower mixture comprising corn marigold, cornflower and corn camomile. Phacelia (Bee's friend) was found to be less useful, though a total of 15 flowering plants attract anthrocorids. Anthrocorids were attracted to predate on pear sucker nymphs *Psyllid*. Pest populations were reduced by 50% in the trials. For field vegetables the flower mixture could be sown in the hedgerow, headlands or in strips across the field.

In 2000 and 2001 an inventory of aphids and predators were listed in organic apples, salads and cabbage crops in Nord Pas de Calais region of France. 640 samples of aphids and 755 samples of predators were made. Hoverflies represented 78% and 54% of samples collected in 2000 and 2001 respectively, ladybirds 19% and 37%. Green lacewings were less numerous (3% in 2000 and 9% in 2001). 11 hoverfly genera, 8 ladybird genera and 2 green lacewing genera were identified. For hoverflies, *Sphaerophoria* and *Episyrphus* were predominant, *Adalia* and *Coccinella* for ladybirds genus, and *Chrysoperla* for green lacewings. In salads and cabbages hoverflies were dominant and hoverflies were effective despite 10- 15% parasitism of the hoverfly larvae. In lettuces *Nasanovia* root aphid comprised 53% of aphids collected and for cabbages mealy aphids *Brevicoryne brassicae* were dominant 96% (Trouve, 2001 reported by Sumption, pers. comm). At the same time of the survey a list of conservation and enhancement methods was made. The leading role of vegetable diversity for attracting beneficial insects and the advantages of artificial shelters to protect over-wintering predators was emphasised. Flowering plants are very important and yellow and blue colours in particular.

Box 4: Plant species that attract predatory insects

Cruciferae: White campion (*Silene latifolia*)
Compositae: Sow thistles (*Sonchus spp.*), Scentless mayweed (*Matricaria inodora*),
Thistles (*Cirsium spp.*), Cornflower/Bachelor's Button (blue). (*Centaurea cyanus*),
Brassicaceae: Hedge Mustard (*Sisymbrium officinale*), Charlock (*Sinapis arvensis*), Gold-of-pleasure
(*Camelina sativa*)
Hydrophyllaceae: Phacelia (*Phacelia tanacetifolia*)
Umbelliferae Fool's parsley (*Aethusa cynapium*), Hemlock (*Conium spp.*), Coriander (*Coriandrum sativum*)
Polygonaceae Buckwheat (*Fagopyrum esculentum*)

Source: Trouve, 2001

Brassicaceae green manures can be used to reduce damage by pests to organic crops using trap crops such as tyfon (turnip x Chinese cabbage) as a trap for flea beetle *Phyllotreta spp* (Lees, 2001). Similarly, clovers can be grown amongst brassicaceae crops to deter pests (Wolfe, 2002). There is anecdotal evidence that pigeons prefer fresh clover to brassicas, and one grower designs his rotations to ensure that there is always some near to his brassicas to ensure they stay free from pigeon damage (Sumption, pers.comm)

Bio-control agents

There are a number of organic-permitted, commercially available bio-control products for use against aphids, caterpillars, whitefly, vine weevil, sciarid fly, and thrips. The main use of bio-controls is in greenhouses and polytunnels to protect crops against aphids and to protect brassicas in organic field crops. This is a developing area with bio-controls being developed for fruit, brassica and carrot pests (Koppert, 2000). Insecticidal soft soap can be used to control whitefly, mealy bug, scale insects, aphids, spider mite, thrips and leafhopper. It can be used on selected brassicas, ornamentals, cucumbers, peppers, fruit trees, lettuce and tomatoes. Products such as derris are restricted because of their wide-spectrum effect which is harmful to beneficial pest predators. Permission from the appropriate certifying body needs to be obtained before such products are used. Some 'biopesticides', such as preparations of a toxin from the soil bacterium *Bacillus thuringiensis*, or viruses that attack insects, can also be used.

Table 3 : Commercially available bio-control agents

Pest	Bio-control agents
Caterpillar	Parasitic wasp <i>Trichogramma brassicae</i> ; Bacterium <i>Bacillus thuringiensis</i> ; Predatory bug <i>Podisus maculiventris</i>
Spider mite	Predatory mite <i>Phytoseiulus persimilis</i> Predatory mite <i>Amblyseius californicus</i> Gall-midge (larva) <i>Feltiella acarisuga</i>
Thrips	Predatory mite <i>Amblyseius cucumeris</i> Predatory mite <i>Amblyseius degenerans</i> Predatory bug <i>Orius laevigatus</i> Predatory bug <i>Orius majusculus</i> Fungus <i>Verticillium lecanii</i>
Aphid	Parasitic wasp <i>Aphidius colemani</i> Gall-midge (larva) <i>Aphidoletes aphidimyza</i> Parasitic wasp <i>Aphidius ervi</i> Ladybird <i>Hippodamia convergens</i> Lacewing <i>Chrysoperla carnea</i>
Whitefly	Parasitic wasp <i>Encarsia formosa</i> Predatory bug <i>Macrolophus caliginous</i> Parasitic wasp <i>Eretmocerus eremicus</i> Fungus <i>Verticillium lecanii</i>
Leaf-miner	Parasitic wasp <i>Encarsia formosa</i> Parasitic wasp <i>Diglyphus isaea</i>
Sciarid fly	Predatory mite <i>Hypoaspis spp.</i> Nematode <i>Steinernema feltiae</i>
Mealybug	Parasitic wasp <i>Anagyrus pseudococci</i>

	Parasitic wasp <i>Leptomastix dactylopii</i> Predatory beetle <i>Cryptolaemus montrouzieri</i>
Vine weevil	Nematode <i>Heterorhabditis megidis</i>

Source: Koppert Biological Systems

Soil Borne Pests

Crop rotation is the key to the control of soil borne pests and is essential to control potato cyst nematode, white rot on alliums and club root in brassicas. Selection of varieties bred for resistance is also important. Diseases such as *Alternaria* in carrots can be seed borne (Gladders et al, 2002). Only healthy organically raised seedlings and transplants should be brought from propagating nurseries. The use of well prepared compost both in protected cropping systems and for outdoor crops can increase the number and diversity of beneficial soil micro-organisms that can help to suppress fungal diseases.

Wireworm

Wireworms are a soil inhabiting crop pest. Larvae attack many crops particularly potatoes and even low populations can cause an economic level of damage. In the UK, high wireworm populations are traditionally associated with long-term grass leys (Parker and Howard, 2001). In the case of organic production, potato crops frequently follow a long-term fertility building grass ley. Organically grown potatoes, where soil treatment with insecticides is prohibited, are therefore particularly vulnerable to wireworm damage.

Alternatives to pesticide control include cultural methods which discourage wireworm attack such as rotating a vulnerable crop with a resistant non-host crop. Mustard (*Brassica nigra* and *Sinapsis alba*) is claimed in the organic gardening literature as a soil conditioner that can control soil born pests in general and wireworms in particular. (Franck, 1983; Soper, 1996; de Bairacli Levy, 1966; Hills, 1971). This suggestion has not been scientifically tested (Parker, pers comm). It has also been suggested that mustard has a root exudate toxic to wireworms that controls the pest and it is known that glucosinolates contained in cruciferous plant tissues are hydrolysed to a variety of biologically active products that can control soil-borne pests (Parker and Howard, *ibid.*; Lichtenstein *et al.*, 1964). In 2001, ADAS undertook a field experiment at Pwllpeiran in mid Wales to test the hypothesis that wireworm damage to potato crops can be controlled by the use of brassicae green manures (Frost et al., 2001). The trial found a trend to lower levels of slug damage on the mustard treatments in comparison to the control and fodder rape treatment. This was also noted for wireworm damage but the results were not statistically significant.

Leatherjackets

Leatherjackets are the larvae of crane flies (*Tipula* spp). The grubs, up to 50mm long, can seriously damage horticultural crops such as lettuce by feeding on roots and stems below soil level. Adult crane flies emerge from the pupae stage in August and September. Females then lay eggs in the soil near plants. Eggs hatch in late summer and early autumn and the larvae feed during the autumn and the following spring but are less active during winter. High populations can develop after a prolonged warm and wet spell in summer/early autumn. Ground beetles predate on leatherjackets and these can be encourage by ground cover plants (Soil Association, quoted by Skinner, 2003). Birds, particularly rooks and starlings, also feed on leatherjackets and this method of control can be encouraged by undertaking numerous shallow cultivations to expose the pest to predators. Keeping grass tightly grazed in later summer can also help to prevent the adult crane flies laying eggs (Soil Association, quoted by Skinner, 2003).

Slugs

Surveys have shown that farmers and growers consider slugs to be the most serious single pest problem of arable and horticultural crops. An estimated £30m a year is spent in the UK to protect lettuce, Brussels sprouts, potatoes and winter wheat from slugs and snails (Krug, 2003). Controlling slugs in organic systems requires a combination of techniques and an integrated approach. The slug-parasitic nematode *Phasmarhadtis hermaphrodita* is available as an emergency measure (Symondson, 1999).

The main strategy in an integrated approach is to remove slug habitats. Slugs aggregate in areas of damp, poorly drained soil, in weed infested areas and in loose soils where they have access to subterranean parts of plants. Thorough cultivation destroys slugs and exposes eggs and juveniles to desiccation and predation. Using slug resistant cultivars (e.g. of potatoes) and providing trap plants to divert slugs away from crops are also useful strategies in an integrated approach.

Carabid beetles, *Pterostichus spp* are an important slug control agent; they preferentially feed on slugs and can suppress slug populations over a period of years. Carabid populations can be maximised by autumn cultivations, avoiding insecticides and encouraging alternative prey when slug densities are low (Symondson, 1999).

Barriers of sharp sand or proprietary products may protect plants from slugs (Caspell, 1999) and it has been suggested that clays like vermiculite, and perlite would work as slug repellents (Haward, pers. comm). If these work it would be in the way that the product SnailBan works (by absorbing moisture from the slug/snail) or by providing a prickly/rough barrier in the way that crushed eggshell, oyster shell, ashes, crushed gorse, etc., are supposed to work. Cat litter (Fuller's Earth - calcined montmorillonite) might be a better material (Hitchings, pers.comm)

Recent work has investigated the feeding deterrent effect of carvone on the slug *A. lusitanicus*. Carvone, a natural compound from caraway seeds, was incorporated into mulch to reduce its inherent volatility. In laboratory tests, carvone concentrations reduced slug feeding on lettuce in comparison with the untreated control. At the highest concentration of carvone (0.75 ml per l) 50% mortality was recorded over a period of 5 days, indicating a clear molluscicidal effect. Due to its volatility carvone did not decrease plant defoliation by the slug when applied directly onto lettuce. Subsequent field evaluation showed carvone mulch to reduce slug feeding damage partially, but not sufficiently to increase lettuce yield significantly (Frank et al, 2002, reported by Davies pers. comm). Garlic has also recently been claimed as a slug deterrent. Biologists from the University of Newcastle found that a barrier of garlic oil repelled slugs. An experiment with Ecoguard, refined garlic, effectively deterred slugs. It is suspected that the oil damages the slug's nervous system. (Krug, 2003).

Research at the Scottish Agricultural College has shown that crop variety is important in slug control and that the concentration of sugar in the seed and the speed at which it is released at germination are key factors in varietal differences to slug susceptibility (Allen-Stevens, 2002).

Resistant varieties

The selection of appropriate crop species and cultivars is an important strategy for organic growers, one that paradoxically will become more difficult to exploit fully as the range of varieties available to growers is restricted to those produced organically (Deane, pers comm). The National Institute of Agricultural Botany in conjunction with the Henry Doubleday Research Association has been trialing crop varieties suitable for organic growers (www.niab.com) and there is also current work undertaken on blight resistant varieties of potatoes (Shaw, 2001). Vegetable seed trials are in progress at the Welsh College of Horticulture's Organic Unit at Northop as part of the Farming Connect Organic Development Centre programme.

For potatoes, tuber blight resistance is most important for organic growers, foliage blight resistance is less important (Saunders, 1999). Potato blight, *Phytophthora infestans*, is a major limiting factor on organic potato production in Wales and the problems of controlling it are increasing year on year. The British Potato Council has launched a *Fight against Blight* initiative with a comprehensive leaflet covering methods of blight control available to organic growers (British Potato Council, 2003).

From NIAB trials in 1998/99 the following varieties were recommended for organic growers: Parti-coloured *Cara*, White skinned *Cosmos* and *Valor*, Salad variety *Jutlandia*. It was also noted that new varieties were being introduced from the former eastern bloc which had very good disease resistance. In trials *Sarpo Extra* had no blight all season. It had all round vigour but was late maturing (Saunders, 1999.)

The BPC are also supporting blight research including the trialing of Sarpo varieties from Hungary. The Sarvari family has been breeding potatoes for more than 50 years and they are producing new varieties with very high resistance to late blight and common virus diseases. The Sarvari Research Trust was set up in close association with Bangor University in 2002 to co-ordinate blight resistance research. 16 potato varieties are being evaluated for resistance to late-blight disease at the Henfaes Research Centre near Bangor. In 2003, *Remarka*, *Sante*, *Cosmos*, *Cara* and *Valor* were showing leaf and stem blight in September whereas *Stirling* and *Lady Balfour* were much less blighted. The Sarpo varieties were healthy and blight free. These findings were paralleled by ADAS trials in Ceredigion where a blight prone crop of *King Edward* first became infected in July. By mid August, over 80% were infected and by the second week of September blight infection was 100%. On the other hand, the three Sarpo varieties in the trial remained blight free throughout this entire period.

NIAB have identified varietal characteristics suitable for organic cultivation for a number of crops. For broccoli, the variation in soil fertility associated with organic growing means that plants mature over a longer period than when grown with artificial fertilisers and a wider range are required to provide a good cutting spread. Organic growers should look for vigorous and dark coloured varieties (Withers, 1999). Larger modules may suit organic growing. A larger transplant gives an earlier start and better weed competition. In NIAB trials, desirable characteristics for organic carrots were identified as vigour of emergence, speed of bulking, good top size and disease resistance (Day, 1999). For organic onion growers the main problem is weed control, multi-seeded blocks/modules and sets are therefore preferred to direct drilling. Sets give higher yields than blocks or modules but have more disease problems (Day, 1999). For organic parsnips early vigour is vital, as parsnip is not a good weed competitor. Hybrid varieties are therefore useful for organic growers. Canker and leaf blight are the main P&D problems (Day, 1999).

Use of UV covers for pest control in protected cropping

Trials of ultraviolet blocking greenhouse polythene covers for insect pest control are being undertaken at the Welsh College of Horticulture as part of the Farming Connect Organic Development Centre programme (Morris, Pers.comm.). Ultraviolet (UV) light absorbent polythene film will be used as a tunnel cover over organically grown vegetable crops and flying insect pest incidence, infestation and damage to the plants will be measured. 'Sterilite HDF' research film is one of the most commonly used UV-blocking films in the UK (McGrath, 2000, Shaddick, 2000; Sutton, 2000; HDC, 2001). Indications are that it is effective against insect pests in the UK (McGrath, 2000; HRI, 2001; Doukas, 2001; Morris, 2002). It removes all UV light between 380 and 360nm, the range most crucial to insect visual perception (Costa *et al.*, 2002).

UV blocking films have been shown significantly to reduce numbers of many insects. Antignus (2000) suggested that the lack of UV light in greenhouses interferes with insect flight orientation and therefore reduces the numbers entering, as well as limiting the activity and ability to disperse of those that do get in. It also affects landing behaviour due to the elimination of UV reflected from the foliage. An HRI trial with UV-blocking films over strawberries was inconclusive (HRI, 2001), as were pest counts made at the HDC nursery stock trials in Norfolk (Morris, 2002) and other HDC trials (HDC, 2001). Work at Reading (Doukas, 2001) indicated that such films could be useful in UK conditions and Morris (2002, 2003) showed a positive effect on spring and summer alatae of *Aphis fabae*.

Weed Control in Horticultural Crops

The failure to control weeds can lead to major yield losses in organic horticulture and an integrated weed control programme is very important for successful organic crop production. In such programmes rotation design plays a key role and weed susceptible crops are usually planned to follow weed-suppressing crops. Alternating between autumn and spring germinating crops and between annual and perennial crops (including grass) also helps to prevent any single weed species becoming dominant and impossible to manage. Under-sowing crops, green manures, and well-made compost are also important. Transplanting techniques are widely used because they avoid inaccurate plant spacing that comes from uneven germination and they allow the crop to become established ahead of the weeds.

A comprehensive survey of weed control in organic farming systems was provided by Leake (2000) who concluded that the most effective methods are those which avoid weeds germinating within the crop period. The Defra-funded Initiative on Organic Weed Management (project OF 0315) has also produced a working document on weed management (IOR, 2002). This is a compilation from published literature and gives a broad overview of organic weed management. A fuller cited scientific review will be compiled on particular theme areas of research interest: three themed focus groups have been established on Docks, Systems and Communication. The Soil Association stages annual producer events on mechanical weed control for organic agriculture which provides an opportunity for suppliers to demonstrate machinery and equipment and for researchers to communicate findings to growers.

Crop rotation

Crop rotation is the key feature of any organic cropping system and it provides the most effective indirect method of minimising weed problems (Jordan, 1992). Different crop sequences and crop growth habitats effect the development of various weed species (Leake, 2000).

Table 4: Elements of a crop rotation designed for weed control

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| <ul style="list-style-type: none">• Alternating between autumn and spring germinating crops• Alternating between annual and perennial crops (including grass)• Alternating between closed, dense crops which shade out weeds, and open crops such as onions which encourage weeds• A variety of cultivations and cutting or topping operations |
|---|

Source: Lampkin, 1990; IOR, 2002

Timing

Timing of weeding operations is crucial. One well-timed weeding is usually better than several operations at the wrong time. For many crops, the early stages of development (4- 6 weeks) are particularly important. If weeds are left uncontrolled for too long they may compete with the crop, but premature weeding before the main flush of weed germination requires repeat controls. Studies of weed germination led to the concept of a *weeding window* (Bond, 1999). In field vegetables a carefully timed short weed-free period (the critical period) or a single weeding may be all that is required to prevent crop yield loss (IOR, 2002). The first weeding operation of the year may be necessary across a whole field to provide a weed-free environment for planting or sowing, although subsequent operations can be confined to inter-row weeding, intra-row or patch weeding.

Cultural methods of weed control

Cultural methods include stale seedbeds, blind harrowing, manipulating sowing dates and crop densities, mulches and allelopathy. Seed rates tend to be higher in organic crops and high crop densities will help to suppress weeds in crops such as cabbages. Green manures such as grazing rye, vetch, phacelia, mustard, etc can also be grown between crops as an inter-row weed suppressant.

Stale seedbeds

A stale or false seedbed is prepared by cultivating the soil some four weeks before sowing crop seeds to stimulate a flush of weed seeds. These can be removed by cultivation or thermal weeding prior to drilling or planting the crop (IOR, 2002). This technique is especially effective where the previous crop is harvested before September (Leake, 2002).

Blind harrowing

Pre-emergence or blind harrowing can destroy weeds at the 'white-thread' or 'thread needle' stage of development when they are vulnerable to desiccation. Spring crops provide a better opportunity for this technique than autumn sown crops (Leake, 2000).

Photo control

Exposure to light is one stimuli to germination and some weed seeds require a flash of light to trigger germination. Replicated trials of soil cultivation in darkness in Germany indicated that the darker the conditions the less weeds germinated (Ascard, 1993). To be effective as a single means of control, reduction in weed germination would need to be over 85% (Leake, 2000). Variability in observed results may be due to weed species, location, soil conditions, method of cultivation and an interaction of these factors (IOR, 2002).

Manipulating sowing dates

Alternating between autumn and spring sowing can help organic farmers and growers prevent the build up of either autumn or spring weed germination. Delaying drilling in the autumn can also be effective in reducing weed pressure, particular in combination with the stale seedbed technique. CWS agriculture carried out a trial to compare the effect of crop sowing date and seed rate on weed suppression and found the technique to be effective in preserving yield (Leake, 2000).

Crop densities

In drilled and transplanted crops proximity determines the competitiveness of the plant stand as a whole. Seed rates tend to be higher for organic than conventional crops (IOR, 2002). Establishing and maintaining a competitive crop stand is the most effective way of limiting and reducing weed seed production. Crop competition is exerted by height, tillering ability, canopy density and earliness of canopy closure (Leake, 2000).

Mixed/inter-cropping and undersowing

The advantage of intercropping is the greater ground coverage by crops with less area for weed infestation. Leeks and celery when grown together increased weed suppression and reduced reproductive capacity of late emerging Groundsel, *Senecion vulgaris* (IOR, 2002). Undersowing reduces weed emergence by covering the ground quickly with a dense layer of vegetation. Undersowing cash crops with fertility building crops, as widely practised in cereal production, can reduce the need for fertility building periods in the rotation.

Mulches

Mulching prevents weeds from germinating and growing by excluding light from reaching the soil surface. They are widely used in horticulture and are particularly effective in perennial crops such as strawberries where they can be used to suppress weeds such as couch, *Elymus repens* (Leake, 2000). Crops can be sheeted with plastic, paper or woven fabric; mulched with a thick layer of compost, straw, wood chips, bark, spoiled hay etc.; or a low growing ground covering crop can be grown. Annual crops are planted through these mulches. Biodegradable materials such as cardboard, hay, leafmold and carpet have been trialed (Lennartsson, 1990). For permanent crops such as top and soft fruit, mulching can be combined with mowing.

Table 5. Main types of mulching for weed control

1. Sheeted	Layer of material such as plastic, woven paper fabric covers the soil surface
2. Particle	Layer of material such as compost, straw, bark, wood chip or shredded crop residues is spread over the soil
3. Living	A low growing ground covering crop is sown, e.g. clover

Source: IOR, 2002

Composting

Effective composting systems, such as controlled microbial composting where temperatures reach 60 degrees C, kill weed seeds and prevent weed seed dispersal (Baars date?, 2003). Good quality compost and can be used as an effective weed mulch especially in protected cropping (Evans, 2003). Research has also indicated that placing manures more accurately can benefit crops rather than weeds. In horticultural systems, if manure is placed 10 cm below the soil surface the deeper rooting or deeper sown crop seeds are encouraged to grow down into the nutrient rich layer in preference to the weeds (IOR, 2002).

Allelopathy

Allelopathy is the direct or indirect chemical effects of one plant on the germination, growth or development of neighbouring plants (IOR, 2002). It has been bred out of many commercially grown plant species, but it is a potential weed control system for organic growers which is being studied both in its own right and as part of an integrated weed control programme. Certain crops such as oats and mustard have been reported to suppress germination of surrounding weed seeds (Leake, 2000). It has been suggested that cruxifers chemically suppress other weed plants and researchers in Poland isolated root exudates from mustard which inhibited germination when applied to weed seeds (Ursell, 1995). At HRI Wellesbourne a crop of garden cress grown on an outside plot suppressed all competitive

weeds (Bond, 1999). Grazing rye, vetch, phacelia and mustard can be grown between crops as an inter-row weed suppressant. Rainwater shed by the Walnut tree is a traditional allelopath (Bond, 1999) and in New Zealand the natural herbicide Interceptor which has received organic certification, is based on an extract from pine needles (IOR, 2002).

Mechanical weed control methods

The main methods are thermal weeding (flame or infra-red), inter-row cultivations, hoeing and hand weeding. This is a developing area with a range of tractor mounted equipment available such as steerage hoes, brush weeders, comb harrows, finger weeders and flame weeders. Many growers find that a certain degree of hand weeding may be necessary in drilled field crops such as carrots and in greenhouse and polytunnel crops, though some advisors will suggest that if weeds have emerged weeding operations are already too late because the best time to kill weeds is at the white thread stage (IOR,2002).

Table 6: Main types of mechanical weed control

Machinery type	Examples
Broadspectrum	Chain or drag harrows, spring or flexi tines
Inter-row non-powered	Sweeps/shares/ducksfoot hoes/steerage hoes
Rotary cultivators – non powered	Cage or basket weeder, star hoe or rotary harrow, split hoe
Rotary cultivators –powered	Brush weeder
Intra-row	Finger weeder, torsion weeder
Precision guidance	Vision guided hoe
Manual	Tractor mounted flat-bed weeder
Thermal	Flame weeder, infra-red weeder

Source : IOR, 2002

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Further Information : Websites

Pest and weed Control

There is no website dedicated to the organic management of pests and diseases in the UK. However, there are a number web based resources for integrated pest management (IPM) and integrated crop management (ICM), that are relevant organic growers. Please note that some of the sites are USA focused, and may not be directly relevant to the UK, particularly in terms of the timings of pest management operations and key stages in insect life cycles.

Cyber-Help for Organic Farmers	http://www.certifiedorganic.bc.ca/rcbtoa/training/pestmanagement.htm
Database of IPM Resources	http://ippc.orst.edu/DIR/index.htm
Henry Doubleday Research Association	http://www.hdra.org
ICM Focus	http://www.icmfocus.com
IPM Net	http://www.ipmnet.org
National Institute for Agricultural Botany	http://www.niab.com/
Radcliffe's IPM World Textbook	http://ipmworld.umn.edu/textbook.htm
Virtual Centre for Integrated Pest Management	http://cipm.ncsu.edu/index.html

Weed Control

Cyber-Help for Organic Farmers	http://www.certifiedorganic.bc.ca/rcbtoa/training/pestmanagement.htm
Elm Farm Research Centre	http://www.efrc.com/research
Henry Doubleday Research Association	http://www.hdra.org
Organic Weed Management project	http://www.hdra.org.uk.research/forums/index.php
ICM Focus	http://www.icmfocus.com
Practical guide to organic weed control	http://www.merfield.com/research/organic-weed-management-a-practical-guide.pdf
National Institute for Agricultural Botany	http://www.niab.com/
The Organic Weed Management Website	http://www.css.cornell.edu/WeedEco/WeedDatabase/index2.htm