DEPARTMENT for ENVIRONMENT, FOOD and RURAL AFFAIRS

Research and Development

Final Project Report

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Project title	Development of disease control strategies for organically grown field vegetables (DOVE).
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Executive summary (maximum 2 sides A4)

This project aimed to improve understanding and awareness of diseases in organic field vegetables. There is an increasing demand for organic produce from consumers but over 70% of produce is imported. Expansion of production through large growers is almost certainly required to provide the volume and continuity of supplies demanded by major retailers. Diseases pose a threat to both quality and yield and both must be managed if organic production is to expand and remain sustainable.

To satisfy these requirements, the project addressed four main objectives:

Objective 1.
To review the significance of diseases in organically grown field vegetables and the potential effectiveness of current control strategies when the scale of production is increased.

Objective 2.
To evaluate novel techniques and strategies for control of diseases in organically grown field vegetables

Objective 3.
To monitor disease development in organic crops in relation to rotation and size of enterprise.

Objective 4.
To update, produce and publicise advisory literature for disease control in organic field vegetables.

Literature review
The philosophy of disease control in organic systems was reviewed together with recent literature on diseases and disease control in organic field vegetables. A wider literature on disease control in conventional agriculture and horticulture was also considered in order to provide novel approaches for organic producers. There is very little quantitative information on diseases in organic vegetables and advisory literature often presents lists of diseases and how to control them with no

information on their relative importance. Potato late blight was considered the most important single problem by growers overall. Cultural control and rotations will remain the cornerstones of safe organic production, but recent developments in understanding interactions between soil micro-organisms, plants, pathogens and the environment offer the opportunity to manage specific disease problems should they occur. The use of composts, soil amendments and/or cover crops appear to offer good prospects for improving disease control. The use of covers and mulches should provide a range of benefits particularly if used for successive crops. Biological control agents either naturally occurring or introduced may be advantageous against particularly damaging or persistent problems. Similarly, plant extracts require further evaluation for specific uses. Disease problems occur throughout the production cycle from seed to propagation to the growing crop and to its harvest and storage. Approaches for disease control are considered at each stage. Organic growers will almost certainly require stringent standards for seed and propagation to ensure that diseases are not introduced into their systems. A long-term commitment to strategic studies of organic systems will be needed to ensure that the planned expansion in production can meet the challenges it undoubtedly faces.

Novel approaches

The benefits of using wider plant spacing and mulches of paper or black, red or blue polythene for control of lettuce diseases was investigated in two replicated field experiments on cv. Saladin in 1999. There were no significant effects of treatment on the severity of lettuce downy mildew at harvest. Polythene mulches increased soil temperatures significantly and this contributed to higher yields at harvest. Paper mulch disintegrated during the experiment and gave lower soil temperatures than the uncovered control. This was attributed to evaporation of water from the paper mulch, giving a cooling effect. The mulches also gave useful weed suppression.

Lettuce variety mixtures were used to investigate their value for control of downy mildew. Three cultivars were used in each of three experiments and grown in single variety plots (100 lettuce/plot), as alternating single rows of each cultivar and as systematically arranged alternating cultivars within each row. In 2000, two downy mildew resistant cultivars (Taverna and Pinnokio) gave significant reductions in downy mildew severity at harvest on the susceptible Little Gem type cv. Delight when grown within the mixtures. Mixing cultivars within rows delayed the downy mildew epidemic by about 10 days. In two further experiments, one of the selected resistant cultivars became more susceptible which reduced the effectiveness of the variety mixtures.

Cultivar mixtures offer useful disease control but require that at least two cultivars out of a three component mixture have higher disease resistance. To be effective, up-to-date information is required on the current status of disease resistance in a range of cultivars and of the relevant pathogen virulences. If diverse resistances are available, the mixture strategy can be used with a changing spectrum of mixture components to reduce the risk of new pathotypes emerging. Mixtures often have positive effects in addition against pests, weeds and abiotic stress.

Glasshouse experiments with foliar spray treatments were carried out to determine the spectrum of activity of a range of organic treatments against lettuce downy mildew, grey mould of lettuce and dark leaf spot of brassicas. Seedlings were inoculated after receiving four sprays of each treatment and assessed for diseases 2-4 weeks after treatment. All treatments, aspirin, garlic oil, seaweed extract, neem, dock root extract, comfrey, rapeseed oil, milk and copper fungicide (as Bordeaux Mixture) and a standard fungicide (metalaxyl for downy mildew and iprodione for dark leaf spot and grey mould), gave significant control of lettuce downy mildew and dark leaf spot, but none (except the standard) showed activity against grey mould.

Field evaluation of foliar treatments was carried out in 2000 and 2001. Three sprays at weekly intervals in April failed to control downy mildew in September 2000, but a more extensive five spray regime in 2001 demonstrated good control of downy mildew with both rapeseed oil and neem. It would appear that some organic treatments can provide effective control of foliar diseases, but they need to be used as protectant sprays with a short interval between treatments.

Soil amendments with green crop residues, composts, manures and other treatments were evaluated in glasshouse pot experiments against club root of brassicas, pea foot rot diseases, stem canker and black scurf of potatoes, and damping off (*Rhizoctonia solani*) in lettuce. Most treatments gave no disease suppression and there were complex interactions with some effects on soil pH, available nitrogen and plant growth. Cabbage and chitin treatments showed activity against black scurf on potatoes, whilst chitin, rye and straw reduced club root severity.

Disease monitoring

Disease observations were made on 5 organic farms selected to provide different scales of production and contrasting regional differences. In Lancashire, crops on one large and two small farms were monitored three times each year during May – October 1999-2001, were contrasted with one large and one small grower in the eastern counties. Disease assessments were made on 25 plants/crop at each visit. Collated records from 489 crops (156 on large farms, 333 on small farms) illustrated that there was a greater diversity of cropping on small farms, but the diseases recorded were similar to those found in conventional cropping. Diseases were often present at a low incidence and low severity in organic crops and severe infections were recorded in only 8% of crops on small farms and 16% of crops on large farms. Although these groups of farms grew different ranges of crops, these results provide new information to suggest that larger scale production is more prone to disease problems. This observation is consistent with other epidemiological studies, including the mixture effect, which suggest that increasing the diversity of potential disease hosts per unit area tends to reduce the probability of infection. Particularly serious problems were leaf spot of celery (*Septoria apiicola*) in 1999, downy mildew in bulb onions in 1999 and 2000, late blight, spraing and black scurf in potatoes. Phloeospora leaf spot *(Phloeospora heraclei*) in parsnip and septoria in lettuce (*Septoria lactucae*), uncommon diseases in the UK, were encountered in several organic crops.

A systematic analysis of disease problems allowed the main sources of such problems to be identified. It would appear that celery leaf spot, septoria in lettuce and alternaria blight in carrots are primarily seed-borne problems which can be managed by testing seed stocks and using seed treatments. Club root, allium white rot and rhizoctonia diseases are soil-borne diseases which might be managed by rotation and avoiding known problem areas. Forward planning is critical for organic production and simple cropping schemes which avoid year-round production and planting of successive crops next to each other may have helped reduce the impact of brassica foliar diseases and leek rust.

There is no doubt that organic crops tend to be more weedy than conventional crops and that the weeds themselves can become diseased (any weed survivors in conventional crops may be sprayed with fungicide). The majority of the parasites involved are not adapted to crop plants. However, the presence of the weed parasite spores and of semiochemicals released from the weeds could have some influence in restricting disease development in crops through induction of resistance. This area should also be investigated further.

The results of farm monitoring closely mirrored disease problems reported by growers. Potato blight was the most frequent problem reported each year during 1999-2001, followed by downy mildews on onions, brassica seedlings and lettuce, celery leaf spot and leek rust. Some caution is required over the interpretation of the economic impact of diseases in organic vegetables as there were few records from late autumn or winter when many vegetables reach harvest maturity.

Conclusions

Diseases are common in organic vegetable crops, but severe infection leading to significant losses of yield or quality affected few crops (11%). Seed-borne diseases are important and availability of healthy seed would reduce losses in vegetables. Soil-borne diseases continue to trouble organic growers and can be managed through rotation or avoiding badly infested areas. The size of the organic enterprise is considered to be less important than the market outlet for the produce. Direct sales and box schemes allow greater flexibility for marketing than contracts with major retailers, requiring scheduled, high quality products.

Organic growers can exploit genetic diversity through cultivar and species mixtures, but development and guidance is required to develop practical systems. Disease management using organic conditioners, biological control agents and soil amendments merit investigation in farm-scale experiments.

Key components of disease management strategies for organic vegetables have been made available to growers in a booklet produced as part of this project.

Scientific report (maximum 20 sides A4)

Introduction

This project had the objective of identifying and quantifying opportunities to improve disease management in vegetables so that the scale of organic field vegetable production in the UK can be safely expanded to meet consumer demands.

Consumer demand for organic produce currently exceeds the supply of home-grown produce and this demand is increasing. Organic vegetables, in particular, are seen as an area of market growth. Whilst imports of organic vegetables are available and represent about 70% of current sales, there is potential to expand UK production. Local production and distribution is particularly favoured as this minimises use of natural resources (notably fossil fuel energy) in the supply chain from producer to consumer. Currently vegetable production is limited (total UK organic production of **all** crops is estimated at 0.4% of agricultural land) and growers produce a wide range of crops, finding outlets locally, often through box schemes. The major challenge is to increase the scale of production to increase supplies of vegetables through major retailers, whilst maintaining quality and minimising losses from pests, diseases and weeds.

There have been numerous recent scientific and technical developments which have not been fully examined or exploited for organic field vegetable production. In addition, the importance of diseases in organic production is poorly documented. This project provides an overview of the current status of diseases and disease control strategies on organic vegetables and has examined the effectiveness of some new approaches to organic disease management. Dissemination of this information to growers and advisors was an important part of the project and this will provide confidence for safe expansion of production, meeting DEFRA objectives of encouraging organic production, substituting imports, minimising the use of pesticides and protection of environment.

Objectives

1. To review the significance of diseases in organically grown field vegetables and the potential effectiveness of current control strategies when the scale of production is increased.

2. To evaluate novel techniques and strategies for control of diseases in organically grown field vegetables

3. To monitor disease development in organic crops in relation to rotation and size of enterprise.

4. To update, produce and publicise advisory literature for disease control in field vegetables.

Methods

1. Literature and technical review (Abstract)

The philosophy of disease control in organic systems was reviewed together with recent literature on diseases and disease control in organic field vegetables. A wider literature on disease control in conventional agriculture and horticulture was considered to provide information on novel approaches for organic producers. There is very little quantitative information on diseases in organic vegetables and advisory literature often presents lists of diseases and how to control them with no information on their relative importance. Potato blight was considered the most important single problem by growers overall. Cultural control and rotations will remain the cornerstones of safe organic production, but recent developments in understanding interactions among soil micro-organisms, plants, pathogens and the environment offer the opportunity to manage specific disease problems should they occur. The use of composts, soil amendments and/or cover crops appears to offer good prospects for improving disease control. The use of covers and mulches could provide a range of benefits, particularly if used for successive crops. Biological control agents either naturally occurring or introduced, may be advantageous against particularly damaging or persistent problems. Similarly, plant extracts require further evaluation for specific uses. Disease problems occur throughout the production cycle from seed and propagation to the growing crop and through to harvest and storage. Approaches for disease control are considered at each stage. Organic growers will almost certainly require stringent standards for seed and propagation to ensure that diseases are not introduced into their systems. A long term commitment to strategic studies of organic systems will be needed to ensure that the planned expansion in production can meet the challenges it undoubtedly faces.

2. Novel techniques and strategies for disease control

Two approaches were used in this section of the project. First, potential organic treatments identified from the literature review were evaluated against specific foliar and soil-borne pathogens in glasshouse experiments to identify their efficacy and spectrum of activity. Secondly, replicated field experiments were carried out using lettuce downy mildew (*Bremia lactucae*) as the disease target on organic farms to investigate both non-chemical control measures and foliar treatments identified from the glasshouse experiments. Non-chemical treatments included polythene mulches, plant spacing and cultivar mixtures.

2.1 Glasshouse experiments

2.1A. Foliar treatments

Potential conditioners or biocides were evaluated against downy mildew (*Bremia lactucae*) and grey mould (*Botrytis cinerea*) on lettuce cv. Saladin and against dark leaf spot (*Alternaria brassicae*) on chinese cabbage. Commercially grown organic transplants were planted into Levington M2 compost with three per 12.5 cm pot and arranged in a randomised block design with four replicates. Treatments (Table 1) were applied twice to lettuce as high volume (1000 l water/ha) sprays (with a one week interval between sprays) by hand-held sprayer and inoculated with a spore suspension (1×10^5 spores/ml) one day after the second spray and kept enclosed in polythene bags for three days. The initial inoculations were unsuccessful and re-inoculation was carried out after two further spray applications. The incidence and severity of diseases were recorded after 2-4 weeks and data were analysed using GENSTAT.

Table 1. Treatments evaluated for foliar disease control in pot experiments.

Treatment	**Rate**
Favour 600 SC (standard fungicide)	3 ml/litre (for lettuce downy mildew only)
Rovral WP (standard fungicide)	1 g/litre (for alternaria and botrytis only)
Copper sulphate - Bordeaux mixture (Vitax)	23 g/litre
Rapeseed oil - Bio Naturen insecticide (Pan Brittania)	20 ml/litre
Garlic oil (Garlic Barrier)	10 ml/litre
Neem oil - Bug Me Not (Amazing Neem Products)	10 ml/litre
Salicylic acid (Aspirin)	0.2 g/litre
Milk	50 % v/v
Dock root extract	15 g/litre
Seaweed extract - Maxicrop Original seaweed extract	5 ml/litre
Comfrey extract	1:30 v/v

2.1B. Soil organic amendments (HDRA)

Organic amendments can potentially combat soil-borne pathogens in a number of ways (e.g. Lumsden *et al.*, 1983; Lazarovits *et al.*, 2001). Mechanisms of action can be direct or indirect and can range from the direct inhibition of pathogens (in some cases) to indirect effects on soil quality and ecology that act to suppress pathogens. Treatments were selected to provide a diversity of effects on soil organisms and pathogens.

A series of glasshouse trials was undertaken to investigate the potential for using organic soil amendments as part of disease management strategies in organic horticultural production. The use of amendments was evaluated with a range of specific crop-disease combinations: 1) lettuce damping off (*Rhizoctonia solani*), 2) pea foot rot complex (*Fusarium* spp., *Pythium* spp., *Phoma medicaginis* var *pinodella*), 3) brassica club root (*Plasmodiophora brassicae*) and 4) potato canker/black scurf (*Rhizoctonia solani*). The range of amendments used was similar in the various experiments and represented either amendments that organic growers would normally use (e.g. green manures, manure composts) or those available commercially and eligible under organic standards (e.g seaweed meal, composts).

All pot trials were undertaken in the glasshouse over the winter period in each season. All amendments were used at recommended or realistic rates of application and timings (see Table 2 for treatment summary). Naturally infested soil was used as the source of inoculum except for *R. solani* on lettuce where it was produced from laboratory cultures. The soil used in the trials was obtained from organic land. A randomised block design was used in all trials with six replications. Disease incidence and severity was evaluated for each crop-disease combination using appropriate methodology or keys at appropriate times. Observations were made on plant vigour (1-9 scale where 1 = most vigorous) and growth (length of shoots or roots) in most cases.

Table 2. Organic amendments used in glasshouse pot experiments, HDRA 2000 – 2002.

N^o	Amendment	Application Rate	Application Time	pH after amendment [a]	N applied (g/m^3)[b]	Source
1	Vetch	1250 g/m^2	4 weeks before sowing	7.81	76	Ryton Organic Gardens
2	Grazing Rye	3000 g/m^2	4 weeks before sowing	8.01	132	Ryton Organic Gardens
3	Clover	1250 g/m^2	4 weeks before sowing	7.82	76	Ryton Organic Gardens
4	Cabbage	2000 g/m^2	4 weeks before sowing	8.16	124	HDRA Conversion Site
5	Straw	2500 g/m^2	4 weeks before sowing	8.06	246	Ryton Organic Gardens
6	Compost	3500 g/m^2	4 weeks before sowing	7.89	294	Ryton Organic Gardens
7	Seaweed Meal	140 g/m^2	4 weeks before and at sowing	7.95	45	Chase Organics Ltd.
8	Chitin	800 g/m^2	4 weeks before and at sowing	8.83	342	Ocean Organics Ltd
9	Neem	10 g/m^2	4 weeks before and at sowing	8.09	Effectively 0	Stringer Labs Ltd.
10	Manure (FYM)	2500 g/m^2	4 weeks before sowing	7.95	14	Ryton Organic Gardens
11	Composted Manure	3500 g/m^2	4 weeks before sowing	8.16	258	Reference Farm
13	Comfrey	Dilute 4 ml. in 100 ml water	Weekly until sowing	8.05	Effectively 0	Chase Organics Ltd.
14	Seaweed Extract	Dilute 1ml in 100ml water	Weekly until sowing	7.75	Effectively 0	Chase Organics Ltd.

[a] black scurf trial, pH of soil after trial, unamended pH =7.88 [b] black scurf trial

2.2 Field experiments

2.2A. Lettuce mulch/spacing experiments

The objective of this trial was to evaluate the potential of two cultural control methods, mulching and plant spacing, to manage lettuce downy mildew (LDM) in field grown lettuce. Spacing is known to affect disease development in crops and organic crops are often planted at wider spacing than conventional crops to reduce disease incidence. Mulches have been shown to improve crop yield due to various causes including moisture retention, weed control and elevated soil temperatures (Runham, 1998). In addition some recent work has indicated that light reflected from different coloured mulches can affect root and leaf development and may even affect disease development on crops (Antonius *et. al.,* 1996; Boyce, 1998).

The experimental design was a split plot with four replications with mulch treatments on the main plots (none, paper, black plastic, red plastic, blue plastic and lettuce spacing either close (25cm x 35 cm) or wide (30cm x 40cm) on sub-plots. Two experiments were carried out in late summer 1999 on the downy mildew susceptible lettuce cv. Saladin, one at HDRA and the second on an organic farm in Norfolk. Observations were made on disease development, crop development and yield data (head weights, marketable heads). In addition, temperatures under the mulch were taken on one occasion using a digital thermometer with probe.

2.2B. Lettuce cultivar mixture experiments

The objective of these experiments was to evaluate the potential for lettuce varietal mixtures to manage lettuce downy mildew (LDM) in a late summer crop. The use of mixtures has the potential to reduce the build up of inoculum during the season and to slow the spread of the disease in the growing crop (Finckh *et al.*, 2000). The mechanisms of action are well-known for cereal crops (Finckh *et al.,* 1999), but information for field vegetables is scarce.

The specific aims of the trial were to compare the development of LDM in two spatial arrangements of lettuce variety mixtures with their pure stand equivalents in field experiments. The mixtures tested were formed from three varieties, one highly susceptible to LDM (cv. Delight, a Little Gem type) and two more resistant (vars Pinnokio and Taverna, a cos and salad type respectively) at HDRA. Two mixtures were tested; one comprising alternate rows of three varieties within a six row bed and the other comprising plants of each variety planted alternatively in all rows of a six row bed. The trial design was a latin square with 5 treatments in two seasons; treatments and arrangement were the same in both seasons to allow a comparison across seasons. A third randomised block experiment was carried out in Lincs in 2001 using the varieties Remus (cos), Cherokee (red) and Attico (Little Gem type). Spatial variation within 6 row beds included single and double row arrangements as well as systematic alternation within the rows. The progress of downy mildew was followed closely.

2.2C. Experiments with conditioners against lettuce downy mildew

Two field experiments were used to evaluate the use of spray conditioners to manage LDM, which had been chosen as a model disease in an organic situation. Although organic pest and disease control usually depends on preventative, and, often, cultural methods, crops do suffer some pest/disease damage. This is problematic when considering crops for which there is a low tolerance for pest or disease damage as in lettuce. In this case, growers may resort to the use of plant conditioning sprays. A selection of plant conditioners that showed promise in glasshouse experiments or that have been traditionally used by organic growers against LDM on lettuce in the field, were included (see Table 10). Treatments were applied to small plots (103 plants/plot) in a randomised complete block design in the two seasons. In 2000, three applications were made at weekly intervals from mid to late August and LDM assessments made weekly from the end of treatment to harvest on 21 September. In 2001, five applications were made at weekly intervals from mid August to mid September (starting earlier and finishing later in the crop cycle) and LDM assessments made at weekly intervals thereafter until harvest on 19 October. Disease and yield data were collected at harvest.

3. Disease monitoring on organic farms

Five farms were monitored on three occasions during May to early October during 1999-2001. One large and two small growers were in the north west (Lancs) and one large and one small grower were used in eastern counties. Small farms had 1-15 ha of organic cropping and large units up to 120 ha. At each visit, a representative range of crops, both immature and mature, were examined for diseases and 25 plants per crop were assessed individually for diseases. Samples of root crops were washed prior to assessment. A total of 489 crop records have been collated (Table 3). In addition to the formal farm surveys, observations were made at Fressingfield, Suffolk in the Companion Cropping experiments (OF0181). Informal surveys were made at open days and workshops to solicit information on diseases perceived as important by organic vegetable growers. Tables 11 and 12 summarise crop inspection results and grower surveys.

Table 3. Summary of crop observations on organic vegetables by crop and by farm size 1999-2001.

		Number of Observations		
		Farm size		
Crop Type	Crop	large	small	Total
Alliums	Leeks	1	26	27
	Onion	14	13	27
Brassicas	Brussels sprouts	13	9	22
	Cabbage	16	26	42
	Calabrese	7	4	11
	Cauliflower	16	11	27
	Kale		12	12
	Kohl Rabi		12	12
	Spring Greens		5	5
	Swedes	1	6	7
	Turnip		5	5
Cucurbits	Courgettes	6	7	13
	Pumpkin		3	3
	Squash		10	10
Graminae	Sweetcorn	6	9	15
Legumes	Field beans		2	2
	French/dwarf beans	2	1	3
	Peas	2		2
Roots	Beet root	8	13	21
Salads	Chard		5	5
	Lettuce	17	76	93
	Spinach beet		1	1
Solanaceae	Peppers		2	2
	Potato	20	7	27
	Tomato		4	4
Umbellifers	Carrot	13	7	20
	Celeriac		1	1
	Celery	5	17	22
	Fennel		6	6
	Parsnips	9	1	10
Herbs	Parsley		5	5
	Mint		6	6
	Marjoram		6	6
	Thyme		4	4
	Sage		6	6
	Rosemary		3	3
	Tarragon		2	2
Total		156	333	489

4. Booklet on diseases of organic vegetables

A review of organic literature indicated that there was some information available on diseases, but no readily available publication dealing with disease management in vegetable crops as a whole. Colour illustrations of symptoms and an appraisal of key problems affecting crops in the UK were lacking. A booklet summarising organic principles and components of disease management together with descriptions, colour photographs and management guidelines has been produced within the project.

Results

2.1 Glasshouse experiments

2.1A. Foliar treatments

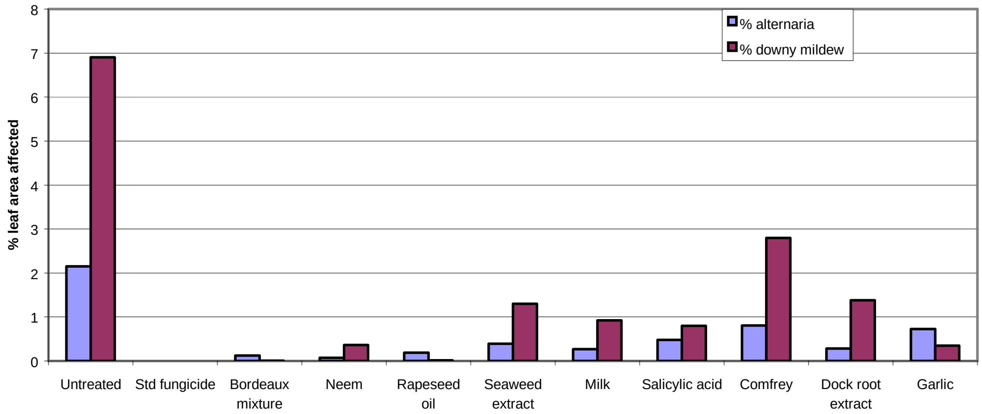

Fig.1. Control of lettuce downy mildew and dark leaf spot of brassicas in glasshouse experiments with various organic treatments and standard fungicides

All treatments gave significant reductions in the severity of dark leaf spot and downy mildew (Fig.1) and complete control was achieved with the standard fungicides. Botrytis was moderately severe in the lettuce plants reaching an index of 48 (0-100 scale) and none of the test treatments gave significant reductions in disease severity apart from the Rovral fungicide standard (index 10). There were some effects of treatments on plant growth notably black spotting on chinese cabbage with dock root extract and some cupping of leaves after rapeseed oil and neem treatments. Milk stimulated the growth of sooty moulds on chinese cabbage.

2.1B. Soil amendments

The results for the series of trials are summarised below for: Rhizoctonia damping off on lettuce (Table 4), pea foot rot complex (Table 5), stem canker/black scurf of potato (Table 6) and club root of brassicas (Table 7).

Organic amendments had some effects on plant disease development but that these effects are likely to be complex and difficult to define in terms of spectrum of activity. There were often significant differences between treatments and some reductions in disease compared with unamended control treatments. Rhizoctonia in lettuce and black scurf were reduced by rye, cabbage and chitin, whilst straw and chitin reduced club root severity. This highlights two important considerations: 1) organic amendments need not necessarily be entirely beneficial from a disease management perspective and in certain situations might exacerbate a problem if detailed knowledge of the pathogen, crop or environment on which to base management decisions are not first obtained; 2) in these experiments, realistic rates of amendment were used. Often, in the reported literature, differences between amended and unamended soils have been found through adding unrealistically large amounts of amendment that will have limited use for practical situations although they may serve to draw out differences for experimental purposes.

Detailed explanations as to the effects observed reside in the complex soil – plant – pathogen interactions that are occurring in even such an apparently simple pot trial. These include direct affects on the disease and indirect effects on plant nutrition. Observations made in this trial generally support current knowledge (Lazarovits *et al.*, 2001). Taking two examples; chitin amendment would be expected to stimulate a chitin- digesting flora in the soil and this in turn could be expected to suppress sclerotia as observed in the black scurf assessment in the potato experiment (Table 6). Also, *R.*

solani is a necrotroph, and adding large amounts of fresh manure might, in some cases, be expected to stimulate its saprophytic development and stimulate disease development, as noted for black scurf (Table 6).

Table 4. Effect of soil organic amendments for control of *Rhizoctonia* damping off on lettuce, HDRA 1999.

Amendment	Expt 1		Expt 2	
	Plant vigour (1-9)	% damping off	Plant vigour (1-9)	% damping off
Vetch	5.17	61.8	5.83	49.4
Grazing rye	7.67	22.2	9.00	6.1
Clover	6.50	35.4	5.33	40.0
Cabbage	7.50	46.7	8.00	10.3
Straw	2.00	45.9	4.83	15.7
Bark compost	6.00	37.7	4.17	53.2
Compost	6.67	25.3	5.00	13.7
Seaweed meal	5.50	26.2	4.50	9.4
Chitin	5.50	34.9	8.33	10.0
Neem	6.33	27.8	6.00	19.6
Manure (FYM)	7.67	18.8	5.50	22.5
Comfrey	5.67	23.9	4.50	45.3
Seaweed extract	6.17	22.2	4.83	25.4
No amendment	6.33	28.6	4.92	40.0
HDRA soil	4.25	17.8	2.50	27.7
SED (82 df)	0.59	11.71	0.58	10.96
Significance	***	ns	***	***

Table 5. Effect of soil organic amendment trials on pea foot rot complex, HDRA 1999.

Amendment	% seeds emerged at 25 days	Plant vigour (1-9)	% damping off	% dead plants
Vetch	81.3	6.33	25.0	18.8
Grazing rye	62.5	8.00	37.5	37.5
Clover	85.4	6.17	14.6	14.6
Cabbage	81.3	6.17	20.8	18.8
Straw	83.3	5.17	18.8	16.7
Bark	79.2	4.50	20.8	20.8
Compost	87.5	5.83	12.5	12.5
Seaweed meal	77.1	5.50	22.9	22.9
Chitin	79.2	7.00	22.9	20.8
Neem	60.4	6.00	41.7	39.6
Manure (FYM)	64.6	4.67	37.5	35.4
Comfrey	68.8	4.33	31.3	31.3
Seaweed extract	70.8	5.17	29.2	29.2
No amendment	77.1	5.08	25.0	22.9
HDRA soil	91.7	6.17	8.3	8.3
SED (82 df)	7.70	0.61	7.97	7.70
Significance	**	***	**	**

Table 7. Effect of soil organic amendments on stem canker and black scurf of potatoes, HDRA 2001.

Amendment	Shoot Vigour (1-9)	No. Shoots with dead tips	% Shoots with stem canker	% area of black scurf on tubers
Vetch	5.1	1.6	62.8	0.39 (1.5)
Rye	3.2	0.4	37.8	0.42 (1.6)
Clover	4.7	1.2	44.6	0.78 (5.0)
Cabbage	5.3	1.1	69.8	0.35 (1.2)
Straw	7.2	0.7	41.2	0.77 (4.9)
Compost	4.3	0.5	45.4	0.87 (6.4)
Seaweed meal	6.0	0.8	52.1	1.05 (10.2)
Chitin	3.6	0.7	44.4	0.15 (0.4)
Neem	6.2	1.4	69.0	0.92 (7.2)
Manure (FYM)	6.5	1.3	65.3	0.97 (8.3)
Comp. manure	5.8	0.9	63.4	0.63 (3.3)
Comfrey	6.2	0.7	61.3	0.86 (6.2)
Seaweed extract	6.8	1.3	68.9	0.83 (5.8)
Untreated	5.1	0.8	39.7	0.77 (4.9)
SED (71 df)	0.82	0.37	15.68	0.21[b]
Significance	***[a]	*	ns	**

[a] *** *P*<0.001, ** *P*<0.01, **P*<0.05, ns not significant
[b] data transformed (log(x+1)) for ANOVA, original treatment means shown in parentheses

Table 8. Effect of soil organic amendments on club root of brassicas, HDRA 2002.

Amendment	Clubroot (1-9)	Plant vigour (1-9)	Stem length (cm)	Root length (cm)	Plant dry weight (g)
Vetch	4.8	2.3	18.3	8.0	0.83
Rye	4.4	2.7	18.8	6.9	0.77
Clover	4.7	2.7	19.1	7.2	0.83
Cabbage	4.5	2.7	18.4	7.8	0.73
Straw	1.7	7.0	9.3	11.5	0.19
Compost	5.2	3.0	17.3	7.7	0.76
Seaweed meal	4.9	2.7	16.5	8.2	0.76
Chitin	1.1	2.0	19.3	10.5	0.84
Neem	6.2	3.0	18.3	6.1	0.82
Manure	4.9	3.0	18.1	6.9	0.84
Composted manure	5.4	3.0	17.6	7.6	0.83
Calcified seaweed meal	6.9	3.0	17.1	7.3	0.81
Polyversum	7.1	3.0	16.4	6.3	0.78
Untreated	5.9	2.5	17.8	7.1	0.84
SED (71 df)	0.65	0.38	0.62	0.75	0.04
Significance	***[a]	***	***	***	***

[a] *** *P*<0.001, ** *P*<0.01, **P*<0.05, ns not significant

Apart from the suppressive or stimulatory effects of amendments on the disease affecting plant vigour indirectly, the amendments are also likely to have nutritive or physical effects on plant vigour (see Table 1 for N in amendments and alterations to pH due to amendments in some trials). Straw for example was not well degraded in any of the trials and is probably present in excess, thereby locking-up N, whilst rye and chitin were rapidly degraded leaving N available for the plants. This is reflected to some extent in the plant vigour scores reported for each trial.

2.2 Field experiments

2.2A. Lettuce mulch/spacing experiment

LDM increased to cover about 20% of leaf area during the course of the experiment at HDRA and by the final sampling dates, significant (P<0.05) differences were seen in LDM severity between mulches and close and wide spacings (Table 8a). Significant differences were also seen in plant vigour with different coloured mulches, but these disappeared over the course of the trial and no difference in vigour was seen with spacing. Head and leaf development were generally better with plants on plastic mulch and significant differences were observed in head weight between mulch treatments, but not with spacing. However, significantly more marketable heads were harvested at the closer spacings and over the polythene mulched treatments. Downy mildew appeared within two weeks of planting in Norfolk and showed less severe infection in black and blue polythene treatments on 8 September (Table 8b). These differences were not maintained. There were significant differences in soil temperatures under the mulches, being lowest under paper and highest under red polythene. There were no significant effects on yield, though the crop was harvested early to avoid frost damage.

The wider spacing had little effect on LDM severity, plant growth or yield, but marketable head weight was slightly higher at wide spacing (Table 8a). Lettuce growth was improved by the use of plastic mulch which was better than paper mulch and which, in turn, was an improvement over no mulch. Mulch had little or even a negative effect on LDM severity. Marketable yield and head weight were slightly improved by plastic mulch and red or black mulch were better at the HDRA site in this respect.

In conclusion, mulch, in itself, is unlikely to offer a commercially viable method of LDM control. The use of coloured mulch to increase lettuce production would require a more detailed economic or partial budget analysis before making recommendations for future work or for growers. A broader view of the benefits including weed suppression, soil-borne disease control and pest management should be taken. Future work should explore other methods of cultural disease control.

Table 8a. Effects of mulches and plant spacing on lettuce downy mildew, vigour and yield, HDRA 1999.

Treatment	LDM severity (% leaf area)				Plant vigour (1-9)		Head weight (g)	No. marketable heads	Marketable head weight (g)
Date	3	4	5	6	4	5	6	6	6
Spacing									
Close	2.5	9.8	15.7	13.5	5.8	5.8	178	17.7	151
Wide	2.7	9.4	16.2	17.3	5.9	6.1	186	14.9	176
SED (12 df)	0.44	0.8	1.2	0.6	0.3	0.3	7.4	0.8	5.8
	ns	ns	ns	*	ns	ns	ns	*	*
Mulch									
No mulch	2.3	7.8	11.3	13.3	5.3	5.4	128	13.4	115
Paper	2.8	10.1	13.8	13.3	4.6	5.5	150	16.0	135
Black	2.5	9.5	20.0	15.1	6.3	6.5	222	17.1	199
Red	2.4	10.1	17.3	17.7	6.5	6.4	219	18.1	190
Blue	3.0	10.4	17.6	17.5	6.5	6.0	193	16.8	181
SED (15 df)	0.9	1.1	1.6	2.2	0.4	0.4	17.5	1.6	15.1
	ns	ns	**	**	**	ns	***	*	***

Assessments: 2- 17 Sept, 3- 24 Sept, 4-1 Oct, 5- 11 Oct, 6- 22 Oct

Table 8b. Effects of mulches and plant spacing on lettuce downy mildew, soil temperature, vigour and yield, Norfolk 1999.

Treatment	LDM severity (% leaf area)			Soil temperature (ºC)	Total head weight (g)	Marketable head weight (g)
Date	2	3	5	4	5	5
Spacing						
Close	0.22	0.93	1.75	11.2	4214	2539
Wide	0.25	1.01	1.76	11.4	4602	2818
SED (18 df)	0.038	0.092	0.163	0.11	328.3	213.7
	ns	ns	ns	ns	ns	ns
Mulch						
No mulch	0.35	0.85	2.01	10.6	4018	2613
Paper	0.32	0.76	1.51	10.4	3531	2024
Black	0.10	1.08	1.70	11.8	4847	2903
Red	0.29	0.95	1.82	12.2	4685	2872
Blue	0.13	1.19	1.73	11.6	4958	2980
SED (18 df)	0.061	0.144	0.257	0.17	519.2	337.8
	***	ns	ns	***	ns	ns

Assessments: 2- 8 Sept, 3- 28 Sept, 4- 12 Oct, 5- 20 Oct

2.2B. Lettuce cultivar mixture experiments

The results of the trials over two seasons are summarised below for the number of plants with downy mildew (1 week before optimum harvest date), percentage leaf cover with disease (at optimum harvest date), plant vigour (at optimum harvest date) and trimmed head weight at harvest (1-2 weeks after optimum harvest date) (Table 9).

In neither season did the alternating row layout appear to affect disease development, although, overall, head weight did increase slightly in both years. However, the complete mix layout, within and between rows, had a considerable effect, particularly in the first season when both Taverna and Pinnokio acted as resistant varieties. In this instance, disease overall was reduced by more than half in the mixture relative to the mean of the pure stands with Little Gem sustaining only 43% of its disease level in pure stand. The complete mixture yield per head was 10% higher than the mean of the components, but it is not clear to what extent this was due to the disease restriction or to over-compensation for the low yield of Little Gem.

In the second season, the resistance of Taverna decreased considerably, though it still remained more resistant than Little Gem. In this season, therefore, the complete mixture gave less effective disease control (17% reduction overall) although both Taverna and Little Gem were protected to some extent. Interestingly, despite the reduced disease effect, the mixture produced 115% of the mean yield of the components. Despite the disease protection, the yield of Little Gem did not increase in the mixture, suggesting that the other varieties were competitive at a range of disease levels and, again, were able to compensate for the lower yield of Little Gem.

Clearly, the mixture performed better with a higher proportion of resistant variety components, a common experience in other studies on mixtures. This was confirmed in Lincs in 2001, where the previously resistant Attico showed a high incidence of downy mildew (84% plants affected) and only the pure stand of cv. Remus showed significantly less downy mildew (39% plants affected) than the other treatments. The results indicate that a three variety mixture is most effective when at least two of the component varieties show good resistance to the pathogen. It would be valuable to look at the performance of more complex mixtures. The most important result, also common from experience with other species, is that complete mixing of the components is considerably more effective than more regular spatial arrangements.

Table 9. Control of lettuce downy mildew using cultivar mixtures in 2000 and 2001.

		2000				2001			
	Treatment	No. plants LDM	% area LDM	Plant vigour (1-9)	Trimmed head weight (kg)	No. plants LDM	% area LDM	Plant vigour (1-9)	Trimmed head weight (kg)
1	Taverna (pure stand)	1.2	3.3	1.2	0.590	8.2	10.7	2.4	0.242
2	Pinnokio (pure stand)	0.2	1.1	1.4	0.566	0.6	0.3	1.2	0.269
3	Little Gem (pure stand)	7.8	41.5	6.8	0.238	3.8	18.8	4.0	0.143
4a	<u>Alternate lines</u>	2.7	14.4	3.0	0.484	4.4	10.2	2.8	0.224
4b	*Taverna (alt lines)*	*1.4*	*4.6*	*2.0*	*0.595*	*6.0*	*8.8*	*2.0*	*0.252*
4c	*Pinnokio (alt lines)*	*1.4*	*2.4*	*2.2*	*0.635*	*3.2*	*1.3*	*2.6*	*0.281*
4d	*Little Gem (alt lines)*	*5.4*	*36.2*	*4.8*	*0.223*	*4.0*	*20.5*	*3.8*	*0.139*
5a	<u>Alternate plants</u>	1.7	7.1	2.3	0.510	4.2	8.2	2.9	0.251
5b	*Taverna (alt plants)*	*0.6*	*3.8*	*1.4*	*0.610*	*7.0*	*6.6*	*2.2*	*0.289*
5c	*Pinnokio(alt plants)*	*0.2*	*1.8*	*1.4*	*0.706*	*2.2*	*1.3*	*2.8*	*0.313*
5d	*Little Gem (alt plants)*	*4.4*	*15.7*	*4.0*	*0.214*	*3.4*	*16.7*	*3.8*	*0.151*
a	SED (12 df)	1.0	7.1	0.48	0.02	1.2	4.2	0.53	0.02
a	Significance	***	***	***	***	***	*	**	***
b	SED (12 df)	1.1	6.3	0.48	0.03	1.0	4.0	0.59	0.02
b	Significance	***	**	***	***	***	**	**	***
c	SED (12 df)	0.9	6.2	0.6	0.03	1.43	3.8	0.60	0.03
c	Significance	***	***	***	***	**	***	**	***
d	SED (12 df)	1.3	10.3	0.6	0.06	1.03	5.25	0.59	0.01
d	Significance	***	**	***	***	***	*	**	***

2.2C. Lettuce conditioner experiments

Severe downy mildew developed in two experiments at HDRA and good control was demonstrated in 2001. In 2000 and 2001, both rapeseed oil and neem showed the lowest downy mildew severity and differences were significant in 2001 when spraying was carried out more frequently than in the first year. The conditioning sprays did not affect plant vigour or trimmed head weight of the lettuce in either season.

Table 10. Effects of organic plant conditioners on lettuce downy mildew, plant vigour and yield in 2000-2001.

	2000			2001		
Treatment	%area LDM	Plant vigour (1-9)	Trimmed head weight (g)	%area LDM	Plant vigour (1-9)	Trimmed head weight (g)
Water	38.0	3.8	241	20.3	4.3	168
Milk	43.1	4.0	264	24.5	4.0	153
Comfrey	40.1	4.0	271	47.2	4.0	164
SM3	45.1	4.3	266	35.6	5.3	140
Maxicrop	-	-	-	18.9	4.0	145
Citrox	-	-	-	9.8	3.0	143
Rapeseed oil	26.0	3.0	260	3.1	3.0	157
Sulphur	47.6	3.8	254	29.8	3.7	152
Garlic	38.9	3.8	263	27.8	4.3	148
Neem	26.7	3.0	268	3.5	2.7	150
SED (14 df in 2000) (18 df in 2001)	87.9	0.64	11.0	11.07	0.72	14.5
Significance	ns	ns	ns	*	ns	ns

In summary, these experiments indicate that some of the conditioning treatments show some potential to ameliorate the infestation of downy mildew on lettuce. However, further work would be needed to define under what conditions these sprays might be more effective against LDM and in raising marketable yields. This might involve assessments of varying concentrations and/or timings of the products showing the most promise (neem, rapeseed oil). Timings could be considered in relation to periods of risk of LDM and rainfall or irrigation (that washes treatments off the plants). Consideration needs to be given to the place of such treatments within organic farming systems before extensive testing programmes are carried out.

3. Disease monitoring on organic farms

Five farms were monitored on three occasions during May to early October during 1999-2001. One large and two small growers were in the north west (Lancs) and one large and one small grower were used in eastern counties. Small farms had 1-15 ha of organic cropping and large units up to 120 ha. At each visit, a representative range of crops, both immature and mature, were examined for diseases and 25 plants per crop were assessed individually for diseases. Samples of root crops were washed prior to assessment. A total of 488 crop records have been collated (Tables 3, 11). In addition to the formal farm surveys, observations were made at Fressingfield, Suffolk in the Companion Cropping experiments (OF0181). Informal surveys were made at open days and workshops to solicit information on diseases perceived as important by organic vegetable growers.

Table 11 provides a summary of disease observations made on crops over the three seasons. Some observations represent the same crop at different growth stages. In general, the farms with smaller production areas grew a much wider range of crops at the inspection sites than the farms with the large enterprises. Crop types on the small farms averaged 2.3 diseases per crop compared with 4.2 diseases per crop on the large farms. Among the wide range of diseases observed on the survey holdings, some were assessed as moderate (17% of observations) or severe (11% of observations) in terms of damage to the crop (Table 12).The division of disease records into slight, moderate and severe infection was identical for both sizes of farm. These observations suggest that small farms with many small crops provide small targets for initial infection relative to larger farms, but that, once established, the rates of epidemic development are similar on both sizes of farm.

Table 11. Observed disease severity on organic vegetables by farm size, 1999-2001.

			Count of severity								
Farm size			large			small			Total		
Disease Severity sl=slight,m=moderate, sev=severe			sl	m	sev	sl	m	sev	sl	m	sev
Crop	Disease	Latin name									
Alliums											
Leeks	leaf rot	*Botrytis spp.*				3			3		
	rust	*Puccinia allii*				4	6			4	6
Onion	downy mildew	*Peronospora destructor*	2		4	9		2	11		6
	neck rot	*Botrytis allii*	1			1			2		
Brassicas											
Brussels sprouts	dark leaf spot	*Alternaria brassicae/A. brassicicola*	7				1		7	1	
	downy mildew	*Peronospora parasitica*	3			2			5		
	ring spot	*Mycosphaerella brassicicola*	4			2			6		
	white blister	*Albugo candida*	2			1	2		3	2	
Cabbage	clubroot	*Plasmodiophora brassicae*	1						1		
	dark leaf spot	*Alternaria* spp.	5			5			10		
	downy mildew	*Peronospora parasitica*	5			4			9		
	ring spot	*Mycosphaerella brassicicola*	1			5			6		
	white blister	*Albugo candida*	4			11			15		
Calabrese	clubroot	*Plasmodiophora brassicae*			1	1			1		1
	dark leaf spot	*Alternaria* spp.	1						1		
	downy mildew	*Peronospora parasitica*	2	1		3			5	1	
	ring spot	*Mycosphaerella brassicicola*	2						2		
	white blister	*Albugo candida*	1						1		
Cauliflower	clubroot	*Plasmodiophora brassicae*				1			1		
	dark leaf spot	*Alternaria* spp.	2		1	1			3		1
	downy mildew	*Peronospora parasitica*	6			4			10		
	ring spot	*Mycosphaerella brassicicola*	3			2			5		
	white blister	*Albugo candida*	4	1		2			6	1	
Kale	alternaria	*Alternaria* spp.				3			3		
	downy mildew	*Peronospora parasitica*				5	1		5	1	
	ring spot	*Mycosphaerella brassicicola*				4			4		
	phoma	*Phoma lingam*				1			1		
	powdery mildew	*Erysiphe cruciferarum*				1			1		
	white blister	*Albugo candida*				1	2		1	2	
Kohl rabi	downy mildew	*Peronospora parasitica*				4			4		
	ring spot	*Mycosphaerella brassicicola*				5			5		
	white blister	*Albugo candida*				3			3		
Spring	alternaria	*Alternaria* spp.				1			1		
greens	downy mildew	*Peronospora parasitica*				3			3		
	phoma leaf spot	*Phoma lingam*				2			2		
	ring spot	*Mycosphaerella brassicicola*				2			2		
	white blister	*Albugo candida*				2			2		
Swedes	alternaria	*Alternaria* spp.	1						1		

				Count of severity (contd)								
				large			small			Total		
				sl	m	sev	sl	m	sev	sl	m	sev
		clubroot	*Plasmodiophora brassicae*				1			1		
		downy mildew	*Peronospora parasitica*	1			2			3		
		powdery mildew	*Erysiphe cruciferarum*				2			2		
		ring spot	*Mycosphaerella brassicicola*				1			1		
	Turnip	downy mildew	*Peronospora parasitica*				3			3		
		ring spot	*Mycosphaerella brassicicola*				1			1		
		white blister	*Albugo candida*				1			1		
Cucurbits												
	Courgettes	fruit/tip rot	*Botrytis cinerea*	1						1		
		grey mould	*Botrytis cinerea*	1			1			2		
		powdery mildew	*Erysiphe cichoracearum*	3			4	1		7	1	
		virus	*CMV?*	1						1		
	Squashes	grey mould	*Botrytis cinerea*				1		1	1		1
		powdery mildew	*Erysiphe cichoracearum*				4	2		4	2	
		virus?	*CMV?*				2					
	Pumpkin	powdery mildew	*Erysiphe cichoracearum*				1		1	1		1
Graminae												
	Sweetcorn	leaf spot	*Helminthosporium* sp.*?*				1			1		
		rust	*Puccinia spp*				1			1		
Legumes												
	Field beans	chocolate spot	*Botrytis fabae*				1			1		
	French beans	botrytis	*Botrytis cinerea*	2						2		
		sclerotinia	*Sclerotinia sclerotiorum*	1						1		
		foot rot	*Thielaviopsis basicola*			1						1
	Peas	root rot	*Fusarium spp; Phoma medicaginis var pinodella*	1						1		
		leaf spot	*Mycosphaerella pinodes*	1						1		
Roots												
	Beetroot	leaf spot	*Ramularia beticola/ Cercospora beticola*	2			5			7		
		scab	*Streptomyces* sp.	1		2	1			2		2
		rust	*Uromyces betae*	1	2	1	1		1	2	3	2
		rhizoctonia scab	*Rhizoctonia solani*	2						2		
		powdery mildew	*Erysiphe betae*		1		1			1	1	
		ramularia	*Ramularia beticola*	3			1			4		
		crown rot	*?Phoma betae*				1			1		
Salads												
	Lettuce	downy mildew	*Bremia lactucae*	1	8	1	4	16	10	5	24	11
		head rot	*Botrytis cinerea*	1			14	4	10	15	4	10
		head soft rots	*Erwinia carotovora*		1	1					1	1
		sclerotinia rot	*Sclerotinia sclerotiorum*	2	1					2	1	
		septoria	*Septoria lactucae*				4			4		
		ring spot	*Michrodochium panattonianum*	1			1			2		
	Spinach beet	leaf spot	*Cercospora beticola*				1			1		
	Chard	downy mildew	*Peronospora farinosa*				2			2		
		virus yellow	*BMYV*				1			1		
		ramularia	*Ramularia beticola*				1			1		
Solanaceae												
	Tomato	grey mould stem rot	*Botrytis cinerea*				1	1		1	1	

				Count of severity (contd)								
				large			small			Total		
				sl	m	sev	sl	m	sev	sl	m	sev
		leaf mould	*Fulvia fulva*				1	1		1	1	
	Peppers	grey mould	*Botrytis cinerea*				2			1		
	Potato	blackleg/soft rot	*Erwinia carotovora*	9	2		1			10	2	
		common scab	*Streptomyces scabies*	5	3	1	2			7	3	1
		mosaic virus	*Potato virus Y*				1			1		
		black scurf	*Rhizoctonia solani*	3	1	4	1			4	1	4
		late blight	*Phytophthora infestans*	2			1			3		
		late blight (tuber)	*Phytophthora infestans*	1			1			2		
		silver scurf	*Helminthosporium solani*	4						4		
		black dot	*Colletotrichum coccodes*	4	1					4	1	
		spraing	*Tobacco rattle virus*			2						2
		hollow heart	*Physiological*	2		1				2		1
		internal rust spot	*Physiological*			1						1
		stem canker	*Rhizoctonia solani*	2						2		
		rhizoctonia scab	*Rhizoctonia solani*	3	4					3	4	
Umbellifers												
	Carrot	leaf blight	*Alternaria dauci*	7			4			11		
		cavity spot	*Pythium* spp.	3				1		3	1	
		violet root rot	*Helicobasidium purpureum*					1			1	
		virus	*Carrot motley dwarf virus*				1			1		
		scab	*Streptomyces sp.*		1						1	
		powdery mildew	*Erysiphe heraclei*		1						1	
		fang	*Nematode/Pythium* spp.	1	2					1	2	
		black scurf	*Rhizoctonia solani*	1						1		
	Celeriac	septoria	*Septoria apiicola*				1			1		
	Celery	leaf spot	*Septoria apiicola*	3	2		6		3	9	2	3
		soft rot in hearts	*Physiological*				1			1		
		mosaic virus	*Celery mosaic virus*				2			2		
	Parsnips	canker?	*Itersonilia pastinacae/Phoma complanata*				1			1		
		phloeospora leaf spot	*Phloeospora heraclei*	1		2				1		2
		fang	*Nematode/Pythium* spp.	1		1				1		1
		black scurf	*Rhizoctonia solani*	1						1		
		crown spotting		2						2		
		lateral spotting		2						2		
		cavity spot	*Pythium violae*	2						2		
		canker	*Itersonilia pastinacae*	1						1		
		virus	*Parsnip yellow fleck virus*	1						1		
		ramularia	*Ramularia pastinacae*	2						2		
		powdery mildew	*Erysiphe polygoni*	1						1		
Herbs												
	Parsley	septoria	*Septoria petroselini*				2	2		2	2	
		virus	*Carrot motley dwarf virus*					1			1	
	Mint	rust	*Puccinia menthae*					2			2	
	Marjoram	rust	*Puccinia menthae*				1			1		
	Sage	powdery mildew	*Oidium* sp.				3	1		3	1	

Observations made over the course of the three seasons indicate that diseases are often present and widespread in organic vegetable production systems. In general, many do not seem to cause large scale economic damage although this depends to some extent on the type of enterprise and the season. The small growers had a greater range of crops than the large growers but fewer diseases per crop. There were also differences in disease incidence between the small and large growers. Expressing the number of disease records as a percentage of number of crops examined showed moderate and severe disease affected 20.5% and 16% crops respectively on large farms and 13.5% and 8.4% on small farms. For slight disease infections, the average was 95.0% crops affected on large farms and 62.5% on small farms. There were seasonal differences and these farm size efects are probably greater than regional climatic effects. Severe disease is estimated to have reduced financial returns by at least 25% and moderate disease caused losses of at least 10%. Leaf spot of celery was common in 1999, but was contained by crop rotation and general hygiene until late in the season in 2000 and 2001. Onion downy mildew was particularly severe in bulb onions in 1999 and 2000, declining somewhat in 2001 after a colder winter. Potato late blight was recorded each year and remains the most important disease of vegetables in the opinion of growers. Potato blight and lettuce downy mildew presented problems for growers because previously resistant varieties succumbed to new races of the pathogen. Whilst most diseases encountered are familiar to conventional growers, phloeospora leaf spot on parsnip and septoria leaf spot on lettuce are uncommon.

Disease records in Companion Cropping experiments in Suffolk (OF 0181) showed similar patterns to monitored farms even though crops were grown in single rows in small plots. Rust on broad beans was moderately severe in 1999, affecting 10% leaf area by mid August. Potato blight affected 4.7% leaf area on cv. Pentland Javelin on 10 August compared with 0.003% on cv. Valor. Potato blight developed again in 2000 and affected 13% leaf area of cv Nicola on 25 July with no significant effects of previous companion crop, mulching with mowings or compost. Tuber blight affected 6.7% tubers overall in 2000 and there was a companion crop/compost interaction ($P<0.05$) with least tuber blight (0.9%) after vetch with no compost and most tuber blight where potatoes followed vetch with compost (7.3%) or clover with no compost (8.0%). Soil-borne diseases such as common scab and violet root rot also affected potatoes but the latter was in localised areas and neither was affected by previous treatments. Pea downy mildew was severe on some plants, suggesting a soil-borne problem. Red and spinach beets and chard were affected by rust and ramularia spotting and cercospora leaf spot was confirmed in 2001. Nearby sugar beet cropping could have been the source of these pathogens.

There were fewer problems in brassica crops and leeks than expected. This has been attributed to simplified cropping in that year-round production is not practised and, in some cases, only single crops were grown. Interactions with nearby arable crops were considered important; notably the spread of diseases from oilseed rape to brassicas, sugar beet to leaf beet vegetables and field beans to broad beans.

Analysis of the origin of disease problems allows weaknesses in disease management to be identified. It appears that celery leaf spot, alternaria blight in carrots and septoria in lettuce are primarily seed-borne and could be marginalised if healthy seed stocks were available. Soil-borne disease such as club root, allium white rot, violet root rot and powdery scab may be managed by crop rotation and avoiding the most severely affected fields.

Grower opinions

Grower's opinions about significant disease problems on their holdings during the survey period were collated using questionnaires at three vegetable variety Open Days in 1999, 2000 and 2001 (Table 12). These observations reflect both the range of crops being grown and the occurrence of problems. Late blight of potatoes was the most important disease in all three years and was cited by 54%, 73% and 67% of respondents in successive years (Note blight also affected outdoor tomatoes). The other vegetables were probably grown on fewer holdings but serious losses within any crop will have financial implications for the grower. The downy mildews in lettuce and onions have been particularly severe in field crops during the course of this project and brassica downy mildew has been important during propagation. Septoria leaf spot in celery, leek rust and ring spot of brassicas were clearly identified as problems for many growers.

Discussion

Lettuce downy mildew (*Bremia lactucae*) was used as a model disease-crop system in a series of experiments. Modifying plant spacing appears to offer limited benefits and growers would be conscious of the detrimental effect on overall yield if wider spacing was appropriate. Mulch treatments merit further consideration as they could aid management of soil-borne diseases as well as being beneficial for weed control and giving earlier or higher yield. Repeated cropping using the same mulch might well make them more cost-effective, but would require specialist planting machinery for moderate to large scale production. There is clearly good activity from some plant conditioners, though organic growers may not be prepared to make the necessary frequent spray applications. Product registration may be a problem if treatments are considered as pesticides. The literature review identified biological control agents as having potential in organic systems, though registration costs may be prohibitive.

Use of cultivar resistance and species diversity are cornerstones of organic systems. Lettuce variety mixtures can make a contribution to disease control and further work should be considered for other crop-disease combinations. More attention should be given to a detailed analysis of the underlying epidemiology of such mixtures (e.g. building on the work of Garrett and Mundt (1999) and Xu and Ridout (2000)). This work could also help to address the most effective manner of mixing the varieties to make the technology more acceptable to growers, for instance it might be possible to plant in small blocks rather than a random mix of plants to gain the same effect. It is also important to know if the effectiveness of the mixtures increases with the number of components or with increased scale of planting. If random mixtures of varieties are more effective this might suit some types of marketing schemes over others. Some time would also have to be spent on determining the best mixes of varieties or types of lettuce to use. Growers are exploiting this spatial variation to a limited extent by growing strips of different crops. Particular problems were encountered where successive plantings of the same crop/variety allowed diseases to spread from batch to batch. Late plantings were vulnerable because disease development started early in the life of the crop and had a severe effect on yield.

Work is in progress on variety mixtures in other vegetables but particularly in the management of potato late blight, clearly a priority area given the prospect of losing copper fungicides in the future. To be sustainable, growers will require detailed and up to date information on relative degrees of resistance of different cultivars and of virulence/avirulence combinations in the pathogen and their frequencies. This is currently not available. In the longer term, conservation of genetic sources of resistance could be assisted by growing changing combinations of resistant varieties.

Disease monitoring on organic farms has revealed some serious disease problems and extended the range of significant problems identified by Peacock and Norton (1990). However, in most crops disease problems were of minor importance. It is anticipated that disease problems will vary from year to year and the project monitored seasons favourable for downy mildews and splash-dispersed pathogens. The full extent of disease problems has not been established as crops maturing in late autumn and winter (e.g. brassicas, leeks, stored crops) were not monitored. Extending the monitoring to a wider range of mature crops would enable more comprehensive strategies to be put forward. In addition, the farms used for monitoring may face different diseases to those encountered on recently converted land in areas with considerable conventional production. These observations underline the value of a more continuous systematic survey which would build up a database on the prevalence of diseases in organic vegetables and any changes over time, which in turn will allow the identification of periods of risk and the identification of better disease management strategies for organic growers.

Pests and diseases are often perceived by conventional growers as being a major constraint to converting to organic production methods, whilst proponents of organic production systems often rate them as of less importance (Alteiri, 1984). There are claims that the proportion of organic crops lost to pests and diseases is often smaller in organic than in conventional systems (Plumb, 2000), which is partially explained by the lower yields of organic crops, but also due to other factors such as the low N status of the crop reducing susceptibility to diseases and pests. Recently, Litterick *et al.*, (2002) have judged that the lack of economic crop protection strategies is one of the key factors limiting expansion of UK organic agriculture. This project provides quantitative data on the occurrence of disease problems, though further losses to pests and weeds are also occurring.

There are several diseases which can be assigned high priority in organic vegetable production systems. These include: potato late blight (*Phytophthora infestans*), celery leaf spot (*Septoria apiicola),* leek rust (*Puccinia allii*), lettuce downy mildew (*Bremia lactucae*), onion downy mildew (*Peronospora destructor*) and neck rot (*Botrytis allii*), plus brassica foliar diseases when they directly affect the marketable parts of the plant (e.g. dark leaf spot (*Alternaria brassicicola*), ring spot (*Mycosphaerella brassicicola*) and white blister (*Albugo candida*)), club root (*Plasmodiophora brassicae*).

Table 12. Disease problems reported by growers on organic vegetables at Open Days at HDRA 1999-2002.

Crop	***Disease***	***Pathogen***	***Number of growers with problems (Total =76)***	***%***
Brassicas (Brussels/Cabbage/ etc..)	Ring spot	*Mycosphaerella brassicicola*	7	9.2
	Dark leaf spot	*Alternaria spp.*	5	6.6
	Downy mildew	*Peronospora parasitica*	10	13.2
	White blister	*Albugo candida*	1	1.3
	Black rot	*Xanthomonas campestris*	2	2.6
	Phoma leaf spot	*Phoma lingam*	1	1.3
	Damping off	*Rhizoctonia solani*	1	1.3
	Botrytis rot	*Botrytis cinerea*	1	1.3
Beetroot	Leaf spot	*Cercospora beticola/Ramularia beticola*	1	1.3
Broad beans	Chocolate spot	*Botrytis fabae*	4	5.3
	Rust	*Uromyces viciae-fabae*	2	2.6
Carrot	Cavity spot	*Pythium spp.*	2	2.6
	Leaf blight	*Alternaria dauci*	4	5.3
		Rhizopus?	1	1.3
	Scab	*Streptomyces scabies*	1	1.3
Celery /Celeriac	Leaf spot	*Septoria apiicola*	11	14.5
	Soft rot	*?*	1	1.3
Courgettes	Powdery mildew	*Erysiphe cichoracearum*	7	9.2
Other Cucurbits	Powdery mildew	*Erysiphe cichoracearum*	5	6.6
	Mosaic virus	CMV/ZYMV	2	2.6
	Downy mildew	*Bremia lactucae*	14	18.4
	Damping off	*Rhizoctonia solani*	1	1.3
	Head rot	*Botrytis cinerea*	6	7.9
	Septoria leaf spot	*Septoria lactucae*	1	1.3
Leeks	Rust	*Puccinia allii*	10	13.2
	White tip	*Phytophthora porri*	3	3.9
Onions and garlic	Downy mildew	*Peronospora destructor*	12	15.8
	Neck rot	*Botrytis alli*	5	6.6
	Rust	*Puccinia allii*	1	1.3
	White rot	*Sclerotium cepivorum*	5	6.6
Parsnip	Canker	*Itersonilia pastinacae*	2	2.6
	Brown lesions	*?*	1	1.3
Peas	Mildew	*? Peronospora viciae*	3	3.9
Potato	Late blight	*Phytophthora infestans*	48	63.2
	Common scab	*Streptomyces scabies*	4	5.3
	Powdery scab	*Spongospora subterranea*	1	1.3
	Blackleg	*Erwinia carotovora*	2	2.6
	Black scurf	*Rhizoctonia solani*	2	2.6
	Spraing	Tobacco rattle virus	1	1.3
	Silver scurf	*Helminthosporium solani*	1	1.3
Spinach (beet)	Powdery mildew	*? Erysiphe sp.*	1	1.3
	Leaf blotches	*? Cladosporium sp./R. beticola*	1	1.3
	Rust	*Uromyces betae*	1	1.3
Swedes	Downy mildew	*Peronospora parasitica*	1	1.3
Tomato	Blight	*Phytophthora infestans*	8	10.5
	Grey mould	*Botrytis cinerea*	3	3.9
	Damping off	*Rhizoctonia solani*	2	2.6

Virus	PMV	1	1.3

Publications and technology transfer during the project.

Awareness of this project was raised through contacts with advisers and growers. Features included Elm Farm Bulletin 43, p.4 (July 1999) and a report by G Davies entitled 'Scientific study to help organic veg growers' in '*The Organic Way*' Issue 159 (Spring 2000) pp. 18-19.
Davies, G (2001) Taking control. The Grower 22 March 2001 pp. 20-22.
Growers received details of the project at an HDRA/NIAB Vegetable Events Day at HDRA, November 1999, 2000 and 2001 and provided valuable feedback on their disease problems.
Lettuce disease management was featured at a growers event at HDRA in autumn 2001. Numerous farm walks involving individuals and a wide range of farmer and other groups have demonstrated the vegetable production experiments at Wakelyns Agroforestry, Fressingfield, Suffolk from 1999 onwards. These trials are still being continued and demonstrated (2002).

Two conference papers were published and presented as posters:
Davies, G, Lennartsson, M, Gladders, P, Wolfe, M, Haward, R (2000). Disease control strategies for organically grown field vegetables. *Proceedings of the BCPC Conference - Pests and Diseases 2000,* 3, 999-1004.
Davies, G, Lennartsson, M, Gladders, P, Wolfe, M, Haward, R (2000). Development of disease control strategies for organically grown field vegetables : the DOVE project. *Proceedings of the 13th International IFOAM Scientific Conference, Basel*.
Two draft papers for the BCPC Conference – Pests and diseases 2002 are in preparation.
Project booklet made available to organic vegetable growers:
Gladders, P, Davies, G, Wolfe, M, Haward, R (2002) Diseases of organic vegetables.
ADAS publication, 80 pp.

Priorities for future research

1. Further monitoring of organic crops is recommended to establish economic the importance of diseases, pests and weeds as these threaten the viability of organic systems. Studies on diseases should be extended to include winter crops and more diverse geographic areas, again with the inclusion of large and small growers.

2. Practical disease management techniques should be developed and evaluated at the field scale, possibly using participative research. This would include manipulation of rotation, crop scheduling and forecasting systems.

3. Control of seed-borne diseases in organic seed should be investigated as infected seed is the main source of diseases in some crops.

4. Soil amendments and plant conditioners have shown good activity against some fiungal pathogens and selected treatments merit investigation in larger scale studies.

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