CROP PROTECTION IN ORGANIC CEREALS - A PERSONAL VIEW

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ABSTRACT

A relative lack of research into soil microbiology limits our understanding of the concept of healthy soil/healthy crops. The microbial biomass in soil needs to be managed sympathetically to stimulate plant growth and the importance of adding organic matter to achieve this has been known for many years.

The practical control of weeds, pests and disease in an organic system is based on a sound rotation supplemented with mechanical operations carefully timed and executed. The choice of crops and varieties is important.

PRINCIPLES AND SOIL MICROBIOLOGY

Is conventional agriculture unscientific? Why ask such a question at a Symposium on crop protection in organic farming systems? So much is going on in the soil and yet relatively little research work has been carried out on the life within it. Most research has focussed upon the main nutrients: nitrogen, phosphorus and potassium, with some interest in trace elements. Hardly any attention has been given to the biological activity in the soil.

Whilst planning this paper, I received a telephone call from Gloucestershire, where our previous farm is now managed by the Royal Agricultural College. The crop lecturer had just walked the organic and conventional crops and remarked on how disease-free the organic crops were in comparison to the conventional which seemed so full of disease. This said it all. My question is - why were the crops so healthy?

We must look at what is happening in the soil to create these healthy crops - for nothing has been added from above. In my view, crop disease is one of the first signs of the loss of soil fertility. Over 100 years ago, the silt lands south of the Wash were famous for their pasture. This region became one of the principal potato growing areas in the country. When first ploughed, good crops were grown, but as more and more came under cultivation so there was a slow increase in disease. It is obvious to me that a healthy soil produces a healthy plant, but organic farming still has the label of "muck and mystery". That compost can introduce a high degree of resistance was documented by Sir Albert Howard (1940) when he described his Indore Method of compost making. The fact that many thatchers favour organic straw for their trade is because they find that it lasts up to twice as long as straw from conventional systems. This practical observation is supported by studies at Bath University and it indicates the extent to which organic crops may be able to resist disease both when they are growing and afterwards.

Turning to the complex biological processes in the soil, I would like to mention the role of mycorrhizal associations (MA). I believe they are an important part of the organic system, but so little work has been done that we cannot say with confidence what part they play. The association, which forms a 'bridge' between the humus in the soil and the roots of the plant, was first recognised as long ago as 1847. We know that organic matter in the soil encourages the association, but how well do we understand the effect that soluble fertilisers and pesticides have on soil fungi in general and mycorrizal fungi in particular? The analysis of compost and FYM does not adequately explain the increased nutrition of the plant, and so it seems self evident that MA provide something extra, and may also increase disease resistance. In addition we now know that many soil fungi release growth promoting substances.

The activity in organically managed soils has been simply demonstrated by Lady Eve Balfour (1943a), who reported that the inclusion of composted organic matter very significantly increased cellular decomposition. She buried cotton wool pads in untreated soil, woodland soil, and soil with compost added. After 4 months in the untreated soil, only 10% of the cellulose had decomposed; in the woodland soil 33.6%; but in the compost treated soil 91% of the pad had decayed. By implication, artificial fertilisers do not aid cellular decomposition.

Researchers at Rothamsted Experimental Station highlight the importance of microbial activity (Brookes, 1990). "Few farmers realise that below the soil surface exists a highly complex population of microscopic organisms that need to be managed as carefully as does the crop growing above the ground. They play a vital role in making nutrients accessible to plants and removing potentially harmful debris and waste from the soil." "This biomass is equivalent to 100 sheep per hectare, but none are visible to the naked eye." There are more 'goodies' in a teaspoonful of fertile soil than there are people in the world but, despite this huge number, they still need to be managed, tended and utilised. Their waste products act as a glue to bind soil particles together and improve structure. Some directly attack such pests as eelworm, thus reducing crop loss. At Rothamsted even the simple operation of incorporating straw has produced a doubling of microbial biomass in 7 days. Recent research also reveals a warning - bacteria, particularly those that fix atmospheric nitrogen, can be very severely affected by heavy metals in soil. Practices such as sewage sludge application must therefore be carefully controlled or it might be impossible to grow clovers in the future on contaminated land.

Sykes said many years ago that materialistic science may be misleading us. It seems to me that the area of nuclear energy and alternative sources of power can be used as an analogy with the situation which has developed in agricultural research. If a fraction of the research money that has been spent on nuclear power had been channelled into alternative energy sources, we surely would have a viable and safe alternative energy source today. In the case of agriculture, there has been an over-emphasis on soil chemistry since Liebig made his discoveries. Perhaps there is some truth in the saying that conventional agriculture is unscientific!

PRACTICALITIES

As an organic farmer I was asked about the practical implications of weed, pest and disease control. The most important issue is that the organic approach to crop production must involve looking at the whole. We have to think 'systems'. Here are two illustrations of the problems of failing to do this. Until recently some organic standards allowed the use of Chilean Nitrate as a top dressing. It was considered to be a "natural" material that is "only dug up out of the ground". However using such a soluble form of nitrogen laid the way open to elongation of the cell walls, rapid plant growth and increased disease incidence in crops. The second illustration comes from my own farm, where in our spring calving sucklers we had retained afterbirth in one heifer. A blood sample revealed severe selenium and copper deficiency. She had been wintered on silage from ground that had only received soluble fertilisers for the past 10 years without sufficient attention to the trace elements essential to provide a balanced nutrition.

Crop establishment

The first principle of organic crop protection is a nutritionally balanced plant able to compete with weeds and resist pest attack. Most organic cereals are grown after a 3-year ley. We would begin by putting on compost/FYM in the spring of the third year of the ley with lime and possibly rock phosphate and rock potash if soil analysis reveals that these are necessary. As far as possible, it is important to shallow plough since the biological activity is principally at the surface, which is where it should be kept.

When to plough? If we do it early to get a good weed strike, we risk a greater loss of nutrients. If you plant early the nutrients are not lost, and a winter grazing of the crop using sheep could be an option which can also be beneficial for disease control. If ploughing is late, there is less biological activity in the soil and hence less loss of nutrients. In addition there is less opportunity for weed control. Later ploughing and establishment avoids wheat bulb fly, but is only possible on lighter land. Elm Farm Research Centre have been carrying out a range of trials looking at the optimal time to break pasture and also exploring the best ways to integrate the use of cover crops within organic rotations.

A high seed rate is often beneficial, and the choice of the best variety with a strong ability to compete against weeds (long strawed rather than short) and good disease resistance is obviously very important. The use of variety blends is an approach to limiting the development of disease within a crop which may have potential as another weapon in our armoury. The use of seed produced on organic farms is considered to improve the vigour and health of the crop. Many organic farmers believe that farm saved seed, adapted to the particular conditions of the farm on which it is produced, can introduce resistance to diseases which are prevalent on the farm.

Weed control

It is important to stress that we are talking about weed control rather than weed elimination. The crucial approach to weed control, indeed the main feature of all organic agriculture, is the use of rotations. Without suitable rotations there is no organic farming - whatever you are growing - and this applies to livestock, cereals and vegetables. The best control is obviously a strong and healthy crop after starting with a high seed rate and good soil conditions. Rogueing can be completely effective, something which we know is not achievable by chemical control! The use of in-crop weed control can be useful, for example by the Tearaway weeder in a standing crop, although a high plant population is essential if this method is chosen. The use of inter-row hoeing in arable crops is an approach which although little used in this country at the present time could be of value in the future. All methods of mechanical weed control within the growing crop are considered to have the additional advantage of leading to soil disturbance, thus aiding aeration with the consequent mineralisation of nitrogen. It is very important that the timing of any cultivation aimed at achieving weed control is related to the time of weed seed germination as well as the development of the crop.

Pest and disease

Field size is an important aspect. Having a few large fields can lead to difficulties in establishing viable rotations. Hedges harbour predators of insects and a field size of larger than 25 acres means that the middle of the field is too far away to benefit from the hedgerow.

It has been shown that deficiencies of trace elements can lead to plants being affected by aphids. The enzymes that control cell metabolism are dependent on trace minerals and the availability of these is dependent on soil micro-organisms. The absence of trace elements means that some amino acids may be missing, which means weak plants, which in turn means vulnerability to attack.

Large quantities of green manure or FYM can significantly reduce the populations of eelworms due to the increase of predatory fungi and nematodes. Cultural activities are also important. Wireworms thrive under aerobic conditions, thus rolling the soil helps to reduce soil populations. Rolling can also control slugs to a great extent. The use of substances such as seaweed may be beneficial to improve crop health and by implication the resistance of the crop.

Perhaps I could end this section by quoting Lady Eve Balfour's theory on resistance (Balfour, 1943b). 1. The vigour of plants grown with added compost makes them able to repair damaged tissue much more quickly. 2. Organic crops are more nourishing, and therefore parasites are content with less. 3. The greater strength of cell walls offers resistance to insect mandibles. 4. Plants are less attractive, possibly due to a different 'smell'. 5. Pests are nature's way of removing the unfit.

Rotations

Rotations are vital to all organic systems - monoculture is not how God made the natural world. The best farmers are those who observe how nature operates with constant soil cover and the diversity obtained through variety in space and time. Rotations are vital for weed, pest and disease control. We need to break life cycles and the population of soil-borne pests and disease, for example cyst nematodes and eyespot and of course weeds. Black grass and sterile brome are indicative of poor or non-existent rotations. Wheat, wheat, barley, oil seed rape, is a sequence of crops, it is not a rotation which is viable from the point of view of organic farmers.

Finally those silent but most active of workers - the earthworm. In an average fertile soil, earthworms bring 25 tonnes per hectare per year of casts to the surface with their neutral colloidal humus. These casts contain five times more nitrogen, seven times more phosphate, eleven times more potash, and 40% more humus than is normally found in the top 15 cm of soil. Estimated numbers of worms at Rothamsted are 1.2×10^6 per hectare in unmanured land, 6.9×10^6 in FYM treated arable land and 21.5×10^6 in grassland - hence the importance of grassland in a rotation.

Can we possibly afford not to concern ourselves with all these vital issues of soil biological activity? They are certainly most important for weed, pest and disease control in organic production.

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6.
Posters

WEED STUDIES IN ORGANIC AND CONVENTIONAL CEREALS

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ABSTRACT

Weed occurrence and distribution was compared in fields recently converted to organic production with fields in an intensive arable rotation. There was a greater range and number of weeds in the organic crops. Alopecurus myosuroides and Galium aparine were the main weeds in the inorganic crops; these weeds were only present at very low levels in some of the organic fields. The most important weeds occurring in the organic crops were perennials such as Poa trivialis, Cirsium arvense and Rumex spp.

INTRODUCTION

In the autumn of 1987 the Royal Agricultural College started share farming at Harnhill Manor Farm, Cirencester. The total farm is 243ha with 48ha certified by The Soil Association (The Soil Association, 1989) for organic production. Conversion to organic production began 8 years ago.

It is often assumed that organic production will lead to a serious build up of weed problems. In 1987 the Weed Research Division (WRD) at Long Ashton Research Station undertook weed monitoring on 2 organic fields at Harnhill (Wilson 1988). This has been continued by staff and students at the College. Most of the organic cereal crops have been monitored since 1987, some conventional crops have also been included.

MATERIALS AND METHODS

Weed species and distribution were monitored using a WRD system (Wilson et al., 1982). Most fields were monitored in the spring and/or summer on an approximate 40m square grid. Every 50 paces weeds were recorded using 4 quadrats at each site ($0.1m^2$ or $0.125m^2$).

Rotations on the organic and conventional fields are very different (Table 1). Cereals are only grown 3 years in 7 in the organic rotation, and most were harrowed in the spring between crop tillering and stem extension. The conventional fields are mainly in a continuous arable rotation and were treated with standard broad spectrum grass and broadleaved weed herbicides e.g isoproturon plus diflufenican.

TABLE 1. Crop Rotations.

Field Number Organic fields	Year 1986/87	 1987/88	 1988/89	 1989/90
1	L	L	WW*	SO
2	CL	W & SW*	SO	RC
3	RC	WW*	WR	CL
4	WW*	SO	RC	WB
5	CL	CL	CL	WW*
6	CL	WW*	SO	RC
7	WO	SB	WW	CL
Inorganic Fields				
1	WB	WOSR	WW	WW
2	WW	WB	WOSR	WW
3	WB	SB	WB	Ley

*First organic wheat crop

Key

L = Lucerne	WW = Winter wheat	WOSR = Winter oilseed rape
CL = Clover/Ley	WO = Winter oats	SO = Spring oats
RC = Red Clover	WR = Winter rye	SB = Spring barley
	WB = Winter barley	SW = Spring wheat

RESULTS

A larger range of weed species was recorded in the organic compared with the herbicide treated crops (Table 2). The largest number of species was usually recorded in the winter cereal crops.

In the conventionally grown crops Alopecurus myosuroides and Galium aparine were the most commonly occurring weeds remaining after treatment. Only very occasional plants of A. myosuroides have been found in five of the organic fields.

The main weed problem in the organic fields has been from perennial weeds (Table 3). One field (6) has a large area infested with Cirsium arvense. There have occasionally been high levels of Poa trivialis and volunteer Trifolium spp. The small areas of Elymus repens and Rumex spp. have had a similar distribution through the years of this study.

One weed that has not been recorded in the conventional arable fields at Harnhill but is found in most of the organic fields is Petroselinum segetum (corn caraway).

In the organic crops most of the annual weeds died back before harvest and did not pose any combining problems. The perennial weeds affected ease of harvesting. Field 6 yielded 1t/ha less of spring oats in 1989 than field 2. This yield reduction could partly have been due to the weed population as well as later drilling.

TABLE 2. Main weeds recorded during years of assessment and highest number of weed species recorded.

Field number	Main weeds recorded (Year)	Highest number of species recorded (Year)
Organic fields		
1	Veronica hederifolia Poa annua Taraxacum officinale	19 (1989)
2	Myosotis arvensis Lamium purpureum Trifolium spp. Cirsium vulgare (1990)	22 (1988)
3	Lamium spp. Stellaria media Poa spp. Veronica spp. Trifolium pratense (1988)	24 (1988)
4	Lamium purpureum Rumex spp. Poa annua Poa trivialis (1987) Lolium multiflorum (1990) Papaver rhoeas (1990)	20 (1987) & (1988)
5	Sinapis arvensis (1990) Stellaria media Veronica persica Rumex spp. Avena spp. (1990)	19 (1990)
6	Cirsium spp. Rumex spp. Poa trivialis Lolium spp. (1988) Polygonum spp. Veronica spp.	15 (1988)
7	Stellaria media Polygonum spp. Rumex spp.	20 (1987)
Conventional fields		
1	{ Alopecurus myosuroides	5
2	{ Galium aparine	4
3	{ Veronica spp.	3

TABLE 3. Presence of Alopecurus myosuroides, Elymus repens, Rumex spp. and Cirsium spp. in organic and conventionally grown cereals.

Field Number	A. myosuroides	E. repens	Rumex spp.	Cirsium spp.
Organic fields				
1	*	0	*	0
2	*	0	0	*
3	0	*	*	0
4	*	*	*	0
5	*	0	*	0
6	0	*	*	*
7	*	0	*	*
Conventional fields				
1	*	0	*	0
2	*	0	*	0
3	*	0	0	0

* Present
0 None Recorded

DISCUSSION

Due partly to the differences in the rotations and in the crops grown, weed problems were different in the organic and conventionally grown crops. Where they are present perennial weeds are more of a problem in the organic fields than are the annuals. The stale seedbed technique and late sowing were used to reduce weed populations in the organic crops, as well as within crop cultivations in the spring.

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THE USE OF SURFACE MULCHES TO CLEAR GRASS PASTURE AND CONTROL WEEDS IN ORGANIC HORTICULTURAL SYSTEMS

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ABSTRACT

Carpet, cardboard, black polythene and hay were used as soil surface mulches to clear an established grass pasture and its associated weeds. These methods were compared with machine rotovation. The clearing techniques were shown to influence yield of Brussels sprouts and onions grown during and after the clearing period respectively. The diversity and abundance of weeds in the season following the removal of the mulches were also influenced by the method of clearing.

Biodegradable and non-biodegradable soil surface mulches were used, in different trials, to control the growth of weeds in annual and perennial crops.

INTRODUCTION

As alternatives to hand or machine cultivation, organic or non-biodegradable soil surface mulches can be used to clear land of weeds, grass pastures, green manures or to control weeds in annual or perennial crops. At present, light exclusion techniques for land clearance are almost exclusively used on a small scale, for example in gardens. However, materials like black polythene, poly-propylene and paper are used for weed control in a wide range of horticultural crops grown commercially.

Soil surface mulches are used to improve soil moisture retention, manipulate soil temperature, conserve and improve soil structure and to supply plant nutrients, as well as to control weeds.

METHODS

Mulches to clear grass pasture

Carpet, cardboard, black polythene and a thick layer of hay (20cm) were used as light excluding mulches to clear a grass pasture and its associated weeds. These methods were compared with machine rotovation. After mowing the pasture, the plots (3m x 4m) were covered with the different mulches for 12 (March 1988-March 1989) or 18 (September 1987-March 1989) months. Brussels sprouts (Brassica oleracea var. gemmifera cv. Telda) were grown (June 1988-February 1989) through the mulches to assess whether the land could be productively used whilst being cleared. Onions (Allium cepa cv. Turbo) were grown (April-August 1989) in the first season after the removal of the mulches and the yield of both of these crops were recorded. The abundance and the diversity (results not presented here) of weeds in the first season following the clearing period were also assessed. Full experimental details are described in Lennartsson et al. 1990.

Mulches to control weeds in annual and perennial crops

Biodegradable and non-biodegradable mulches were used for dwarf French beans (*Phaseolus vulgaris* cv. Marcello) and for strawberries (*Fragaria* x *ananassa* cv. Cambridge vigour), planted in the autumn. In both trials the treatments were: bare soil; soil covered with Plantex (a non-woven, water permeable, 100% polypropylene, manufactured by DuPont de Nemoures, Luxembourg); soil covered with Plantex with a layer (3-5cm) of leafmould on top; soil covered with leafmould on its own and soil covered with black polythene. In these trials the mulches were evaluated in terms of their effect on the moisture retention and temperature of the soil, on the establishment, growth and yield of the plants and on the occurrence of weeds. The results of the yield and weed assessments have been presented here.

In another trial, two mulches were used for growing potatoes (*Solanum tuberosum* cv Desiree). Plants were grown according to a no-dig method, in which the seed tubers were placed on the soil surface and then covered with a deep (30cm) organic mulch consisting of composted farm yard manure, wet hay and grass mowings. This treatment was compared with cultivation through black polythene and in bare soil. The aim of this experiment was primarily to compare the yields of the different growing techniques. The plots were kept free of weeds by regular hoeing and no assessments were made on the occurrence of weeds. Lennartsson (1988) describes further details of this experiment.

Biodegradable mulches have also been used on a practical basis for a wide range of soft and top fruit. For this purpose the soil around the base of the fruit is covered, annually, with a layer (20cm) of hay, either on its own or on top of newspaper or cardboard. The mulch is topped up with grass mowings at regular intervals throughout the growing season. The purpose of this mulch is to improve the moisture retention and the structure of the soil and to supply nutrients, as well as to control weeds.

RESULTS AND DISCUSSION

Mulches to clear pasture

The grass pasture was effectively cleared by all of the light excluding mulches and there were no visible differences whether the pasture had been covered for 12 or 18 months. Only minimal cultivation with a garden rake was required to produce a tilth suitable for planting onion sets.

The results showed that it was possible to use the land whilst clearing it, by growing Brussels sprouts through the mulches. The yield however, was influenced by the method of clearing. Plants grown through hay mulch produced the highest yield and plants in rotovated soil the lowest (Table 1). The yield differences were thought to be related to the availability of nutrients in the soil. Apart from an application of rock phosphate, no additional nutrients were applied to the Brussels sprouts and, as expected, some plants showed nitrogen deficiency symptoms. Plants grown in rotovated soil appeared to have least nitrogen, which was probably because soil nitrogen was immobilized during the decomposition of the incorporated pasture. In the other treatments the organic matter was left on the soil surface and the decomposition did not appear to influence the availability of nutrients around the roots of the plants. Mulching with hay was the only treatment which involved an addition of nutrients and nitrogen was probably released into the soil as the hay was decomposed and leached by rain. The low yield from plots with cardboard was due to mechanical damage of some plants, as the cardboard was moved by wind.

The yield of onions, grown in the first season after the clearing period, was also affected by the method of clearing. The highest yield was obtained in plots cleared with hay (Table 1). Again, the yield differences were thought to be due to the differences in the availability of nitrogen in the soil.

The recurrence of weeds in the first season after the clearing period was also influenced by the clearing method. In May 1989 the abundance of weeds was significantly greater in plots cleared by rotovation than in plots cleared with mulching (Table 1). The greater abundance of weeds in these plots was primarily due to rampant growth of corn spurry (_Spergula arvensis_). Rotovating the soil must have triggered the seeds of this species to germinate. Only a few specimens of this species were present in the other plots (Lennartsson _et al_, 1990).

TABLE 1. Yield of Brussels sprouts and onions, grown during and after the clearing period respectively. Abundance of weeds in the first season after the clearing period. Values followed by different letters are significantly different at $p<0.05$ (Tukey's test). Compare values in vertical columns only.

	Yield (kg/m^2)		Dry weight of weeds (g/m^2)	
Treatment	B. sprouts	Onions	May '89	July '89
Carpet	0.992 b	2.469 a	88.9 a	275.5 a
Cardboard	0.633 a	2.619 ab	61.8 a	350.3 a
Black polythene	1.104 b	2.755 ab	37.2 a	242.1 a
Hay	1.158 b	3.422 b	70.3 a	257.0 a
Rotovation	0.620 a	2.354 a	164.6 b	300.0 a

Mulches to control weeds in annual and perennial crops

Mulching with black polythene or Plantex, with or without leafmould on top, successfully controlled the weeds in dwarf french beans. Leafmould on its own also controlled the weeds to some degree (Table 2). There were no clear advantages of the mulches in terms of yield of the dwarf French beans (Table 2).

Black polythene and Plantex with leafmould on top provided effective weed control in the trial with strawberries as well (Table 2). However, Plantex on its own was unsatisfactory, as the polypropylene was not sufficiently opaque to prevent weeds from growing. In this treatment the development of the strawberries was severely restricted due to intense competition with weeds growing underneath the mulch. As a result, the yield of strawberries in the first season was low (Table 2). Leafmould on its own was also unsatisfactory in terms of weed control.

As in the previous trial, neither of the mulches improved the yield of the strawberries. Despite the fact that the soil moisture retention was improved by the mulches, particularly by the leafmould (unpublished data), this appeared to be of no direct benefit to the plants. The highest yield was in fact obtained from plants grown in bare soil (Table 2).

TABLE 2. The effect of mulching dwarf french beans and strawberries on crop yield and abundance of weeds. Values followed by different letters are significantly different at $p<0.05$ (Tukey's test). Compare values in vertical columns only.

Treatment	Yield (kg/m^2)		Fresh weight of weeds (g/m^2)	
	Beans	Strawberries	Beans1	Strawberries2
Bare soil	2.60 a	0.328 b	545 a	1330 b
Plantex	2.71 a	0.048 a	29 b	nd3
Plantex/leafmould	2.52 a	0.123 a	83 b	520 a
Leafmould	2.66 a	0.173 ab	225 b	1940 b
Black polythene	2.62 a	0.267 b	4 b	0 a

1 - total weight of weeds removed from July 1988 - September 1988.
2 - total weight of weeds removed from Septmber 1989 - August 1989.
3 - nd means not determined.

In the trial with potatoes, the yield was not significantly different whether the plants were grown in bare soil or through black polythene. However, the yield was significantly reduced when the plants were grown through the hay mulch. This was thought to be the result of an inadequate and irregular supply of water for the plants as the mulch dried in the wind.

Mulching with hay was also shown to influence the incidence of tuber blight (Phytophthora infestans). 44.4% of the yield from bare soil was damaged by blight, compared with only 14.1% when the plants grew in the hay. The dense organic mulch was thought to have prevented the spores from reaching the tubers, whilst in bare soil they were readily washed down to the tubers. The black polythene was not an effective barrier for the spores and 45.5% of the yield were damaged by blight. In these plots the rain collected on the plastic and then drained towards the planting holes, thus the spores were directed to the plants (Lennartsson, 1988).

TABLE 3. Yield of potatoes and extent of damage by blight. Values followed by different letters are significantly different at $p<0.05$ (Tukey's test). Compare values in vertical columns only.

Treatment	Total yield (kg/m^2)	Tubers damaged by blight (%)
Bare soil	5.6 a	44.4 a
Hay	3.7 b	14.1 b
Black polythene	5.5 a	45.5 a

CONCLUSIONS AND REMARKS

The results of these experiments have confirmed that a wide range of soil surface mulches can be used both to clear pasture and to control weeds in annual and perennial crops.

Carpet, cardboard, black polythene or hay were used effectively to clear a grass pasture with abundant weeds. The hay mulch was the best treatment in terms of the yield of crops grown during and after the clearing period. The yield differences between the treatments were thought to be related to the availability of nutrients in the soil.

The limitations for clearing land with light exclusion techniques are obviously the practical problems of covering large areas, the cost of the mulches and the time involved. However, the results of this study suggest that light exclusion techniques may offer a way of manipulating the mineralization or the immobilization of nitrogen during the decomposition of organic matter. It may, therefore, be worth looking into how these methods could be adapted for use on larger scale eg. to clear weeds or green manures in horticultural bed systems.

Growing annual or perennial plants through black polythene was an effective way of controlling weeds. The water permeable polypropylene, Plantex, also controlled weeds effectively when used for dwarf french beans. However, Plantex on its own was not effective when used on a longer term to control weeds during the establishment and first season of strawberries. The polypropylene was not sufficiently opaque to prevent the weeds from growing underneath the mulch. The effectivness of the Plantex in terms of weed control was improved when it was used with leafmould on top.

Weeds in annual and perennial crops were also controlled by mulching with organic materials eg. hay. The nature of the materials and the thickness at which they are used are important factors for their effectiveness to control weeds. The results of this work showed that the use of hay mulch on potatoes reduced the incidence tuber blight.

In practice the benefits of controlling weeds with mulches will have to be considered together with the cost and practicalities of using them.

For whatever purpose a mulch is used, it is important to consider the potential environmental problems of using man-made products like polythene, cardboard and carpet. It is not known what their break-down products are or how they influence the soil, chemically, physically and biologically.

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THE FLAME TREATMENT OF WEED SEEDLINGS UNDER CONTROLLED CONDITIONS

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ABSTRACT

In order to investigate the effect of flames on the survival of seedlings, tests were carried out on plants produced in a glasshouse. Seedlings which had germinated over a short period were best treated at an early plant growth stage, whereas for those plants, more representative of a weed population which emerged over a longer period, a later treatment was more effective. These findings were supported by the results of a field experiment.

INTRODUCTION

Flame weeding is an integral part of the weed control strategy for many organically produced row crops. In UK conditions flaming is an appropriate pre-emergence operation for horticultural crops which are slow to germinate, for example carrots and parsnips. Crops which can tolerate severe heat at some growth stages after emergence, for example onions, are suitable for post emergence flame weeding (Parish, 1990). The use of flaming in crop production has been an established technique for several decades, for operations such as the destruction of bulb foliage, and straw burning, as well as for weed control (Wolfe and Horton, 1958). The first equipment designs were based on the use of paraffin or vapourising oil, whereas more recent developments use liquified petroleum gas (LPG), usually propane, as the fuel. Much of the early work on flame weeding was discontinued due to the development of effective synthetic herbicides, and the increase in oil prices.

The increase in the production of organic food crops has renewed interest in flame weeding, especially for weed control within the crop rows. In mainland Europe, where the demand for organic food preceded that in the UK by several years, a number of workers have been developing flame weeding equipment, and carrying out field trials (Castille, 1984). However, because of the wide range of equipment developed and used under diverse conditions, it has been difficult to compare the results obtained by such work.

In order to assess the effect of a range of flaming equipment, a procedure was developed to grow trays of seedlings in a glasshouse, and treat them on an experimental rig under controlled thermal conditions (Parish, 1989). Experiments were initially carried out using white mustard (Sinapis alba) and Italian ryegrass (Colium multiflorum) as standard plants. The seeds were sown in narrow bands into compost, and the seedlings were subjected to a range of treatments, where the variables included burner design, gas pressure, forward speed, burner angle and burner height. The tentative conclusions drawn from this work were that treatments at earlier plant growth stages were more effective, as were higher gas pressures and slower forward speeds, but the best position (ie height and angle) for the burner depended on its design.

THE EXPERIMENTAL PROCEDURE

The experimental rig was used to treat a range of plant species. Previously established criteria for effective use of the burners are shown in Table 1, and experiments were carried out to investigate the effect of the timing of the flame treatment.

TABLE 1. Criteria for burner use in the experiments.

Burner	Pressure	Gas use	Speed	Angle	Height
diameter 25 mm	2 bar	0.46 kg/h	0.5 m/s	60°	100 mm
diameter 30 mm	1 bar	0.60 kg/h	0.5 m/s	60°	100 mm

Plant trays were prepared, and randomly allocated to the three treatment timings, which were: early, early and late (ie treated twice), and late. For grasses, the early stage was defined as shoot emergence only, and the later stage as the 2 or 3 leaf stage. For the broadleaf plants, the stages were cotyledon leaves only, and the first true leaf stage. The data collected per plant tray included the number of seedlings emerged by the treatment date, the number of seedlings to have survived the treatment by at least two weeks, and the dry weight of survived seedlings, cut at the compost surface. The results presented here are based solely on the number of survived seedlings, expressed as a percentage of the number emerged at treatment. For plants which did not germinate evenly, a value exceeding 100% was therefore possible.

Experiments were carried out on mustard and ryegrass, and on a range of weeds species. Of the latter, only those which germinated in sufficient numbers were treated.

Results from the experiments

Results from the treatment of the plants grown as standards (Figure 1) reinforce the view that grasses are more resistant to flaming than broadleaf plants. The mustard was more susceptible to heat at the early stage than at the later stage, and the repeated treatment was even more effective.

For comparison with the weed species, mustard and ryegrass were also included in the later experiments. The data was combined into grass and broadleaf categories, as shown in Figure 2. The poor effect on the grasses suggests that the flame treatments were of insufficient severity to affect these plants, but results from the broadleaf plants show an interesting trend. In contrast to the treatment of mustard, the later treatment was more effective on the broadleaf weeds than the early, although a double treatment was again the most effective. The explanation for this is likely to be the range of seed emergence times for the wild species, whereas the crop species germinated and emerged more evenly. The inference to draw from this would be that under field conditions, a later flame treatment would be more effective than an early treatment.

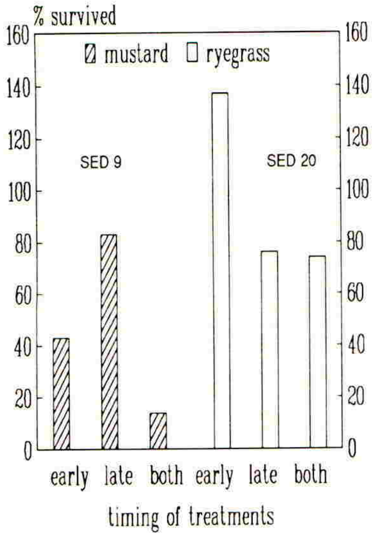

FIGURE 1 Effect of treatment timing on standard plants

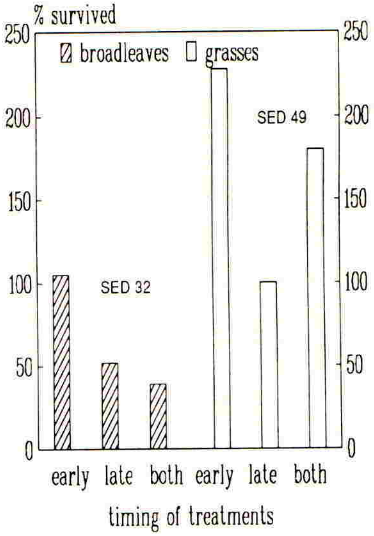

FIGURE 2 Effect of treatment timing on weeds.

THE FIELD TRIAL

A field trial was carried out in parallel with the indoor work. The main aims of the trial were to compare the effects of the two burners and the timing of the flaming operations on the weeds, and the trial was also taken through to harvest. The field used was in its second year of conversion to organic vegetable production and was sown with two 5 row 1.8 m beds of carrots. Each bed was divided into 4 blocks of 8 plots, each 3 m in length. The 8 treatments were randomly allocated into each block in turn. The outer rows of each bed were regarded as guard rows, and therefore data was collected from the central metre length of the inner 3 rows per plot. The burners used were the same as those used for the experimental rig, but used manually.

The variety Autumn King was sown on 4.6.89, and the appropriate plots flamed on 12.6.89 and/or 15.6.89. Weed numbers were counted on 13.7.89, in the crop rows, using a 100 mm by 500 mm (0.05 m^2 area) wire frame, some six weeks after sowing. All plots were inter row cultivated twice, and a handweeding operation was carried out over the period 28.7.89 to 1.8.89. The plots were harvested over the period 1.11.89 to 15.11.89.

Results from the field trial

No difference between the two burners could be detected from an analysis of variance (Figure 3) with a similar effect obtained from each on both weeds and crop yield. The effect of the timing of the flame treatments is shown in Figure 4. The plots subjected to the later and double treatments produced fewer weeds and greater carrot yields than those flamed earlier, or not flamed at all. The increased yield from the double treatment cannot be easily explained by the weed data alone.

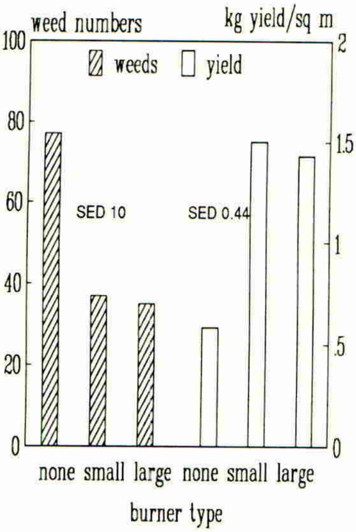

FIGURE 3 The effect of burner size on weeds and yield.

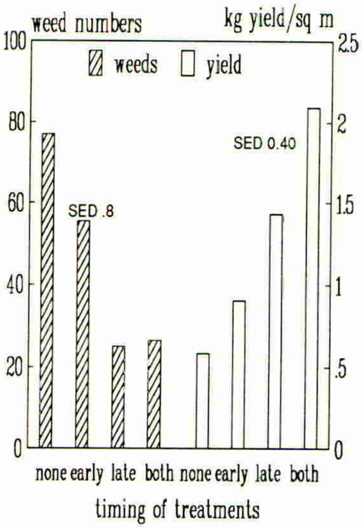

FIGURE 4 The effect of treatment timing on weeds and yield.

CONCLUSIONS

The results tend to confirm the currently accepted technique for pre-emergence flame weeding, which is to leave the flaming operation as late as possible before crop emergence. In this way as many weeds as possible will be treated, although not all will be at their most susceptible growth stage. Treating at two separate stages will be both gas and time consuming, but has the advantage that if, due to adverse conditions, the later treatment cannot be carried out, then at least the first treatment will have had some effect on weed numbers.

ACKNOWLEDGEMENT

This work was funded by a research grant from the Leverhulme Trust, and loan of gas equipment was provided by Calor Gas Limited.

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CROP COMPETITIVENESS AS AN AID TO WEED CONTROL IN CEREALS

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ABSTRACT

There is much interest in the effect of environmental and crop factors on the modification of herbicide dose to control weed populations. Results presented suggest high cereal crop ground cover is very important in limiting weed growth, but herbicide efficacy can be both enhanced and reduced by dense competitive crops. The latter may be overcome by spraying before stem extension.

INTRODUCTION

Reduction in herbicide rate to control broadleaved weeds in cereals is both economically and environmentally desirable. A reduced rate approach has several advantages over a threshold system based upon a spray/no spray decision. The main advantage is that it is easy to communicate to farmers who will readily accept such advice because they are seeking to cut costs, but are not neccessarily willing to withold herbicide completely because they perceive the cost of allowing weeds to remain uncontrolled as high relative to the cost of control.

A trial series started in Scotland in 1989 began an investigation into the control of broadleaved weeds in cereals at reduced rates of herbicide. Initial results suggested crop competition may be important in reducing weed growth and enhancing herbicide activity. Richards (1989) had identified differences in weed competition between winter wheat varieties and a trial was carried out in 1990 to investigate the interaction between variety of winter wheat and herbicide rate.

MATERIALS AND METHODS

Winter wheat trials in 1989 compared reduced (full, half, quarter and eighth) rates of autumn applied diflufenican/IPU and spring applied metsulfuron-methyl + mecoprop. The trials were in Fife, the Borders and East Lothian including sites at Markle Mains and Upper Dalhousie. The trial methods were reported fully by Whiting and Davies (1990).

In 1990 a trial was conducted comparing weed growth and control in five varieties of winter wheat which were known to have varying competitive abilities: Apollo, Fortress, Mercia, Parade and Slejpner. All varieties were sown on 6.10.89 at a seed rate of 200 kg/ha in 12cm rows. Variety was the mainplot and herbicide treatment (untreated, metsulfuron-methyl + mecoprop at 15g+690g/ha - half rate, or 1.88g+172g/ha - eighth rate) the subplot. Each plot was 2 x 22m with three replicates. Herbicides were applied with a van der Weij knapsack sprayer at pressure of 210 kPa in a water volume of 200 l/ha with a 2m boom (Table 1.). Assessments of earliness of crop ground cover (score 1-9, 9=early) and per cent weed ground cover were made visually.

TABLE 1. Site and spraying details variety x herbicide trial, Ploughlands 1990

Grid reference	NT 630 307
Elevation	76m
Soil type	Sandy Loam
Date of herbicide application	18.4.90
Crop growth stage at spraying	Zadok's GS 31
Weed size at spraying	Fumaria officinalis - 20cm Stellaria media - 20cm

RESULTS AND DISCUSSION

In the trials in 1989 it was found that there was a good correlation between crop ground cover in the spring and ground cover/S. media plant in untreated plots (fig. 1). This reduction in weed growth in trials in which crop ground cover was high seemed to explain differences in control between sites. At both Markle Mains and Upper Dalhousie crops of Riband were sprayed on 25.3.89, the main difference between the sites was the greater crop ground cover at spraying of the earlier drilled crop at Markle Mains. Figure 2. shows the dose response curves, calculated using the method described by Streibig (1988), for the two sites.The herbicide rate calculated to give 90% control (ED90) of the S. media population at Markle Mains was 27.2% of the full herbicide rate compared to 73.1% at Upper Dalhousie. Thus it seemed that crop competition may have enhanced herbicide efficacy and could allow lower herbicide rates to be used to achieve a given level of control.

In the 1990 trial comparing varieties and herbicide rate there was a relationship between earliness of crop ground cover and ground cover of F. officinalis in the untreated (fig. 3.). Again this suggested weed growth was suppressed by varieties such as Apollo which achieved ground cover early. However, when dose response curves were constructed for the five varieties it was found that weed control was poorer at low rates for some varieties, Mercia and Fortress, that achieved ground cover earlier compared to the very poor competitor Parade (Table 2.). This would seem to indicate that varieties with a high ground cover intercepted a greater proportion of the herbicide thus reducing herbicide efficacy. Some indication of higher crop ground cover at spraying is given by scores of crop canopy density at GS. 39. The effect of the crop on spray penetration was probably heightened by spraying at GS 31 when the crop was erect and the spray had further to fall through the canopy.

TABLE 2. Crop growth and ED 90 values for herbicide x variety trial, Ploughlands 1990

Variety	Earliness of ground cover (1-9, 9=early)	Canopy density crop GS 39 (1-9, 9=dense)	ED 90 % full rate of herbicide
Parade	5.0	6.0	17.1
Slejpner	7.0	7.0	17.7
Fortress	7.0	7.7	21.0
Mercia	8.0	7.7	20.1
Apollo	8.7	7.0	14.1
LSD	1.0	0.9	

FIGURE 1. Effect of crop ground cover in spring on *S. media* growth in untreated plots at all sites in 1989

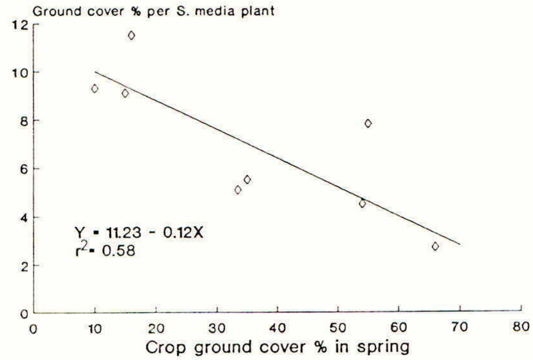


FIGURE 2. Dose response curves - control of *S. media* with metsulfuron-methyl and mecoprop at Upper Dalhousie and Markle Mains 25th March 1989

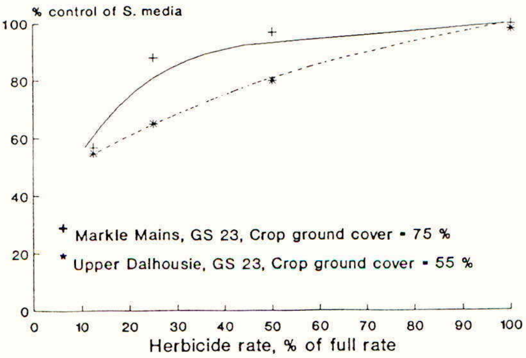
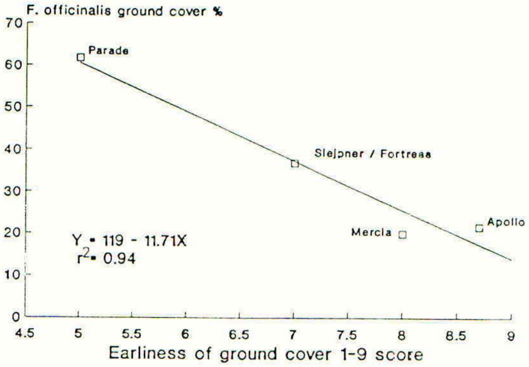


FIGURE 3. Effect of earliness of crop ground cover on weed growth in untreated plots, Ploughlands 1990



CONCLUSIONS

1. Differences in crop ground cover between and within varieties can both enhance and reduce herbicide efficacy. Possible reductions in herbicide efficacy may be avoided by spraying cereals before stem extension.

2. Crop ground cover should be maximised in both conventional and organic systems to optimise weed suppression.

ACKNOWLEDGEMENTS

The support of these trials by the H-GCA is gratefully acknowledged. We would like to thank the farmers on whose farms the trials were carried out.

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NITROGEN UPTAKE AS A MEASURE OF WEED COMPETITION IN ORGANIC CEREAL CROPS

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ABSTRACT

During a two year study nitrogen uptake by cereal crops and the accompanying weed flora was determined in a number of organic fields. Broadleaved weeds were generally well controlled by farm practices and were adequately suppressed by crop growth. Rough stalked meadow grass was potentially a greater problem. In 1986 Sinapis arvensis and Polygymum spp adversely affected a late developing crop of spring wheat. This was the only one of five crops where a large yield benefit was demonstrated when hand weeding was undertaken. The results indicate that on this farm, weed competition was generally at a low level but weather and soil conditions can lead to significant problems in some crops.

INTRODUCTION

Weed control in cereals is often viewed as a major limitation to organic cereal production particularly by those farmers using herbicides. In practice most organic farmers find that acceptable control can be achieved by employing rotational practices, timely cultivations, and stale seed bed techniques supplemented if necessary by within crop cultivation. This paper reports results from two years of study into the weed flora, nitrogen uptake and grain yield on an organic farm. The work was part of a larger monitoring exercise which had identified areas of approximately 1 ha for study in a number of fields on the organic farm and on neighbouring conventional holdings. The nitrogen inputs to the organic system under consideration was restricted to that supplied by grass/clover or clover leys and relatively small quantities of farm yard manure. One measure of weed competition which may be particularly relevant in a system where nitrogen availability is limiting production is nitrogen uptake by the weed flora present.

METHOD

Field work was undertaken in the harvest years of 1985 and 1986 on a farm which was completing conversion to Soil Association standards (1987). All fields studied had attained symbol status. The basic rotation was 3 year grass-clover ley/winter wheat/winter wheat/1 year red clover or grass-red clover ley/winter wheat/spring oats. Late summer (bastard) fallowing is employed together with a stale seed bed technique. Within crop weeding was not undertaken. The soils were either calcareous rendzina's over Upper Chalk (Upton series) or calcareous loams/clay loams formed on colluvial chalk deposits or on Lower Chalk. Surveys of the weed flora were made in 10 randomly selected 0.25 m^2 quadrats within the identified areas but full results are not reported here.

NITROGEN UPTAKE

On 25 April 1985 weed and crop were destructively sampled in 10 x 0.25 m^2 in each of 5 organic fields. The sampling was repeated on a further 10 quadrats between 23-30 June when a further 2 fields were also sampled. A similar technique was employed on 7 July 1986 in 7 fields, although only one of these had also been sampled the previous year. The collected biomass was separated and analysed to determine the partitioning of nitrogen uptake between weeds and cereals.

YIELD EFFECT

In order to assess the potential effect of the weed population on grain yield, 10 x 1 m^2 quadrats were hand weeded on 25 April 1985 and again on 11 June. Nitrogen uptake into the weeds was determined by analysis and compared with the nitrogen uptake by the crop in late June. The sampling was undertaken on two crops of winter wheat grown after 1 year red clover leys. The weeded quadrats were hand harvested on 26 & 28 August together with paired control quadrats identified earlier in the season with comparable crop and weed populations. The ear samples were threshed and cleaned on bench top equipment and grain yields corrected to 86% dry matter.

In 1986 weeds were removed only one occasion. On 18 April from a crop of winter wheat grown after a one year red clover/Italian ryegrass ley, on 16 May from a winter wheat crop which had been oversown with spring wheat being a second cereal crop after a long term (8 year) grass/clover ley, and on 25 May from a crop of spring wheat grown after winter grazed fodder roots. The weeded quadrats and controls were harvested on 27 and 28 August and samples treated as in the previous year.

RESULTS

The organic crops made slow growth in the spring of both years. In 1986 poor establishment the previous autumn together with winter kill resulted in overdrilling on a number of fields. This was followed by dry conditions, in contrast to 1985 when subsequent crop growth had been favoured by regular rainfall. The results of the nitrogen monitoring are shown in Table 1. Growth of both weeds and cereals were restricted in the spring of 1985. By late April 17-35% of total nitrogen uptake was in the weed flora. However subsequently the crops suppressed the weeds and uptake only represented 2-9% by late June. Weed populations were more variable in 1986 and represented 1-62% of total N uptake by early July. The highest value was found in the spring wheat grown after fodder roots where a severe infestation of charlock (Sinapis arvensis) 55 plants/m^2 had developed together with polygymum spp at 60 plants/m^2.

Nitrogen uptake by the cereal crops was low by conventional standards. For example, in April 1985 it varied from 10-23 kg/ha N and in June from 38-122 kg/ha N.

TABLE 1 NITROGEN UPTAKE INTO WEEDS, 7 FIELDS IN EACH OF TWO YEARS EXPRESSED AS kg/ha AND % OF TOTAL CROP AND WEED UPTAKE

1985				1986	
April		June		July	
N Uptake kg/ha	% N Uptake in weeds	N Uptake kg/ha	% N Uptake in weeds	N Uptake kg/ha	% N Uptake in weeds
2.5	17	1.5	4	5.3	14
2.6	20	5.4	9	2.1	5
9.5	31	1.9	2	16.7	62
13.5	35	2.8	4	14.6	3
14.0	18	2.5	4	5.8	10
-	-	0.8	1	10.7	32
-	-	4.6	10	0.7	1

The results of the yield assessments are given in table 2 together with the proportion of nitrogen in the weeds expressed as a proportion of the N uptake in early July.

TABLE 2 YIELD OF WEEDED AND UNWEEDED CROPS (kg/ha AT 86% DRY MATTER) WITH NITROGEN UPTAKE BY WEEDS AS % OF TOTAL N UPTAKE BY WEEDS AND CROP

	Crop	% N Uptake		Yield kg/ha (SE)		
		April	June/July	Control	Weeded	% response
1985	Winter Wheat	9	4	5204 (±303)	5410 (±589)	+4.0%
	Winter Wheat	5	6	3589 (±996)	3268 (±570)	-8.9%
1986	Winter Wheat	-	<1%	6818 (±609)	6272 (±686)	-8.0%
	Winter and Spring Wheat	-	2%	5224 (±626)	5457 (±828)	+4.5%
	Spring Wheat	-	62%	2718 (±718)	3347 (±372)	+23.1%

DISCUSSION

The only grass weed of significance noted in the two years was rough stalked meadow grass (Poa trivialis) which in 1985 appeared in one field with a crop thinned by winter kill. By late June it contained 10% of total N uptake. The problem was more widespread the following year. Polygymum spp were also a greater problem in 1986 and together with Sinapis arvensis caused a major problem on one monitored field. In general however at the level of nitrogen availability pertaining in this system and with the cultivation practices in operation the organic crops were generally able to compete successfully with the weed flora. In only one case was a large proportion of the available nitrogen taken up by weeds. Whilst the crudeness of the technique is acknowledged, this was the only one of five assessments where removing the weeds, gave a large benefit in final cereal yield.

ACKNOWLEDGEMENTS

We are indebted to Mr Barry Wookey for facilities to undertake this work and to the Ministry of Agriculture Chief Scientists Group for funding for Helen Browning and Anthony Smith. Colleagues in ADAS Analytical laboratories undertook the plant analysis.

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PEST MANAGEMENT IN VEGETABLE BRASSICAS WITHOUT INSECTICIDES

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ABSTRACT

A lightweight, transparent fabric cover over cabbage plants ('floating mulch') has been shown to reduce substantially the damage from the caterpillars of some butterflies and moths (e.g. small cabbage white butterfly (Pieris rapae), cabbage moth (Mamestra brassicae) and diamond-back moth (Plutella xylostella)) as well as the maggots of the cabbage root fly (Delia radicum). The cover appears to prohibit access to plants by flying insects. Floating mulches may be a reasonably practicable solution to the problem of managing migrant insect pests on organically grown brassica crops. Slug activity may be increased however by fabric covers.

INTRODUCTION

McKinlay (1987) demonstrated that damage to culinary swede roots by the cabbage root fly (Delia radicum) was greatly reduced by a lightweight, transparent fabric cover over the plants ('floating mulch'). Vegetable plant damage from insect pests other than the cabbage root fly may also be reduced by floating mulches. To test this idea, the incidences of caterpillar damage (principally, small cabbage white butterfly (Pieris rapae), cabbage moth (Mamestra brassicae) and diamond-back moth (Plutella xylostella)) and aphid colonisation (principally, Brevicoryne brassicae) were assessed on cabbages covered and not covered with fabric in a field experiment in 1988.

A similar field experiment was attempted during 1987, without any treatment to suppress slug damage. Unfortunately, the experiment was irretrievably damaged by slugs within a few days of transplanting. A decision was taken therefore to include a slug treatment in the 1988 experiment.

METHOD

Cabbages, cv. Hidena, raised according to Soil Association standards and hardened off, were transplanted 51 cm apart on 26 May 1988 into an imperfectly drained, brown forest soil (Kippen Series). Plot size was 4 x 41 cm wide rows, each 3.4 m long planted with 6 plants. The four treatments tested were (1) untreated; (2) a lightweight, transparent fabric cover (Agryl P17, a non-woven sheet made of continuous heat sealed polypropylene fibres without the use of a chemical binder, from Polycrop Growing Systems, Suffolk IP13 6SL) from transplanting until harvest; (3) IMP Slugtape (a bait based on paper tape containing 7.61% w/w metaldehyde from Impregnated Tapes Ltd., Cornwall PL24 2DS; each of the 4 rows of 6 plants/plot was surrounded by a rectangle of IMP Slugtape

TABLE 1. Effect of treatments on degree of caterpillar damage.

Treatments	% plants damaged by caterpillars	Angular transformations
Fabric cover + Slugtape	25.3	26.8
Fabric cover	36.5	33.7
Slugtape	71.4	58.4
Untreated	74.4	64.6
LSD (*P* = 0.05)		19.42

TABLE 2. Effect of treatments on degree of cabbage root fly damage.

Treatments	% plants damaged by cabbage root fly	Angular transformations
Fabric cover + Slugtape	7.0	10.0
Fabric cover	1.4	5.2
Slugtape	23.8	27.9
Untreated	27.4	28.1
LSD (*P* = 0.05)		17.09

TABLE 3. Effect of treatments on degree of slug damage.

Treatments	% plants damaged by slugs	Angular transformations
Fabric cover + Slugtape	62.2	52.2
Fabric cover	72.7	61.4
Slugtape	60.4	51.1
Untreated	62.5	54.7
LSD (*P* = 0.05)		12.03

anchored to the soil surface at intervals with earth) from transplanting until harvest; and (4) fabric cover + Slugtape from transplanting until harvest. The fabric cover was weighted down around the periphery of each plot with wooden fence posts. The tension on the cover was released periodically to allow for growth of the cabbages. The experiment was designed as a randomised block replicated 6 times. Mulches consisting of brown paper or black plastic overlying the Slugtape suppressed weed growth in the plots. All plants (including roots) in each plot were harvested on 3 October 1988 and each assessed destructively for the presence or absence of damage from cabbage root fly, slugs (principally, field slug (Deroceras reticulatum)), caterpillar and aphid attacks. Cabbage root fly damage was assessed on the roots and damage by slugs, caterpillars or aphids was assessed on the leaves. Angular transformations of the percentages of plants/plot damaged by each pest were statistically analysed by the analysis of variance method.

RESULTS

Tables 1 to 3 show the effects of the treatments on the degrees of caterpillar, cabbage root fly and slug damage respectively to the cabbages. Caterpillars damaged the largest proportion of plants, cabbage root fly the least proportion. Aphids were too few in number to assess.

The fabric cover treatments significantly ($P < 0.05$) reduced damage to cabbages by caterpillars (Table 1) and the cabbage root fly (Table 2). No treatment significantly reduced slug damage to the leaves (Table 3).

DISCUSSION

A lightweight, transparent fabric cover over cabbages has been shown to reduce substantially the plant damage by caterpillars of several butterflies and moths as well as the maggots of the cabbage root fly. The cover appears to restrict access to the plants by flying insects. Although slug damage was increased by covering plants with fabric, this effect was not statistically significant (Table 3). The Slugtape treatment did not reduce slug damage to the leaves of the cabbage plants at harvest (Table 3). This treatment may contribute however to the protection of plants from slug attacks shortly after transplanting, although differences in plant stands between treatments in this experiment were not apparent. The cause of different plant stands between treatments shortly after transplanting, whether slugs or cabbage root flies, would have had to be determined.

In conclusion, floating mulches may be a reasonably practicable solution to the problem of managing migrant insect pests on organically grown brassica crops. Two possible drawbacks to using floating mulches may be an increased weed problem and a reduced crop yield caused by reduced photosynthetically active radiation incident on plants. Weed growth can be suppressed however by mulches laid on the soil surface, as in this experiment, and recent work at the Edinburgh School of Agriculture suggests that cabbage plants exhibit compensatory growth under floating mulches.

ACKNOWLEDGEMENTS

The author wishes to thank the technical staffs of the Crop Protection and Horticulture Departments at the Edinburgh School of Agriculture for their help; and Mr T. Hunter, Scottish Agricultural Statistics Service for his statistical advice and analyses.

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1990 BCPC MONO. No. 45 ORGANIC AND LOW INPUT AGRICULTURE

THE DERIVATION OF ECONOMIC THRESHOLDS FOR INSECT CROP PESTS, AND THEIR ROLE IN CROP PROTECTION DECISION-MAKING IN LOW INPUT AND ORGANIC FARMING SYSTEMS.

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ABSTRACT

The principles used to derive economic thresholds for insect crop pests are briefly discussed. Such thresholds, which already exist for some important UK arable crop pests, offer considerable scope for rationalising pesticide use on low input farms. The applicability of thresholds on organic farms is more limited, as pest management under organic standards relies more on avoidance and prevention rather than curative action.

INTRODUCTION

The current trend in crop protection is towards a reduction in pesticide use for economic, environmental and consumer-driven reasons. A major pre-requisite for implementing such a policy on a rational basis is the development of methods for identifying the levels of pest infestation which can be tolerated before economically significant losses in crop yield and/or quality occur. Such methods, in the form of 'economic thresholds', have already been identified for some major pests of arable crops such as grain aphid (Sitobion avenae) on winter wheat (George & Gair, 1979), although similar techniques for field vegetables (e.g. Wheatley, 1986) have not been widely used due to the very stringent quality demands of the retail outlets where mere signs of pests or damage may lead to rejection. However, against a background of heightened consumer awareness of pesticide usage and growing interest in organic farming in particular, the use of thresholds is likely to become more widespread than at present.

This paper will briefly examine the principles involved in deriving pest thresholds, and the advantages and problems of their application to both low input and organic farming systems.

THE DEFINITION OF AN ECONOMIC THRESHOLD

Pest thresholds are usually defined as either 1) an Economic Injury Level (EIL), which is the level of pest infestation at or above which economically significant pest damage occurs; and 2) an Economic Action (or Treatment) Threshold (EAT), defined as the level of pest infestation judged to justify economically sound crop protection measures. For a given crop/pest situation, the EAT will usually be lower than the EIL, i.e. action has to be taken at the EAT to prevent the EIL being reached.

DERIVING TEST THRESHOLDS

To develop a reliable threshold for a given crop/pest situation, a number of specific objectives have to be met: 1) an accurate and easy-to-use monitoring technique needs to be identified which enables a quick and simple assessment of the pest population to be made. This usually entails either direct counting, trapping, or pre-crop soil sampling depending on the biology of the pest; 2) damage assessment work must be carried out to identify the yield/quality loss caused by different levels of pest infestation as indicated by the chosen monitoring technique, and how this may vary with the growth stage of the crop; 3) data on expected crop yield/price, application and pesticide costs are also required to enable the biological data to be linked to the financial constraints on the crop protection options available.

This type of data can take several years to obtain, validate and update over a range of conditions. However, this process is essential if the resulting threshold is to be adopted widely and with confidence by farmers and advisers.

THE ROLE OF PEST THRESHOLDS IN LOW-INPUT FARMING SYSTEMS

A low input farm should by definition be aiming to use a minimum of inputs such as fertiliser and pesticides. This implies that a managed approach to pest control will be adopted with pesticides being used only in response to a specific need. The use of pest thresholds is fundamental to this approach, and enables rational decisions to be taken on the need to control a particular pest on the basis of actual infestation levels. This will generally result in reduced pesticide inputs compared to a crop managed on the basis of presence/absence or calendar-based treatment decisions (e.g. Wright *et al*., 1987). The advantages of using pest thresholds thus include reduced pesticide and application costs, the maintenance of beneficial insect populations, a reduced risk of pests developing resistance to insecticides and the release of labour for other tasks.

There are currently a number of pest thresholds in use on major arable crops in the UK. ADAS uses experimentally determined action thresholds for aphids on winter wheat, and seed weevil (*Ceutorhynchus assimilis*), pollen beetle (*Meligethes aeneus*) and cabbage stem flea beetle (*Psylliodes chrysocephala*) (Purvis, 1986) on oilseed rape. Many of these thresholds are currently undergoing further development work. More complex techniques include a pea moth (*Cydia nigricana*) monitoring/forecasting system based on pheromone trap catches (Wall *et al*., 1987). The majority of these threshold/forecasting systems would be appropriate for use in low input systems.

The degree of management skill and commitment required to run a successful pest management programme should not be underestimated, and the extra time involved has to be offset against cost savings in pesticides and equipment running costs. In addition, where pesticide applications are deemed to be necessary, there may be a need/desire to use an expensive but selective pesticide in preference to a cheap but broad-spectrum product.

THE ROLE OF PEST THRESHOLDS IN ORGANIC FARMING SYSTEMS

In organic agriculture, the main methods used to manage pest populations are rotation, resistant varieties, strategic planting/harvest dates and the creation of a diverse ecosystem within and around the crop to encourage beneficial insects. Such methods involve advance planning and are essentially preventative in character. As curative means of controlling severe pest infestations (e.g. pesticide applications) are not usually practical options for the organic farmer, economic pest thresholds to aid the timing of crop protection decisions during the growing season are less applicable. However, some components of a threshold system such as monitoring/forecasting techniques may be particularly valuable if used to predict a potential pest problem in advance. Soil sampling for wireworms (*Agriotes* spp) or potato cyst nematodes (*Globodera* spp), cutworm (*Agrotis segetum*) forecasting on vegetables (Bowden *et al*., 1983), and carrot fly (*Psila rosae*)monitoring to identify optimum planting, covering or harvest dates are examples of such techniques.

DISCUSSION & CONCLUSIONS

To be useful, 'pest thresholds' must be scientifically sound, and ideally simple and robust enough for farmers and growers to use them confidently and with a minimum of specialist equipment, technical knowledge and time expenditure. However, these generalised action thresholds inevitably require a certain amount of interpretation in the light of other biological, agronomic and financial variables associated with growing the crop. Often, such interpretations (whether made by the farmer or his/her adviser) can only be made on the basis of past experience and are therefore value judgements open to a degree of error.

To reduce the chances of making an incorrect decision, more complex dynamic pest threshold systems, perhaps involving computer modelling, are required. However, such systems are more difficult to develop, and may require a degree of specialist knowledge beyond the expertise of the farmer. As such, they are more likely to be used by a limited number of specialist crop protection advisers.

Provided pest thresholds are used correctly as part of an overall crop management strategy by farmers/advisers who understand their limitations, pest thresholds offer considerable scope for reduced pesticide and application costs on low-input farms. There will also be an environmental benefit which is difficult to quantify in purely monetary terms.

For the organic farmer, the value of pest thresholds is limited as curative pest controls in the form of pesticides are largely unavailable or inappropriate. Nevertheless, forecasting/monitoring techniques used in the threshold approach in 'conventional' agriculture also have a role in developing crop protection strategies on organic farms.

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THE USE OF NONWOVEN CROP COVERS TO PREVENT INSECT PESTS ON FIELD VEGETABLES

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ABSTRACT

Cauliflowers and carrots were used as test crops in 1989 to evaluate nonwoven crop covers to prevent attack by insect pests. Various grades of material were used to study their strength, agronomic effect on the crop and assess husbandry and physiological problems. The hot summer provided a severe test for preventing pests and producing quality produce. The thinnest grade of polypropylene, 10 g/m^2, was remarkably strong and in common with thicker grades provided a barrier throughout the growing period. Nonwoven crop covers significantly reduced the levels of Cabbage root fly (Delia radicum) and Carrot fly (Psila rosae) but yields tended to be lower compared to full standard spray programmes. However the trials showed promise and with experience and adjustments to husbandry and cultivation techniques it may be possible to improve yield and quality of field vegetables under nonwoven crop covers without the use of insecticides.

INTRODUCTION

Pressure from environmental groups, public concern over residue levels and a diminishing range of insecticides that are approved for use on field vegetables have all increased the need to search for alternative methods of controlling or preventing attack by insect pests. Crop covers were originally used for earliness, but experience soon showed that animal, bird and insect pests were prevented while the intact crop cover was in position. Nonwoven materials can be kept on crops longer than polyethylene, because they are more permeable, produce less temperature extremes and do not scorch the plants. With some early crops they are left on until harvest giving valuable protection both against the weather and aerial pests throughout the growing period.

In Switzerland and Germany finely netted materials have been used since 1982 to prevent insect pest attack, but the material is expensive. The introduction of strong lightweight (10 g/m^2) nonwovens which are cheaper has encouraged growers to give more consideration to using crop covers in order to reduce their dependency on chemicals.

Observations were carried out at Efford EHS and more recently at Arthur Rickwood EHF in 1988. This was followed by several trials carried out by ADAS during 1989 on cauliflower, carrots and lettuce. This paper concentrates on the results of the first trial on cauliflower at Stockbridge House EHS and on carrots at Arthur Rickwood EHF.

MATERIALS AND METHODS

Treatments for carrots

1. Drilling Dates

a. 28 April
b. 25 May

2. Covering/Chemical

a. Control - No second generation control
b. Second generation control using triazophos
c. Agryl P17 at drilling
d. Agryl P17 laid on 27 July
e. Agryl P17 laid on 11 August
f. Agryl P17 laid on 24 August
g. Ridged up on 3 August

A granular insecticide was applied at the 28 April drilling to all treatments except 2c. for first generation control. The variety was Nandor and the spacing was 2 scatter rows per 1.68 m bed to achieve 150 plants/m^2.

Treatments for Cauliflower

a. No chemicals.
b. Cabbage root fly control only
c. Full spray programme
d. 10 g/m^2 cover removed at harvest
e. 17 g/m^2 cover removed at harvest
f. 10 g/m^2 cover removed 10 days before harvest
g. 17 g/m^2 cover removed 10 days before harvest
h. 10 g/m^2 cover removed 10 days before harvest plus supervised control*
i. 17 g/m^2 cover removed 10 days before harvest plus supervised control*

Cover Type: Lutrasil VP 684 (10 g/m^2)) 2m wide to cover
Lutrasil VP 651 (17 g/m^2)) 1.83 m bed

* Supervised: Insecticides applied as required

The variety Dok, was was sown on 28 February into Hassy 308 trays. The plants were planted on 20 April into 100 mm deep furrows with a spacing of 3 rows per 1.83 m bed, 54 cm between the rows and 45 cm within the rows. The crop covers were laid on 21 April.

RESULTS

TABLE 1. Carrots (Mean of 2 Drilling Dates)

	Total Yield > 19 mm 13 Nov (t/ha)	Roots with Carrot fly (%) 13 Nov	Roots with Carrot fly (%) 10 Jan
Control	80	5.6	38.5
Control + 2nd generation sprays	100	2.4	14.8
Crop cover at drilling	66	1.5	5.0
Crop cover from 27 July	76	1.0	6.8
Crop cover from 11 August	82	5.0	22.7
Crop cover from 24 August	95	6.7	40.2
Ridged up 3 August	87	3.3	24.2
Mean	84	3.6	21.7
SED (24 df)	9.2	1.70	4.91

The highest yield was produced by the full insecticide programme which was significantly higher than the crop cover treatments from drilling or from 27 July. The 27 July covering was laid a few days before the first ADAS warning for second generation Carrot fly activity. The highest incidence of Carrot fly damage occurred on the control or when the crop covers were applied in August. The lowest levels were obtained from the full insecticide programme or the 2 earliest crop covers.

TABLE 2. Cauliflower: Marketable Yield and Root Damage Index (RDI)

Cover (g/m^2)	Pest Control	Uncover Date	Cl.I & Cl.II (cr/ha)	Cl.I as a % of Cl.I & II	RDI
None	None	-	540	46	48*
None	CRF only	-	2341	89	49
None	Standard	-	2495	97	40
10	None	6/7	2126	57	11
17	None	6/7	1706	58	7
10	None	28/6	2178	87	16
17	None	28/6	2118	63	9
10)	Super-	28/6	2341	91	13
17)	vised	28/6	2066	72	11
SED (16 df)			262.3	6.9	10.9

* RDI of harvest plants only. Many plants did not reach maturity due to Cabbage root fly damage.

All treatments gave a similar yield except for the 17 g/m^2 cover when removed at the first harvest and the no pest control treatments. The highest number of Class I heads was produced by the standard chemical control, CRF only and the 10 g/m^2 crop covers removed on 28 June. The RDI was significantly lower on all cover treatments compared to no cover whether or not chemicals for CRF control had been applied.

DISCUSSION

The concept of using nonwoven crop covers as a physical barrier to prevent aerial insect pest attack on summer cauliflower and carrots was given a severe test in the hot summer of 1989. This was the first year of replicated trials and the results should therefore be treated with caution. However, the trials at both sites indicated that nonwoven crop covers will significantly reduce levels of Cabbage root fly and Carrot fly damage when laid at the correct time. The results at Arthur Rickwood especially, show the importance of covering before the start of second generation Carrot fly.

The trial at Stockbridge House used narrow sheets. Part of the reduction in yield under crop covers was due to the edge effect. Wide sheets, which would be used in a commercial situation could overcome this problem.

With further experience and by improving husbandry and management skills and identifying the correct crop cover type the technique shows promise that similar yields and quality may be obtainable compared to a full insecticide spray programme. However, it is important to make sure that plants are free of pests before covering and that weeds are properly controlled. Soil pests, for example root aphid or nematodes, may not be prevented by covers.

ACKNOWLEDGEMENT

The collaboration of ADAS Entomology colleagues who assisted in the pest assessments is gratefully appreciated.

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THE EFFECT OF GREEN MANURING AND MIXED SPECIES CROPPING ON TAKE-ALL DISEASE OF WHEAT

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ABSTRACT

Take-all, caused by *Gaeumannomyces graminis* var. *tritici*, is a serious root disease of wheat and barley in conventional agricultural systems, world-wide. The pathogen can be controlled by rotating susceptible cereals with non-host crops thus the disease is not considered a serious problem in organic cropping systems, which are based on extensive rotations. Organic cereal systems are therefore ideal for investigating natural control of the pathogen. The results of this study suggest that specific cultural techniques used in organic systems, i.e. green manuring and mixed species cropping, provide effective control measures against the disease.

The incorporation of trefoil *Medicago lupulina* as a green manure to the soil, reduced the disease significantly. The effect was partly attributed to the release of plant nutrients but was also demonstrated to be linked with microbial changes in the soil. The control of the disease was accompanied by increases in the 'total' number of bacteria and in the number of fluorescent pseudomonads, both in the rhizosphere and in the non-rhizosphere soil. The bacterial diversity and the number of bacteria with antagonistic effects against *G. graminis*, *in vitro*, increased when the soil was amended with trefoil green manure.

Take-all was also reduced when wheat was grown in a mixed cropping system with trefoil. This was shown in numerous glasshouse experiments and was also supported by the results of two field experiments. The wheat rhizosphere bacterial population was influenced, quantitatively and qualitatively by the companion trefoil plants. The diversity and number of rhizosphere bacteria antagonistic to *G. graminis*, *in vitro*, increased when wheat was grown together with trefoil. There was no clear relationship between the changes in the wheat rhizosphere bacterial population and the reduction of the disease.

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THE ROLE OF THE UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY IN CROP PROTECTION

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The United Kingdom Cereal Pathogen Virulence Survey was set up in 1967, following an unexpected epidemic of yellow rust in the widely grown wheat variety Rothwell Perdix. The epidemic was due to a new race of yellow rust, capable of attacking this previously resistant variety. The formation of the UKCPVS was a response to the urgent need to detect new pathogen races at an early stage, before they could become widespread and cause epidemics. During the twenty years of its existence, the UKCPVS has retained this central aim, whilst expanding into new areas of related work as necessary, such as monitoring fungicide insensitivity.

There are two main methods available for the control of cereal disease, both of which are essential components of modern cereal husbandry. These are the use of genetic resistance, in the form of resistant varieties, and chemical control by fungicides. The recent emphasis placed on fungicide use has partly overshadowed the potential benefits of varietal resistance and the two control methods are currently out of balance. The full and proper exploitation of genetically controlled host resistance to pathogens reduces dependence on fungicides and hence slows down the development of pathogen insensitivity. Use of resistant varieties reduces costs, practical problems associated with application of chemicals and risk to both environment and user. The only major drawback of genetic resistance is the possibility that it may be overcome by newly adapted pathogen races.

The UKCPVS provides a formal system of monitoring pathogen variation, which allows early detection of new races. The survey actively supports breeding for improved resistance and promotion of resistant varieties by releasing appropriate, up-to-date, pathogen isolates to breeders and variety testing authorities. The survey also produces variety diversification schemes, which are used by growers to reduce the risk of disease spread between varieties on the farm.

Unfortunately, the current range of cereal varieties has a dangerously narrow genetic base for resistance to an increasingly virulent spectrum of pathogen races, for example in wheat yellow rust and barley mildew. At the same time, there is an increasing incidence of pathogen resistance to the most important groups of cereal fungicides. In this situation, it is vital that the search for more diverse and durable forms of resistance should continue, supported by constant monitoring of pathogen variation by the UKCPVS.

ESTABLISHMENT, DISEASES AND YIELD OF ORGANICALLY-GROWN WHEATS

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ABSTRACT

Field establishment was poor from untreated seed in organically-grown wheat variety trials in autumn at Harnhill Manor Farm near Cirencester in 1987 ,1988 and 1989. Foliar diseases did not develop to any major extent, with the exception of yellow rust on autumn-sown Alexandria spring wheat in May 1989. Grain yields were lower and more variable than conventionally grown wheats on the Royal Agricultural College Farms. Brimstone and Mercia in 1988 and Parade and Mission in 1989 were the higher yielding varieties.

INTRODUCTION

To provide a better basis for improving cereal production in organic farming systems more information is required on variety performance. The opportunity for comparisons was provided at Harnhill Manor Farm near Cirencester, in variety trials of wheats grown on land certified by the Soil Association for organic production. Observations made in 1987, 1988 and 1989 are reported.

MATERIALS AND METHODS

Trials were conducted at Harnhill Farm, Cirencester, in the 1987/88, 1988/89 and 1989/90 seasons. Soil types were a stony calcareous clay loam of the Sherborne Series for the first two years and a clay loam of the Evesham Series in the third year.

In 1987 seventeen varieties and mixtures were grown, namely; Brimstone; Mercia; Maris Widgeon/Brimstone/Mission mixture; Rendezvous; Urban; Mission; Avalon/Mercia/Rendezvous mixture; Parade; Feuvert; Soleil; Axona; Alexandria; Maris Widgeon; Alexandria/Axona/Tonic mixture; Tonic; Rektor and Avalon. In 1988 and 1989 Pastiche and Apostle replaced Rektor and Feuvert. In 1989 Camp Remy replaced Soleil. Samples of seed in 1987 were plated on agar to assess seed-borne infections (Johnston and Booth, 1983).

Trials were drilled in 1987 on 4 November, after a one year red clover ley which followed three years of sainfoin. In 1988 the winter varieties were drilled on 29 October and the spring varieties on 4 November, following three years of lucerne. Winter wheats were drilled on 18 October and the spring varieties on 24 November 1989 following a three year clover ley.

Each year a randomised block design with four replicates was used. Effective plot size averaged 2m x 10.2m. A seed rate of 500/m^2 (average 235kg/ha) was used throughout.

Crop establishment was assessed at the two leaf stage (GS 12, 15 Jan 1988, 18 January 1989 and 3 December 1989). Two 0.5m lengths of row were counted at 3 points per plot. Crop growth and foliar disease development were monitored using standard ADAS assessment keys (Anon 1976). Sooty moulds were assessed during dough development (GS 83-90) using a whole plot method (Anon, 1985). Plots were harvested with a Claas Dominator plot combine on 17 August and 28 July in 1988 and 1989 respectively.

RESULTS

Establishment

Field establishment from the untreated seed varied considerably between varieties (Tables 1 and 2), and did not exceed 50% overall. Tonic, Avalon and Mercia in 1988 established very low plant populations. Seed of these particular varieties were commonly infected by *Fusarium* species and *Septoria nodorum*, and field establishment was further reduced by slug grazing.

TABLE 1. Establishment of winter wheat varieties.

Variety	1988		1989		1990	
	Plants/m²	%	Plants/m²	%	Plants/m²	%
Mercia	140	28	176	35	205	41
Avalon	139	28	147	29	229	46
Rendezvous	222	44	258	52	229	46
Brimstone	190	38	175	35	221	44
Mission	261	52	245	49	225	45
Parade	293	58	326	65	162	32
Urban	243	49	249	50	227	45
Maris Widgeon	293	58	268	54	239	48
Soleil	343	69	94	19	-	-
Feuvert	352	70	-	-	-	-
Rektor	283	57	-	-	-	-
Apostle	-	-	165	33	216	43
Pastiche	-	-	204	41	246	49
Camp Remy	-	-	-	-	255	51
Avalon/Mercia/Rendezvous	153	31	170	34	216	43
Maris Widgeon/Mission/Brimstone	296	59	238	48	263	53
Mean	247	49	209	42	226	45
SEM(3,35df)	3.18		18.20		15.78	

Disease

Foliar disease has been low in these experiments. Occasional Septoria tritici infections on lower leaves of many varieties in the 1987-88 season failed to develop further with stem-extension. Powdery mildew on certain varieties during winter did not subsequently develop. Isolated pustules of brown rust were observed in May and June 1988. Sooty moulds were common on all varieties in July 1988, but did not exceed 5% on the ears overall. Yellow rust developed on the autumn-sown spring wheat Alexandria in 1989 averaging 16% leaf area infection on leaf 3 on 25 May, and 12% infection on flag leaves on 22 June.

TABLE 2. Establishment of autumn-sown spring wheat varieties.

Variety	1988 Plants/m²	%	1989 Plants/m²	%	1990 Plants/m²	%
Alexandria	235	47	204	41	166	33
Axona	392	78	159	32	166	33
Tonic	75	15	188	38	156	31
Alexandria/ Axona/Tonic	230	46	201	40	158	32
Mean	233	47	188	38	162	32
SEM(3,8df)	3.18		21.91		10.84	

TABLE 3. Yield and grain weight, at 85% d.m., of winter wheat varieties.

Variety	1988 Yield (t/ha)	1988 Thousand grain weight (g)	1989 Yield (t/ha)	1989 Thousand grain weight (g)
Mercia	3.62	49.0	4.90	43.1
Avalon	2.77	54.1	4.63	48.1
Rendezvous	3.55	54.9	5.12	47.8
Brimstone	4.02	52.1	5.2	47.9
Mission	3.49	48.7	5.57	46.4
Parade	3.41	47.7	5.65	44.2
Urban	3.54	46.9	4.72	43.3
Maris Widgeon	2.99	51.9	4.82	45.7
Soleil	3.19	49.5	4.85	47.9
Feuvert	3.05	52.0	-	-
Rektor	2.85	49.2	-	-
Apostle	-	-	4.85	41.0
Pastiche	-	-	4.30	48.0
Avalon/Mercia/ Rendezvous	3.47	52.7	5.30	47.6
Maris Widgeon/ Brimstone/ Mission	3.58	50.9	5.32	44.4
Mean	3.35	50.7	5.02	45.8
SEM(3,35df)	0.15	0.51	0.27	0.80

Yield

In 1988 grain yield was lower than 1989. Of the winter wheats, the highest yielding varieties in 1988 were Brimstone and Mercia, and in 1989 Parade and Mission (Table 3). Avalon gave low yields in both seasons. The autumn-sown spring wheats were lower yielding in 1988 and 1989 than most winter varieties (Table 4), but were drilled slightly later. With the exception of the autumn-sown spring wheat mixture in 1988, variety mixtures gave small yield increases compared with the yield of components grown separately.

TABLE 4. Yield and grain weight, at 85% d.m., of spring wheat varieties.

Variety	1988		1989	
	Yield (t/ha)	Thousand grain weight (g)	Yield (t/ha)	Thousand grain weight (g)
Alexandria	3.01	44.9	4.10	39.4
Axona	3.08	46.5	4.13	41.7
Tonic	2.90	54.1	4.20	44.1
Alexandra/ Axona/Tonic	2.92	47.0	4.30	41.0
Mean	2.98	48.1	4.18	41.6
SEM (3,8df)	0.15	0.51	0.13	0.66

DISCUSSION

Poor establishment from the untreated seed was the main feature of these variety trials. Foliar disease development was markedly less in the experiments than in adjacent conventionally-grown crops of some of the same varieties. Possible reasons for lower disease might include the more open crop canopy of the organic crop stands, and a less encouraging crop nutrition with lower nitrogen availability. Wheat yields were lower and more variable than conventionally grown wheats in variety comparisons at the Royal Agricultural College in the same seasons.

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RESPONSES OF WHEAT TO HIGH AND LOW NITROGEN AND FUNGICIDE INPUTS ON SHALLOW LIMESTONE SOIL

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ABSTRACT

In 1988, a season characterised by a cool wet July, positive yield responses of Avalon wheat grown on shallow limestone soil were obtained to fungicide inputs and nitrogen, ranging from 50 - 250kg N/ha. In contrast the very dry warm July in 1989 resulted in negative yield responses to the same nitrogen inputs, and no response to fungicides. Moisture availability appeared the main determinant of wheat yield in these seasons.

INTRODUCTION

Particular interest is being shown in better identifying the cropping potential of land. Reasons include not only concerns for appropriate choice of crop and variety, but also for prospective returns from input costs and environmental considerations. The capacity of Cotswold limestone soils for reliably producing breadmaking samples of wheat is currently being explored, as part of a multi-site Home-Grown Cereals Authority project (0074/1/87), focusing on grain quality and nitrogen-fungicide interactions. Contrasting growing conditions in 1988 and 1989 provided an insight into the potential of wheat grown on Cotswold brash.

MATERIALS AND METHODS

Field experiments were conducted in the 1987-1988 and 1988-1989 seasons at Coates Manor Farm of the Royal Agricultural College, Cirencester, Gloucestershire on a shallow brown rendzina soil of the Sherborne series containing approximately 20% Oolitic limestone. This soil type is the most prevalent on the Cotswolds.

In 1987 and 1988 Avalon winter wheat was drilled at 400 seeds/m^2 using a Falcon seed drill, following a 3 year grass ley, on the 17 and 21 October respectively. Weed control was achieved with an appropriate spring-applied herbicide. Chlormequat was applied at late tillering at 1.75 l/ha and again during stem extension (GS 31) at a rate of 0.75 l/ha in both seasons. Mepiquat chloride at 305g AI/ha and 155g AI/ha of 2-chloroethylphosphonic acid was applied as Terpal (BASF UK Ltd) at flag leaf emergence (GS 37) in the 1987-1988 season.

The experiments were arranged as a randomised design with 4 blocks and 20 treatments per block. All plots received 30kg N/ha, as ammonium nitrate, during late tillering (1 and 14 March in 1988 and 1989 respectively). Five levels of nitrogen (applied at stem extension on 26 and 21 October in 1988 and 1989 respectively) were factorially combined with 3 fungicide treatments and an untreated control. The nitrogen levels were 20kg N/ha, 70kg N/ha, 120kg N/ha, 170kg N/ha and 220 kg N/ha.

Fungicide treatments were 750g AI/ha of fenpropimorph (Corbel: BASF UK Ltd), 400 AI/ha of prochloraz (Sportak: Schering Agriculture Ltd), and 750g AI/ha of fenpropimorph plus 400g AI of prochloraz, applied at flag leaf emergence (GS 39; 20 and 24 May in 1988 and 1989 respectively) and ear emergence (GS 59; 17 and 11 June in 1988 and 1989 respectively) in 200 l water/ha with a hand-held Fox Motori sprayer. Percentage Septoria tritici Rob apud Desm infection was assessed on 10 leaves per plot (Anon, 1976) and confirmed microscopically following incubation of excised leaves on damp blotting paper. Botrytis cinerea infection was assessed on 10 flag leaves per plot using a 0 - 5 linear scale.

Plots were harvested with a Claas Dominator plot combine on the 22 August and 2 August in 1988 and 1989 respectively.

RESULTS

Weather

Rainfall and temperature means for the six months following nitrogen application are shown in Table 1.

TABLE 1. Rainfall and temperature data at the Royal Agricultural College in 1988 and 1989.

Month	Rainfall (mm)			Mean daily temperature (0° C)		
	1988	1989	10 Year Average	1988	1989	10 Year Average
March	88.3	65.6	81.6	6.7	7.0	5.9
April	36.4	81.6	45.3	7.7	6.0	7.7
May	30.8	30.9	61.3	11.6	13.4	11.1
June	52.0	44.8	69.6	13.5	14.4	14.2
July	111.8	18.7	53.0	13.5	19.5	16.5
August	73.9	66.2	64.1	14.7	16.7	15.8

In 1988 and 1989 rainfall in May and June was below average, with the marked contrast of a very wet July in 1988 to the dry weather of July 1989. Temperatures in June, July and August in 1988 were below average in contrast to the higher temperatures during these months in 1989.

Disease

Disease in 1988 was characterised by the development of S. tritici from low levels in March to severe infections in July, with early infections being greatest on the low nitrogen treatments (Table 2). B. cinerea infections developed on flag leaves in July, and was most severe on treatments receiving more than 150kg/ha of nitrogen. Severe S. tritici infection was partially controlled with fungicides by mid-July. Fenpropimorph reduced infection, but prochloraz and prochloraz plus fenpropimorph had the greatest activity against S. tritici.

TABLE 2. Influences of nitrogen on S. tritici infection in 1988.

Nitrogen (kg/ha)	Septoria tritici* (%) 28 April Leaf 3	28 May Leaf 4	3 June Leaf 4	11 July Flag leaf	11 July Leaf 2
50	32.7bc	9.8c	34.0b	6.3b	47.4b
100	25.9a	7.1ab	31.1b	3.4a	37.7a
150	29.9ab	7.4b	27.7a	3.4a	37.6a
200	29.8ab	5.7a	24.6a	2.6a	34.8a
250	35.6c	5.8a	25.3a	2.9a	37.6a
SEM (4,57df)	1.9	0.5	1.7	0.6	2.5
LSD	5.3	1.6	4.9	1.8	7.2

*Different letters within the same column indicate a significant difference between treatments ($P < 0.05$).

Disease in the 1988-1989 season was very low. Slight S. tritici infections observed in April failed to develop, and infections were not apparent in June.

Yield components and grain weight

Yield from the 1988 harvest progressively increased with increments of nitrogen. The 1989 harvest, however had lower yield with nitrogen application above 100kg N/ha (Table 3). Thousand grain weights reflected better grain-fill from lower nitrogen inputs in both seasons, except for the highest rate in 1988. There were fewer grains per ear at the lowest nitrogen level in 1988, but no significant difference in grain number was apparent in 1989. Nitrogen increased the number of ears/m² in 1989, in contrast to 1988 (Table 4).

TABLE 3. Nitrogen influences on the yield and thousand grain weight of Avalon (14% m.c.).

Nitrogen (kg/ha)	Yield (t/ha)* 1988	Yield (t/ha)* 1989	Thousand grain weight (g)* 1988	Thousand grain weight (g)* 1989
50	6.00a	6.37b	55.39c	43.89e
100	7.01b	6.46b	53.83ab	40.06d
150	7.45c	5.98a	53.50a	38.62c
200	7.80cd	5.79a	53.47a	37.89b
250	8.07d	5.74a	54.95bc	36.99a
SEM (4,57df)	0.13	0.10	0.99	0.27
LSD	0.37	0.27	1.37	0.79

*Different letters within the same column indicate a significant difference between treatments ($P < 0.005$).

TABLE 4. The influence of nitrogen on the number of grains per ear and ears/m².

Nitrogen	Grains/ear*		Ears/m²*	
(kg/ha)	1988	1989	1988	1989
50	33.75a	48.96	376	403a
100	39.94b	53.11	373	440b
150	41.52b	52.42	372	483c
200	42.63b	50.83	369	513c
250	41.46b	53.69	369	555d
SEM (4,57df)	1.15	1.28	11.33	11.6
LSD	3.25	-	-	32.7

*Different letters within the same column indicate a significant difference between treatments ($P < 0.05$).

Yield increased with fungicide use, but only significantly with a fenpropimorph-prochloraz treatment (0.53t/ha over the untreated) in 1988. No significant yield difference to fungicide was found in 1989.

DISCUSSION

Positive yield responses were obtained in 1988 to applied nitrogen up to 250 kg/ha and the tank-mix of fungicides, in a season characterised by slightly drier than average weather in late Spring and plentiful moisture from mid-June to early August during grain-filling. In contrast in 1989, a wet April followed by drier and warmer weather than average in May, June and July, resulted in negative responses to increasing nitrogen with no benefit of fungicide treatment. Shortage of moisture during the summer of 1989 did not appear adequate to support the increased tiller numbers previously encouraged by higher levels of nitrogen.

Moisture availability is a major limiting factor for wheat production on shallow free-draining limestone soils in the Cotswolds. The risk of late-season drought on this soil type makes high input wheat production an unpredictable enterprise.

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1990 BCPC MONO. No. 45 ORGANIC AND LOW INPUT AGRICULTURE

ELICITOR-ACTIVE YEAST CELL WALL COMPONENTS AS A NOVEL CROP PROTECTANT

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ABSTRACT

Phytoalexin elicitor-active yeast cell wall components protected barley against powdery mildew (Erysiphe graminis f.sp. hordei) infection in proportion to their ability to elicit phytoalexin accumulation in soybeans. Elicitor treatment induced faster papilla formation on detached leaves of cv. Golden Promise challenged with mildew. In field trials elicitor application reduced mildew infection in cultivars Golden Promise and Triumph and in cv. Triumph yield and thousand grain weight values after treatment were equal to or greater than those obtained with a fungicide. These data indicate that yeast extracts have potential for use as crop protectants.

INTRODUCTION

Widespread use of fungicides on spring barley to control powdery mildew (Erysiphe graminis f.sp. hordei) has been accompanied by a decrease in sensitivity of mildew to the fungicides (Heaney et al., 1984; Brent et al., 1989). An alternative approach to crop protection is to enhance the plants own resistance mechanisms by applying a resistance elicitor. Following elicitor treatment a number of resistance mechanisms can be induced including synthesis of antimicrobial phytoalexins, callose deposition, lignification and production of proteinase inhibitors and lytic enzymes (Dixon, 1986; Lamb et al., 1989). This paper reports on the results of experiments which were undertaken to test the ability of elicitor-active yeast extracts and other compounds to protect spring barley against powdery mildew infection.

METHODS AND MATERIALS

Elicitor preparation

Elicitor-active extracts Y1, Y2, Y3 and Y6 were prepared from dried yeast cell walls (Saccharomyces cerevisiae). Due to ongoing negotiations with potential industrial sponsors, details for obtaining the extracts are confidential. Phytoalexin elicitor activity was measured using the soybean cotyledon bioassay (Ayers et al., 1976).

Field trial

Blocks containing one plot measuring 2.1 m x 1.22 m of each of the cultivars Golden Promise and Triumph were surrounded by plots of the mildew resistant cv. Atem. There was a total of 30 blocks to which ten treatments were randomly applied using a pressurised hand-held sprayer fitted with a hollow cone nozzle delivering 1500 l water/ha at 0.3 l/min. Treatments were; control (con) = no treatment, Agral (Agr) = 0.375 l/ha, arachidonic acid (Ar-4) = 0.06 kg/ha, arachidonic acid (Ar-2) = 0.06 kg/ha, Y1-4 = 0.15 kg/ha, Y1-2 = 0.15 kg/ha, Y2-4 = 0.015 kg/ha, Y2-2 = 0.015 kg/ha, and Y3-4 = 0.105 kg/ha. Agral, Ar-4, Y1-4, Y2-4 and Y3-4 were each applied four times and Ar-2, Y1-2 and Y2-2 were applied twice. Fungicide treatments were Calixin (a.i. tridemorph; BASF) applied at 0.7 l/ha on 26.5.89 and Mistral (a.i. fenpropimorph; BASF) applied at 1.0 l/ha on 9.7.89. Plots were harvested using a small plot combine and yields and thousand grain weights were recorded two days after the grain had been dried to approximately 13% moisture content.

RESULTS

Elicitor activity of each solution used on the field trial (with the exception of fungicide) was assessed by the soybean cotyledon assay (Table 1). Highest activities were obtained from Y3 and arachidonic acid with the poorest response from Agral.

TABLE 1. Elicitor activity of field treatments

Treatment	Elicitor activity (absorbance 286 nm)
Agral	0.034
Arachidonic acid	0.25
Y1	0.20
Y2	0.16
Y3	0.26

Mildew infection was assessed on the two leaves below the flag leaf on eight plants within each plot (Table 2).

TABLE 2. Mildew infection (% of leaf area diseased)

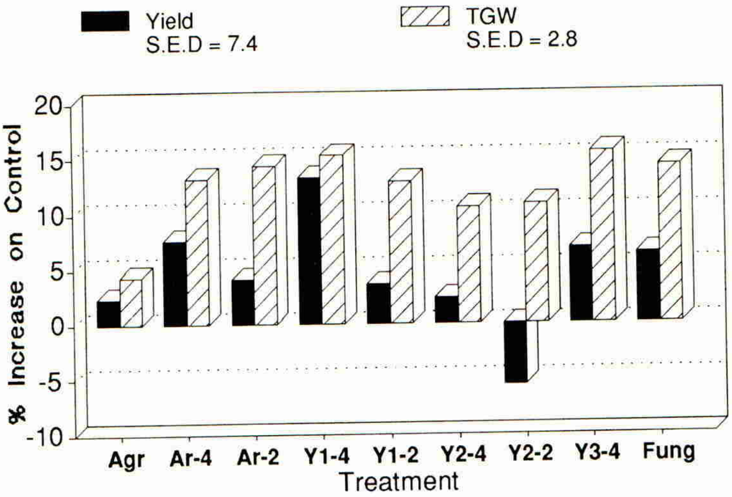
Treatment	Golden Promise		Triumph	
Control	86.7	(69.3)*	8.3	(16.4)
Agr	76.7	(61.5)	7.0	(14.7)
Ar-4	63.3	(53.1)	4.8	(12.2)
Ar-2	68.3	(56.7)	5.7	(13.2)
Y1-4	71.7	(58.3)	4.7	(11.9)
Y1-2	75.8	(60.7)	4.9	(12.2)
Y2-4	67.5	(55.4)	3.5	(9.9)
Y2-2	71.7	(58.0)	6.2	(14.0)
Y3-4	55.0	(47.9)	2.5	(8.0)
Fungicide	0.2	(1.0)	0.0	(0.0)

S.E.D. = 3.6 (2.8)   D.F. = 60 (60)

* = Angular Transformed analysis in parenthesis

Extracts with the highest elicitor activity conferred greatest protection against mildew infection in the field. In the susceptible cv. Golden Promise, significant reductions of infection were apparent with a number of treatments, especially in Y3-4 treated plants, however, none of the treatments attained the level of control achieved by fungicide. In cv. Triumph, which has a greater level of resistance than cv. Golden Promise, Y3-4 treatment reduced mildew infection by over 60% compared with the control.

FIG 1. Yield and thousand grain weight measurements for cv. Triumph compared to control values



In cv. Golden Promise, Ar-4, Y1-4 and Y2-2 each enhanced yield but not to the extent of fungicide treatment, whereas in cv. Triumph (Fig. 1) the yield response to fungicide was equalled by Ar-4 and Y3-4 and exceeded by Y1-4. Similarly, in cv. Triumph, Ar-4, Ar-2, Y1-4 and Y3-4 each enhanced thousand grain weight to the same extent as fungicide treatment. Increasing the number of applications had beneficial effects, reducing infection and increasing yield and thousand grain weight of both cultivars.

DISCUSSION

The application of yeast cell wall components to barley increased resistance to mildew and reduced loss of grain yield and quality. Treatments with highest elicitor activity provided the greatest protection against powdery mildew infection and produced highest yields. No toxic or otherwise detrimental effects of the yeast extracts towards plants have been observed. Recently an extract (Y6) has been produced which shows greater elicitor activity than those used on the above trials. This extract confers enhanced protection against mildew infection and induces faster papilla formation on detached leaves of cv. Golden Promise. Recent studies indicate that early papilla formation can reduce fungal penetration efficiency in barley and so enhance resistance to powdery mildew infection (Bayles et al., 1990). It is anticipated that greater benefits in terms of disease control and yield can be achieved by use of these extracts in subsequent field trials.

As elicitors induce the plant's own defence mechanisms, they should be able to control a wide range of pathogens on a number of crops and it is unlikely that pathogens will develop insensitivity to such extracts. Yeast is widely available as a low value industrial waste product and so extracts should prove relatively inexpensive to produce. It is anticipated that application of elicitors to crops will lead to a reduction in fungicide usage.

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THE USE OF COMPOSTED MATERIALS TO CONTROL PLANT DISEASES

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ABSTRACT

In pot experiments under controlled environmental conditions, composted organic household waste showed a suppression of soilborne plant pathogens. The addition of 10% and 30% compost to potting material artificially infected with *Pythium ultimum* considerably reduced the incidence of disease in different species of host plants. The degree of protection provided by compost depended upon the amount of compost added and upon the vulnerability of the host plant to infection.

INTRODUCTION

The effect of composts originating from different organic materials on the incidence of plant diseases has been studied (Hoitink & Fahy, 1986). Composted sewage sludge (Lumsden *et al*., 1983) as well as composted hardwood bark (Hoitink *et al*., 1977; Spencer and Benson, 1982) have been shown to suppress soilborne plant pathogens. A wide range of organic materials (of industrial and domestic origin) are available and following composting they may be appropriate for use in agriculture and forestry (Parr *et al*., 1986). An example of successful recycling of organic waste material from urban households is given by Vogtmann *et al*. (1986), where separately collected organic household refuse is composted in windrows. Substantial quantities of this composted organic household waste (COHW) would be available if this practice of recycling were to be widely adopted. This paper considers the anti-phytopathogenic qualities of this material.

MATERIALS AND METHODS

The compost used was derived from separately collected organic household waste. A full description of the composting process and the nutrient status of the end product are given in Schuler *et al*. (1989). All media used in the trials were brought to the same nutrient status and pH-level by the addition of mineral fertilisers. Details of culture conditions of the *Pythium ultimum* (Trow) strain used and the growing conditions of the test plants are described in Schueler *et al*

(1989). The planting medium consisted of sieved, steam sterilised sand, with compost added at a rate of 0%, 10% and 30% (except in the case of beetroot where 8% was used). At the same time, finely ground mineral fertiliser was added and the planting medium inoculated with the pathogen at a rate of 0.1%/l where appropriate. Eight pea (*Pisum sativum*,'Lanzet') and bean (*Phaseolus vulgaris*, 'Fori') seeds were sown in plastic pots (14cm dia.) at a depth of 2cm and covered with 1cm of sterile sand. Beetroot (*Beta vulgaris* var. *conditiva*, 'Rotor') was sown at 40 seeds per pot in rectangular pots. Plants were grown under 16hr light conditions (10-20,000 lux) in growth chambers.

Rate of emergence was recorded, plants were evaluated for disease symptoms daily and graded into four categories for severity. Twenty days after seedling emergence, plants were harvested and above-ground fresh weights recorded. Each experiment was performed twice with 5 replicates per treatment in a randomised block design. All data were analysed for significant differences using analysis of variance and Duncan's multiple range test.

RESULTS

The COHW suppressed pre-emergence and post-emergence damping-off of *P. ultimum* in beetroot (Table 1). The addition of 8% compost improved the stand of healthy seedlings when sowing took place simultaneously with the introduction of infection and compost amendment. This effect was achieved when sowing was delayed for seven days.

TABLE 1. Effect of COHW on suppression of *Pythium Ultimum* induced disease in beetroot (*Beta vulgaris*)

% Inoculum-added	% COHW added	Emergence[1] %	Infected plants[2] %
0	0	84.0 b	2.9 a
0.1	0	49.5 a	42.6 b
0.1	8	77.5 b	13.1 a

[1] Numbers are mean of 5 replicates.
[2] Expressed as % of emerged seeds.
Numbers in same column followed by same letter are not statistically different (Duncan-Test, p=0.05)

In peas, the compost also showed suppressiveness towards *P. ultimum*. With simultaneous sowing, addition of COHW kept the rate of emergence at the same level as when pathogen-free sand was used. This was not the case with the final plant weight, although the amendment of compost still resulted in double (at 10% COHW) or three times (at 30% COHW) the amount of fresh matter in the infected medium without COHW (Table 2). When sowing was delayed for seven days, the compost was not able to prevent pre-emergence damping-off.

TABLE 2. Effect of COHW on suppression of *Pythium ultimum* induced disease in peas (*Pisum sativum*).

% Inoculum added	% COHW added	Emergence[1] %	Fresh weight[2] g	%
0	0	87.3 b	13.8 d	100.0
0.1	0	67.5 a	3.0 a	21.0
0.1	10	80.0 ab	6.1 b	44.4
0.1	30	87.5 b	9.1 c	66.0

[1] Numbers are mean of 5 replicates.
[2] Mean of all plants per treatment not dead at end
Numbers in same column followed by same letter are not statistically different (Duncan-Test, p=0.05)

Phaseolus vulgaris was protected from the effects of the disease by the addition of 10% and 30% COHW to infected sand (Table 3). No major difference was observed between sowing dates. The plants grown in compost-amended substrates showed an average weight which was similar to the value of the pathogen-free control.

TABLE 3. Effect of COHW on suppression of *Pythium Ultimum* induced disease in beans (*Phaseolus vulgaris*)

% Inoculum added	% COHW added	Emergence[1] %	Fresh weight[2] g	%
0	0	95.0 b	9.9 b	100.0
0.1	0	57.5 a	2.3 a	23.2
0.1	10	100.0 b	11.6 b	117.0
0.1	30	97.5 b	11.8 b	119.7

[1,2] See table 2 for explanation
Numbers in same column followed by same letter are not statistically different (Duncan-Test, p=0.05)

DISCUSSION

In most cases the compost provided protection to plants against pre- and post- emergence disease. Additionally the plants grown in compost amended infected media showed better growth than plants grown without compost. This suggests that the suppressive action of the compost may be the result of the combined effects of antagonistic organisms present as well as other factors which may have a suppressive effect, for example: improvement of physical soil properties, better soil aeration and enhanced water holding capacity.

The extent of suppression of the pathogen would appear to be dependent upon the amount of compost added. In general an amendment of 30% COHW provided a higher degree of suppression than that achieved with the addition of 10%. Nelson & Hoitink (1983) also observed increased effectiveness with an increased compost amendment whereas Lumsden *et al* (1983) found no significantly different effect in the range between 5% and 30% added compost.

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THE EFFECTS OF VARIETY BLENDS AND SEEDRATES ON DISEASE AND WEED INCIDENCE IN WHEAT GROWN IN ORGANIC SYSTEMS

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ABSTRACT

This paper describes two trial series on sites managed to Soil Association Standards (Soil Association, 1989). In the first series three wheat varieties and 2-way and 3-way combinations of these varieties grown as blends were compared at 3 sites. At 2 of the sites disease incidence was very low, but at the third site the variety blends tended to reduce the incidence of mildew. Septoria tritici levels in the blends were not significantly affected. The 3-way blends gave a small yield response (2-3%) compared to the means of the constituent varieties grown alone. Yield response of the 2-way blends was erratic. In the second trial series, 5 wheat varieties were compared, each drilled at 3 seed rates, 300, 375 and 450 seeds per square metre. There was no significant yield response to seedrate, and disease incidence was not affected. There was a trend for greater weed suppression at the higher seed rates and with cv. M Widgeon. The variety M Widgeon gave the lowest yields in every trial.

INTRODUCTION

Previous work carried out with blends of cultivars of spring barley containing different resistance genes have given increased yields relative to the cultivars grown alone (Wolfe, 1980; Wolfe, 1981; Day, 1982). The increases in yield obtained have often but not always correlated with a reduction in the level and rate of build-up of disease in the crop, principally powdery mildew (Erysiphe graminis fsp hordei). A reduction in the levels of rust (Puccinia striformis) has also been observed in wheat blends and some indication that Septoria nodorum can be similarly reduced. The use of variety blends offers a potential strategy for disease control in an organic system in the absence of fungicides.

The yield of wheat is not particularly sensitive to seed rate (Cromack, 1987; ADAS, 1981), but the presence of a vigorous thick crop has been observed to limit weed growth, reducing consequent yield loss and harvesting problems associated with high weed populations. This paper describes 2 series of trials designed to examine (a) the effects of variety blends and (b) different seed rates on disease and weed incidence in wheat grown in an organic system.

MATERIALS AND METHODS

Variety Blends

Three trials were carried out in 1988/89, located on organic farms in Oxfordshire, Shropshire and Herefordshire (Soil Association, 1989). Three wheat varieties (cv's M Widgeon, Mercia, Axona) were grown in each trial with all possible 2- and 3-way combinations containing equal parts by number of seeds. The trials were established at a seed rate of 400 seeds sown/metre square in a randomised block layout with 4 replicates of each treatment, plot size 20 m x 1.83 m. Disease assessments were carried out at cereal growth stages 30/32 and 75/83 (Zadocks, 1974).

Seedrates

Two trials were carried out in 1988/89 and one trial in 1987/88, located in Wiltshire and Herefordshire (Soil Association, 1989). Five wheat varieties (cv's Avalon, Mercia, Rendezvous, M Widgeon, Alexandria) were grown at 3 different seed rates: 300, 375 and 450 seeds per square metre. Four replicates of each treatment were established in a randomised plot layout.

RESULTS

Variety Blends

Table 1 summarises the yields obtained at each of the 3 sites expressed as a percentage of the mean site yield. M Widgeon was significantly outyielded by Mercia and Axona at all 3 sites, Axona was the highest yielder at 2 sites. Table 2 compares the yields of the blends with the mean of the constituent varieties when grown alone. At all 3 sites the 3-way blend gave a positive but small non-significant response, outyielding the mean value by 2-3%. The yield response of the 2-way mixtures was erratic with only the Mercia/Axona blend giving a positive significant response at the Hereford site. In 7 of the 9 comparisons with the 2-way blends, the blend outyielded the lower yielding culitvar when sown alone but offered no advantage over the high yielding cultivar.

TABLE 1. Grain yield of cultivars and blends expressed as percentage of overall mean at each site.

Variety	Shropshire	Hereford	Oxfordshire
Mercia	114	102	103
Axona	111	124	108
M Widgeon	83	72	87
Mercia/Widgeon	87	82	93
Widgeon/Axona	97	93	99
Mercia/Axona	102	125	110
Mercia/Widgeon/Axona	105	101	101
Mean Yield (t/ha at 85% dm)	4.23	4.24	6.91
LSD (5%)	17	11	5

TABLE 2. Difference in grain yield of blends compared to the mean of their component varieties. Expressed as percentage of site means

Blend	Shropshire	Hereford	Oxfordshire
Mercia/Widgeon	- 11	- 5	- 2
Widgeon/Axona	0	- 5	+ 2
Mercia/Axona	- 10	+ 12	+ 4
Mercia/Widgeon/Axona	+ 3	+ 2	+ 2
LSD (5%)	17	11	5

The incidence of disease at the Oxfordshire and Shropshire sites was very low with mean mildew and S. tritici levels not exceeding 2% at GS30/32 and below 3% at GS75/83. No significant differences in disease levels were recorded between culitvars or blends at either of these sites. Disease levels at the Hereford site were higher and are summarised in Table 3.

TABLE 3. Percentage of mildew and Septoria tritici, Hereford site (GS32 leaf 3, GS83 leaf 1)

Variety	Mildew GS32	Mildew GS83	S. tritici GS32	S. tritici GS83
Mercia	17.3	14.3	14.3	3.1
Axona	9.1	9.1	28.0	3.3
M Widgeon	14.4	11.2	23.8	2.0
Mercia/Widgeon	9.8	8.1	20.0	2.9
Widgeon/Axona	16.3	12.2	16.9	3.6
Mercia/Axona	5.4	5.1	24.4	3.8
Mercia/Widgeon/Axona	1.6	8.4	29.3	4.0
LSD (5%)	4.4	NS	8.7	NS

There was a trend for the levels of mildew to be reduced in the blends compared to their component varieties, although the Widgeon/Axona blend carried more mildew than its constituent varieties grown alone. At the later assessment (GS83) mildew levels tended to be reduced in all of the blends. Levels of Septoria tritici tended to be higher in the blends than their constituent varieties.

Seedrate

Table 5 summarises the yields obtained at each of the 3 sites. M Widgeon was the lowest yielder at each site, Rendezvous yielded well at each site. There was no significant yield response to seedrate and no significant interactions between variety and seedrate.

TABLE 5. Mean grain yield (t/ha at 85% dm) at 3 seed rates

Site	Seedrate (seeds per square metre)		
	300	375	450
Hereford 1988	5.23	5.17	5.31
Hereford 1989	5.17	5.23	5.10
Wilts 1989	5.42	5.61	5.62
LSD (5%)	Not significant		

There was a small trend for the higher seedrate and the taller strawed M Widgeon to give greater weed suppression. Disease incidence and grain quality were not significantly influenced by seedrate.

DISCUSSION

Yields of the 2-way blends were erratic but overall they did not differ significantly from the mean of their constituent varieties. At the Hereford site where higher levels of disease were present, the Mercia/Axona blend gave a significant yield response. There was a trend for mildew levels to be reduced in the blends. Previous work has identified yield responses in blends not associated with disease levels and further work on selecting varieties suitable for blends in organic systems is required. Seedrate had no effect on yield but there was a trend for greater weed suppression at higher seedrates and with the cultivar M Widgeon.

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GROWING CEREALS IN A BASE OF WHITE CLOVER

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ABSTRACT

Cereals require large amounts of potentially environmentally-deleterious and costly applied nitrogen fertiliser to achieve econonically viable yields. Growing cereals in a legume base is seen as a possible means of overcoming these drawbacks.

A technique of oversowing spring barley and oats into a white clover crop was tested in two field experiments during 1987 and 1988. Total herbage (whole-crop) and grain yields in clover crops either partially checked or unchecked were compared with those obtained where clover had been removed herbicidally.

The cereals established satisfactorily in both years but were soon dominated by the unchecked clover, such that the resulting whole-crop and grain yields were small. Where clover had been partially checked before sowing, moderately large whole-crop yields were achieved in both years and of grain in 1987. Sufficient clover persisted in both seasons for the process to be repeated in a subsequent season.

It is concluded that further progress in the regulation of cereal/clover balances is of crucial importance for the development of such a sustainable system of cereal production.

INTRODUCTION

The benefits of growing leguminous and graminaceous crops together have been appreciated for centuries (Nicol, 1935). The value of legumes in crop rotations has also been recognised for a very long time with benefits accruing to succeeding non-legume crops from residual legume nitrogen (Bruulsema & Christie, 1987). There have also been many recent studies to evaluate the beneficial effects of legumes on subsequent crops (Badaruddin & Meyer, 1989; Hargrove, 1986; Papastylianou & Samios, 1987). Mixed cropping and intercropping systems which include legumes continue to be practised in tropical and developing countries, where there has been little investment in fertilisers and crop-protection chemicals (Remison, 1978). In contrast, in developed agriculture the widespread use of fertiliser nitrogen has led to a decline in crop rotations and interest in the use of legumes as sources of nitrogen (Groya & Sheaffer, 1985), compounded by a subsequent escalation in pesticide usage. In recent years increased realisation of the need to devise low input/moderate output, environmentally-sensitive, sustainable agricultural systems has renewed interest in mixed and intercropping systems in temperate regions. At the same time increasing costs of fertiliser nitrogen and concern about environmental pollution (Stewart & Rosswall,

1982) have highlighted the need to reduce use of fertiliser N and to seek alternative sources of nitrogen.

During 1987 and 1988 two field experiments were therefore conducted on the feasibility of oversowing cereals into monocultures of white clover and the consequences assessed in terms of total herbage and grain yields and residual clover growth.

MATERIALS AND METHODS

Sites, experimental treatments and lay-out

The first experiment (1987) was sited within a four-year old crop of large-leaved white clover, cultivar Alice, growing on heavy red sandstone near Hereford. Spring oats (cv. Emrys) and spring barley (cv. Dandy) were oversown at 150 kg ha^{-1} in rows 23 cm apart with a Hunter rotary strip-seeder on 15 April into plots where clover (i) had been killed by herbicide in mid-February (ii) was checked by 5.6 l ha^{-1} of paraquat, just before sowing or (iii) was unchecked.

The second experiment (1988) was sited on medium loam soil at Aberystwyth and involved an 18 month old white clover base, cultivar small-leaved S.184. The same two cereal cultivars, plus the dwarf barley cultivar Digger, were sown on 7 April into the clover given the same treatments as in 1987.

Both experiments were arranged as split randomised-blocks (four in 1987, three in 1988) with crop-cultivar being ascribed to main plots and clover treatment to sub-plots. Both sites had a pH of 6-7 and adequate reserves of P and K.

Assessments

Cereal seedling emergence and growth were assessed regularly during the first two months on the partially checked and clover-killed treatments. Herbage (whole-crop) yields above 5 cm were assessed from all plots in mid-August when the d.m. content of the cereals was c. 50% (and the grain at the 'hard-dough' stage). Dry weights, botanical and chemical compositions (N, acid- and water-soluble carbohydrates and fibre) were determined. Grain yields at maturity were also assessed. Residual clover leaf growth and stolons (1988 only) were assessed in mid-September 1987 and late October 1988, 36 and 29 or 83 and 70 days, after whole-crop harvest for barley and oats respectively.

RESULTS

Emergence and early growth

Seedlings emerged from fewer than 50% of the cereal seed sown in the first experiment, but more than 80% in the second. However, tillering was more restricted in the second experiment so that the mean number of shoots m^{-2}, 63 days after sowing was very similar for the two years (Table 1).

TABLE 1. Number and weight (g) of shoots m^{-2} of cereals at 63 days.

	Dandy (barley)		Digger (barley)		Emrys (oats)		
Clover	Killed	Checked	Killed	Checked	Killed	Checked	s.e.d.
1987(a)	552	382	-	-	459	360	30.8
1988(a)	573	384	957	409	413	332	20.7
1988(b)	354	148	338	102	246	187	16.3

(a) = number, (b) = weight

On average there were 20% fewer shoots of Emrys, 32% of Dandy and 58% of Digger in the checked clover bases than on clover-free plots. Individual shoots were also smaller in the former than in the latter treatment for barley but not for oats.

Whole-crop yield and quality

Largest whole-crop yields were obtained in both years when the cereals were grown without clover. Yields in checked clover were at least 75% of this in both years, whereas yields in unchecked clover were greatly reduced, especially in 1987 (Table 2).

TABLE 2. Whole-crop yields (t d.m. ha^{-1}) and % clover^{+} in early to mid August.

	*Dandy and Digger (Barley)				Emrys (Oats)			
	Killed	Unchecked	Checked	s.e.d.	Killed	Unchecked	Checked	s.e.d.
1987	13.4 (0.2)	3.1 (81)	10.0 (7)	0.61 (4.3)	12.7 (0.2)	4.1 (57)	9.7 (9)	1.37 (7.7)
1988	11.4 (0)	6.2 (63)	9.0 (26)	0.62 (8.0)	11.3 (0)	5.5 (39)	9.1 (14)	0.58 (2.2)

$^{+}$ in parenthesis, * mean of the two cultivars

Differences in chemical composition reflected different clover contents. For instance, in 1987 the N and WSC content of the unchecked treatment exceeded that of the two other treatments which did not themselves differ. In 1988 however, the checked clover treatment had significantly larger contents of both constituents than had the clover-killed treatment.

Grain yields

In 1987 grain yields of barley and oats growing in checked clover bases were 67 and 75% of those obtained on the clover-killed plots (Table 3). In 1988 the equivalent figures were 26% for Digger, 36% for Dandy and 61% for Emrys. The smaller relative yields in the checked clover in 1988 were caused by a further decline in shoot numbers between mid-June (Table 1) and cereal maturity (Table 3). Grain yields per shoot were also reduced by c. 13% on the clover-checked compared to the clover-killed plots in 1988.

TABLE 3. Grain yields (G) (t ha^{-1}) at 88% d.m. and corresponding shoot numbers (N) m^{-2}.

Clover+	Dandy (Barley) K	U	C	s.e.d.	Digger (Barley) K	U	C	s.e.d.	Emrys (Oats) K	U	C	s.e.d.
G 1987	7.4	0.3	5.0	0.53	-	-	-	-	8.4	1.1	6.3	0.43
N 1987	597	26	413	52.0	-	-	-	-	413	93	320	23.5
G 1988	6.1	*	2.2	0.18	6.9	*	1.8	0.18	5.6	*	3.4	0.40
N 1988	630	*	263	26.3	1044	*	294	25.3	349	*	250	24.4

+ treatments as in Table 2, - = not grown, * = not assessed

Residual clover growth

Four and five weeks after whole-crop harvest in 1987, there was a dense network of stolons on unchecked plots and a thinner but nevertheless continous one on plots with initially-checked clover. Mean leaf weight on the checked treatment at this time was 35% of that on the unchecked.

Residual stolon growth was extremely vigorous in both treatments in 1988, with stolon weights (g m^{-2}) even in the checked treatment (385, 494 and 329 for Dandy, Digger and Emrys respectively) greatly exceeding the initial (immediately pre-sowing) value of 182±13.

DISCUSSION

Growing more than one crop in the same field, especially simultaneously during the same year, is considered to give optimal and efficient use of resources (Francis, 1989). The concept of growing cereals in a perennial leguminous sward - with the legume providing nitrogen and some measure of weed control during co-culture and nutritious forage at other times of the year - extends the potential advantages to a sustainable low input/moderate output system of production. However, it is clear from the present experiments that factors controlling the balance of legume and non-legume, whilst being crucially important, may be very complex, and competitive rather than complementary, at least in the short-term. Nevertheless, despite yield reductions during this time there are often benefits to the N economy in the longer-term (Leach et al., 1986).

Large and moderate yields of cereals in 1987 and 1988 respectively following killing of the clover base indicated considerable value of residual nitrogen during breakdown of the clover. Clearly, since these yields exceeded those of cereals growing with clover, the current N fixation and transfer was less than the residual nitrogen of the former treatment. Both experiments indicated the importance of controlling the vigour of the clover crop before oversowing the cereal. Inadequate suppression of the clover (the unchecked treatment) resulted in clover dominance and disappointingly small yields of whole-crop and of grain. In contrast to the two previous treatments, the results for the treatment where the clover was initially checked with paraquat differed greatly between the two seasons (and sites). In 1987 this treatment resulted in an equitable cereal/clover balance, tending towards cereal dominance, but in 1988 (possibly due to very dry conditions following cereal sowing) the clover became dominant and grain yields of the cereals were resultingly small. Nevertheless, good whole-crop yields in both years confirm the potential value of the technique for whole-crop silage (Tetlow and Baker, 1990) and indicate that a relatively small clover content may increase both protein and water-soluble carbohydrate. Similarly the results on cereal grain production, in conjunction with parallel work by Jones (1990), who obtained similar yields to conventional culture, are also promising.

However, to develop the technique, further work is needed on
(1) controlling and defining optimal pre-sowing vigour of the clover without resort to herbicides e.g. by grazing and mechanical disturbance
(2) the influence of different rates and dates of cereal sowing including the use of winter crops to optimise spatial and temporal complementarity
(3) selecting appropriate compatible genotypes of both crops
(4) understanding and manipulating the nitrogen cycle, to maximise the benefits of residual and currently fixed N and to synchronise release and uptake (eg by using winter rather than spring varieties)
(5) the impact of the system on pest, disease and weed control with the objective of reducing use of agrochemicals and minimising environmental pollution.

Progress in the above aspects should help in developing a sustainable system where economic viability, crop quality and environmental protection are paramount.

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ORGANIC SYSTEMS TRIALS IN THE NORTH OF SCOTLAND

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ABSTRACT

A comparative organic and conventional rotational trial was established in 1986. Organic cereal yields were c. 50% lower than conventional in 1987. A top-dressing of chicken manure improved yields of spring cereals but not winter wheat in 1988 and 1989. Organic potato yields were consistently c. 33% lower than conventional yields; organic potatoes suffered less slug damage. Organic swede yields were 6% lower than conventional in 1987 and 1989, but were 31% lower in 1988 following severe aphid infestation.

In a long-term manurial rotational trial farmyard manure was applied with and without NPK. Phosphate was applied as either ground mineral phosphate or superphosphate. Highest yields were obtained with the superphosphate treatment. For a range of crops, yields from plots receiving only farmyard manure were 10-29% lower than from plots receiving additional NPK (superphosphate). No reduction in yield occurred within any treatment over the period 1922-1987, indicating sustainability of each system in trial.

INTRODUCTION

Organic production in the North of Scotland is hampered by slow mineralisation of soil nitrogen in the spring due to cold temperatures, but is aided by generally high soil o.m. levels and reduced incidence or severity of many pests and diseases.

An organic eight-course rotational trial was set up in 1986 in Aberdeenshire to examine yield and quality differences occurring during and after conversion to organic production. In 1922 a manurial six-course rotational trial was set up at the same site to compare yields of crops produced with the use of different fertiliser treatments or farmyard manure (FYM) alone. The effectiveness of ground mineral phosphate (GMP) as compared to single superphosphate was also examined. Apart from FYM, GMP is the only source of phosphate readily available to the organic grower.

METHODS AND MATERIALS

The organic rotational trial was established at Woodlands Field, Craibstone, Aberdeen in autumn 1986. The soil is a free-draining sandy loam of the Countesswells Association and Series, with an organic matter content of 9-11%. Soil phosphate status ranged from moderate (ADAS Index 2) to high (ADAS Index 3-4), and soil potash status from moderate (ADAS

Index 2) to low (ADAS Index 1). Eight plots, each 45.0 m long by 10.1 m wide, already in rotation, were each assigned to one course in an eight-course rotation consisting of three years of grass/clover, winter wheat, potatoes, spring oats, swedes and undersown spring barley. Each main plot was then divided into three subplots, each of which was randomly assigned to one of three management systems.

The trial included an organic system, in which inputs and husbandry methods appropriate to Soil Association standards were utilised, although the land, being comprised of experimental areas only, was not registered for organic certification. The only manurial input in 1987 was 30 t/ha FYM applied prior to ridging to the potato and swede courses. From standard figures, 30 t/ha FYM field-stored for 12 months supplies 9-24-90 kg/ha N-P-K (Anon, 1985). In 1988 and 1989 a top dressing of 6.25 t/ha chicken manure, supplying 32 kg/ha N, was applied to the cereal courses. P_2O_5 was applied at 50 kg/ha to each course each year as GMP.

The trial included an intermediate input system, not directly relevant to this paper. It also included a conventional system in which fertilisers and pesticides were applied according to current Scottish Agricultural Colleges recommendations (Anon, 1985).

This organic rotation trial was set up adjacent to the site of a manurial rotation trial established in 1922. In the manurial trial six main plots, 45.0 m long by 4.9 m wide, were each assigned to one course in a six-course rotation consisting of three years of grass/clover (the first harvested as hay), spring oats, a mixed course of swedes, turnips and potatoes, and a final course of spring barley undersown with grass/clover. Each main plot was then divided into six subplots, each of which was assigned to one of six fertiliser treatments. Three of these are considered here: FYM only, FYM + NPK with phosphate as single superphosphate, and FYM + NPK with phosphate as GMP.

FYM was applied at 30 t/ha prior to ridging to the mixed course of root crops. Where fertiliser was applied, rates were maintained at the original levels. These are low in relation to modern levels, particularly for nitrogen. Nitrogen was applied as sulphate of ammonia, at 26.25 kg/ha N to cereals, hay and root courses. Where phosphate was applied as single superphosphate, rates were 47.5 kg/ha P_2O_5 to cereals and hay and 95.0 kg/ha P_2O_5 to roots. Where phosphate was applied as GMP rates were 75.0 kg/ha P_2O_5 to cereals and hay and 150.0 kg/ha P_2O_5 to roots. Potash was applied as muriate of potash, at 39.0 kg/ha K_2O to cereals and hay and at 75.0 kg/ha K_2O to roots.

RESULTS AND DISCUSSION

In the organic rotation trial in 1987 organic cereal yields were half those of the conventional (Table 1). Following a spring top-dressing of chicken manure, supplying 32 kg/ha nitrogen, spring barley and spring oats yields were increased in 1988 and 1989 to only 15-25% below the conventional. Winter wheat yields in 1988 were still half that of the conventional due to poor winter survival and poor tillering; in 1989, following a mild winter, yields were reduced by only 30%. Generally, organic cereals were less severely affected by powdery mildew (Erysiphe graminis) than conventional cereals. In all three years organic potato yields were approximately a third less than conventional yields, although d.m. was higher and there was less slug damage in the organic potatoes. Organic swede yields were only 6% lower than conventional in 1987 and 1989, but following severe aphid infestation were 31% lower than conventional in 1988. Organic swede d.m. was higher. Use of quassia chip extract as an aphicide on the organic swedes had a very limited success.

Table 1. Yields in organic rotational trial, 1987-89 (t/ha)

Crop	Organic conversion			Conventional		
	1987	1988	1989	1987	1988	1989
Wheat (85% d.m.)	3.2	4.1	6.2	6.8	8.8	8.9
Potatoes (fresh yield)	34.6	27.4	30.1	47.1	42.4	45.4
Oats (85% d.m.)	3.3	3.6	3.4	7.1	4.8	4.2
Swedes (d.m.)	6.1	5.4	4.7	6.5	7.8	5.0
Undersown barley (85% d.m.)	1.9	4.1	3.5	4.8	4.6	4.1
Hay (d.m.)	5.2	5.4	2.6	7.5	10.1	4.7

In the second trial, plots treated with GMP instead of single superphosphate were given proportionately more phosphate. Despite this, cereal, hay and potatoes gave 1.4%-9.0% lower yields with its use, even at the pH of 6.2 maintained on the trial site (Table 2); GMP is more effective the lower the pH. The swede and turnip crops gave similar yields with both phosphate treatments, indicating that these crops can utilise GMP more effectively.

Table 2. Yields in manurial rotation trial, 1922-87 (t/ha)

Crop	FYM only	FYM+NP[1]K	FYM+NP[2]K	SED
Oats (85% d.m.)	2.75	3.78	3.44	0.084
Potatoes (fresh yield)	29.8	38.1	35.5	0.571
Swedes (d.m.)	5.62	6.52	6.56	0.152
Turnips (d.m.)	4.82	5.36	5.42	0.144
Barley (85% d.m.)	2.42	3.08	2.82	0.056
Hay (d.m.)	4.54	6.41	6.32	0.114

[1] single superphosphate; 47.5 kg/ha P_2O_5 cereals, hay; 95 kg/ha P_2O_5 roots
[2] GMP; 75 kg/ha P_2O_5 cereals, hay; 150 kg/ha P_2O_5 roots

Data were also analysed as complete rotations over the period. Oats and swede yields are given as examples (Table 3). Cereal yields rose considerably between 1922 and 1987, while potato, swede and turnip yields remained fairly constant. This occurred within each treatment, indicating the sustainability of all systems in trial.

Table 3. Oats and swede yields in manurial rotation trial, 1922-87 (t/ha)

Rotation	Oats (85% d.m.)			Swedes (d.m.)		
	FYM only	FYM+NP[1]K	FYM+NP[2]K	FYM only	FYM+NP[1]K	FYM+NP[2]K
1922-27	1.4	2.4	2.1	5.8	6.4	6.8
1928-33	2.0	3.1	2.4	5.6	6.3	6.8
1934-39	1.7	3.1	2.6	4.9	5.7	5.9
1946-51	1.9	3.2	2.7	4.7	5.8	5.9
1952-57	2.1	3.1	3.1	6.6	7.7	7.9
1958-63	2.7	3.1	3.0	6.8	7.2	6.9
1964-69	3.6	4.8	4.0	5.9	6.5	6.2
1970-75	3.5	4.4	4.3	5.3	6.1	6.1
1976-81	3.0	3.8	3.7	4.2	5.6	5.7
1982-87	3.9	5.3	4.9	5.7	7.0	7.1
SED	0.24-0.34			0.44-1.07		

[1] single superphosphate; 47.5 kg/ha P_2O_5 oats; 95 kg/ha P_2O_5 swedes
[2] GMP; 75 kg/ha P_2O_5 oats; 150 kg/ha P_2O_5 swedes

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