MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

Date project completed:

Research and Development

Final Project Report

(Not to be used for LINK projects)

•

Section 1 : Identification sheet

1. (a) MAFF Project Code: **OF107**

(b) Project Title: Organic wheat survey

(c) MAFF Project Officer:

(d) Name and address of contractor:
ADAS Boxworth
Boxworth
Cambridge
Postcode CB3 8NN

(e) Contractor's Project Officer:

(f) Project start date: 01/06/1993 Project end date: 31/03/1997

(g) Final year costs: **approved** expenditure:

(h) Total project costs / total staff input: **approved** project expenditure:

actual project expenditure:

***approved** staff input:

***actual** staff input:

(i) Date report sent to MAFF:

(j) Is there any Intellectual Property arising from this project ?

***staff years of direct science effort**

Section 2 : Scientific objectives / Milestones

2. Please list the scientific objectives as set out in CSG 7 (ROAME B). If necessary these can be expressed in an abbreviated form. Indicate where amendments have been agreed with the MAFF Project Officer, giving the date of amendment.

To obtain information on year to year variations in disease levels in organic wheat crops on farms selected to provide a wide geographic spread over England and Wales (1993-1996)
ii) To monitor weed populations through rotations on the same sample of farms and thus obtain information on the development of weed populations in the context of different geographical situations and of varying rotational and cultural practices (harvest years 1993-1996)

3. List the primary milestones for the final year.

It is the responsibility of the contractor to check fully that ALL primary milestones have been met and to provide a detailed explanation if this has not proved possible

Milestones		Target date	Milestones met?	
Number	Title		in full	on time
1				

If any milestones have not been met in the final year, an explanation should be included in Section 5.

Section 3 : Declaration

4. I declare that the information I have given in this report is correct to the best of my knowledge and belief. I understand that the information contained in this form may be held on a computer system.

Name

Position in Organistation

Section 4 : Executive summary

A four-year study to monitor fourteen organic farms for weed incidence throughout England and Wales began in summer 1993. Two farms were selected from each of the 'former ADAS' regions these being: East, Midlands and West, North, South East (Reading), South East (Wye), South West (Bristol) and South West (Starcross). Each pair of farms had been using organic production for different periods of time. On each farm, five fields were selected at random and assessed for weed incidence and severity in December, March, May and July. If a field was in wheat, a sample of fifty tillers was collected at random at GS 75 (July) from a diagonal traverse. Samples were assessed for severity of all foliar, stem-base and ear diseases. Details of cultivations, sowing date and crop husbandry practices were taken for each field. Soil samples were taken in March 1994 and assessed for pH, organic matter, and nutrient status.

The mean number of fields assessed at each assessment date was 58, the differences in numbers assessed was due to lack of crop in the field or the field being grazed by animals. Over all farms the most frequently occurring weeds were common chickweed (64% of fields) and annual meadow-grass (49%). Field speedwell, mayweeds and docks were found in approximately 30% of fields. Couch, black-bindweed, common wild-oat, cultivated oat and volunteer wheat were the least frequently occurring weeds, occurring in fewer than 10% of fields.

Farms were divided into those converted to organic farming pre-1985 and those converted post-1985; this gave approximately 50% of the total farms surveyed in each category. In fields converted to organic farming pre-1985 there was a greater weed incidence overall. Chickweed was still the most frequently occurring weed but was present in 81% of fields converted pre-1985 and only 59% of fields converted after this date. Actual individual weed populations were also greater in fields converted to organic cropping pre-1985. Poppy, chickweed and mayweeds had higher populations in fields converted pre-1985 but black-grass had higher populations in fields converted post this date. Soil type and rotation had very little effect on weed incidence.

The main findings of the project were; the spectrum of most common weeds of organic crops was very similar to that of conventional crops; long periods of organic farming has lead to the build up of specific weeds and the demise of others; weed levels in organic situations were high enough to contribute significantly to economic yield losses in crops; the survey was not large enough to form a complete picture of weeds in organic cropping.

Foliar disease levels in wheat crops were higher in organic crops than in conventionally grown crops. However, as a result of good rotational practices and later sowing dates, incidence of stem-base diseases was lower. An increased number of years in organic farming appeared be associated with reduced incidence and severity of all foliar diseases except *Septoria nodorum* and to increased incidence of eyespot.

Future work should encompass surveys of conventional, integrated and organic crops to provide comparative data on the current situation. This would provide information on changes in the national agricultural weed flora and an early warning system on the build up of resistance in specific weeds that may not be noticed from a local perspective. These surveys would also provide essential data on disease levels occurring in crops under differing management strategies hence providing a measure of the benefits of each system in terms of disease risk and the economic benefits of control.

Section 5 : Scientific report

Introduction

Since its regulations preclude the use of all herbicides and most fungicides and insecticides, organic farming can present problems in the control of weeds, pests and diseases which would readily be overcome by the use of agrochemicals in conventional agriculture. Conversely the methods used by organic farmers (sound rotational practices, reduced rates of nitrogen, use of resistant cultivars) will in themselves reduce the risks for certain crop protection problems. To illustrate these differences, objective data are obtained on the extent of the problems encountered by commercial organic growers and also on the influence of good husbandry practices on these problems.

In 1991 and 1992, ADAS and the Central Science Laboratory (CSL) carried out surveys of the weed, pest and disease problems of organic wheat crops. The results of the surveys showed that while losses due to diseases were generally low and aphid attacks (though occasionally severe) were very erratic, weed competition was by far the most consistent and potentially damaging crop protection problem encountered. There was evidence that certain perennial weeds tended to build up under successive years of organic cropping. Grain aphids were the major pest problem, with high levels being found on occasions. Mean levels of leaf diseases were slightly higher than those found in the CSL/ADAS annual survey of conventional crops. Eyespot, however, was less of a problem in organic crops compared to conventional wheat crops. The data collected during this initial survey referred to wheat crops only. One of the main conclusions from the work was that crop protection problems, particularly weeds, need to be monitored through all parts of the rotation.

A further four year project has been funded to extend the information collected in the earlier survey by detailed monitoring of a sub-sample of the farms in that survey. Particular attention will be paid to monitoring weed populations in all crops in the rotation, but information will also be obtained on year to year variations in the incidence of pests and diseases in cereals. A database has been constructed at CSL to handle complex analysis of the data collected.

Objectives

(i) To obtain information on year to year variations in disease levels in organic wheat crops on farms selected to provide a wide geographical spread over England and Wales (1993-1996).

(ii) To monitor weed populations through rotations on the same sample of farms and thus to obtain information on the development on weed populations in the context of different geographical locations and of varying rotational and cultural practices (harvest years 1993- 1996).

Materials and Methods

Fourteen organic farms were visited by ADAS staff in the years between 1993 and 1996. Selection of farms, where possible, was based on two from each former ‘ADAS region’ which had participated in the previous organic survey and which had been in organic production for different lengths of time (Table 1). On each farm, five fields were selected at random and assessed for weed incidence and severity in twenty quadrats on a transect across the field. If the field was in wheat then a sample of fifty fertile tillers at GS 75 was collected at random from a diagonal traverse of the field. Plant samples were collected by ADAS staff and sent to the CSL for assessment.

Table 1. Farms selected for monitoring

Farm number	Region	First year in organic husbandry (exc. conversion)
1	North	1989
2	North	1949
3	South East (Reading)	1981
4	South East (Reading)	1983
5	Midlands and West	1987
6	Midlands and West	1949
7	South West (Bristol)	1984
8	South West (Bristol)	1983
9	South East (Wye)	1954
10	South East (Wye)	1991
11	East	1989
12	East	1988
13	South West (Starcross)	1983
14	South West (Starcross)	1986

Weed incidence and density assessments

Weed assessments were done on 4 occasions during the cropping year: December, March, May and July. A transect was set between two visible fixed features across the field or part of field, to allow the siting of 10 equidistant quadrats of $1m^{-2}$ between 5 and 30m apart. The first quadrat was within 12m of the field edge and the final quadrat at least 25m from the headland. These transects were established in the first year of the project and were assessed each year.

Weed species were identified and the number of each species occurring in each quadrat counted.

Disease assessments

If the field was in wheat then a sample of fifty fertile tillers at GS 75 was collected at random from a diagonal traverse of the field. Plant samples were collected by ADAS staff and sent to CSL for assessment.

Sub-samples of 25 wheat tillers were assessed on arrival at CSL for foliar, ear and stem-base diseases. Leaf diseases were recorded as the percentage laminar area affected on the flag and second leaves using standard area keys (Anon, 1976). Ear diseases were assessed as the percentage ear area affected by symptoms. Symptoms caused by *Botrytis* spp. or *Fusarium poae* were assessed as the number of glumes affected per ear.

Eyespot and sharp eyespot were recorded as the percentage of tillers affected by slight, moderate or severe symptoms, after the method of Scott & Hollins (1974).

Eyespot and sharp eyespot assessment key

Score	Description
Slight	Lesions girdling less than half the circumference of the stem
Moderate	Lesions girdling more than half the circumference of the stem
Severe	Lesions girdling more than half the circumference of the stem and tissue softened so that lodging would readily occur

The incidence and severity of fusarium stem-base disease symptoms on the nodes and internodes was recorded using the key below.

Fusarium assessment key

Score	Description
Nodes	
00	No infection
01	Staining on one or more nodes but not covering the whole circumference of the stem
02	Staining on one or more nodes covering the whole circumference of the stem
03	One or more nodes rotted - likely to cause lodging
Internodes	
00	No infection
01	Slight streaks on the stem-base
02	General browning on the stem-base
03	stem-base rotten - likely to cause lodging

Soil analyses

Soil samples were taken in March 1994 for pH and nutrient analyses (P, K, Mg) and determination of soil organic matter content.

Agronomic information

Questionnaires giving details of cultivar, sowing date, previous cropping and crop husbandry practices were completed for all fields included in the survey. All data from farm questionnaires and weed and disease assessments were processed at CSL and added to the database.

Results

Agronomic details

The survey comprised ten assessment occasions for weeds and covered two harvests. Limited information on variety, sowing date, previous cropping and crop husbandry practices was available from the questionnaire forms.

The selected farms (Fig. 1) were representative of the whole of England.

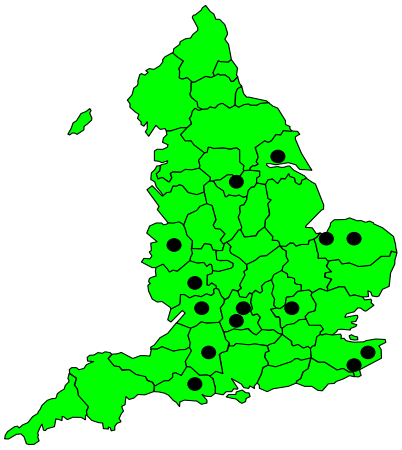

Fig. 1. Location of farms

Weeds

Weed populations were assessed in all crops, counts were not done where weeds were not present or the fields were being grazed by animals.

The mean number of fields assessed at each assessment date was 58. It was not possible to assess all fields on each occasion due to lack of crop in the field or the field being grazed by animals.

Over all farms the most frequently occurring weed was *Stellaria media* (64% of fields) then *Poa annua* (49%), *Veronica persica, Matricaria* spp., and *Rumex* spp. in approximately 30% of fields (Table 4). *Elymus repens, Polygonum persicaria, Avena fatua, Avena sativa* and *Triticum aestivum* were the least frequently occurring weeds, occurring in fewer than 10% of fields. Spring germinating weeds, such as *Fallopia convolvulus* and *Anagallis arvensis*, were more prevalent at the spring assessments but all weeds were present at each assessment date.

Table 4. Percentage of fields affected by weed at each assessment date, 1994-1996, mean of all farms (weed ranking in parentheses)

Assessment date	December	March	May	July	Mean
No of fields affected	58	56	60	59	58
Stellaria media	49 (1=)	68 (1)	77 (1)	67 (1)	64 (1)
Poa annua	49 (1=)	46 (2)	55 (2)	49 (2)	49 (2)
Veronica persica	33 (5=)	32 (5=)	47 (3)	29 (3=)	34 (3)
Matricaria spp.	36 (4)	32 (5=)	39 (5)	29 (3=)	33 (4)
Rumex spp.	32 (7=)	36 (3)	32 (6)	25 (6=)	31 (5)
Sonchus spp.	32 (7=)	23 (11)	28 (11)	26 (5)	27 (6=)
Papaver rhoeas	33 (5=)	24 (10)	30 (9)	21 (11)	27 (6=)
Galium aparine	25 (12)	30 (8)	27 (13)	25 (6=)	27 (6=)
Myosotis spp.	26 (11)	31 (7)	31 (7)	20 (12)	27 (6=)
Polygonum aviculare	46 (3)	13 (18)	43 (4)	2 (30)	25 (10)
Trifolium spp.	29 (10)	20 (12=)	22 (17)	24 (9=)	24 (11)
Viola arvensis	23 (14)	20 (12=)	29 (10)	24 (9=)	23 (12)
Veronica spp.	10 (25)	33 (4)	19 (20)	25 (6=)	22 (13)
Ranunculus spp.	16 (18=)	20 (12=)	24 (15)	19 (14)	19 (14=)
Lamium purpureum	11 (24)	26 (9)	22 (17)	17 (15=)	19 (14=)
Taraxacum officinale	17 (17)	16 (16)	28 (11)	17 (15=)	19 (14=)
Fumaria officinalis	12 (21=)	18 (15)	26 (14)	17 (15=)	17 (17)
Sinapis arvensis	16 (18=)	11 (22)	20 (19)	20 (12)	16 (18=)
Capsella bursa-pastoris	19 (15)	14 (17)	19 (21)	14 (19)	16 (18=)
Fallopia convolvulus	31 (9)	7 (25)	23 (16)	5 (25)	16 (18=)
Chenopodium album	24 (13)	3 (28)	31 (7)	3 (28=)	14 (21)
Alopecurus myosuroides	12 (21=)	13 (18=)	14 (23)	12 (21)	13 (22)
Senecio vulgaris	6 (30)	13 (18=)	11 (24)	15 (18)	11 (23=)
Geranium spp.	10 (25=)	12 (21)	9 (26=)	13 (20)	11 (23=)
Lolium perenne	14 (20)	9 (23)	9 (26=)	10 (22)	11 (23=)
Anagallis arvensis	19 (15)	2 (29=)	15 (22)	6 (24)	10 (26)
Elymus repens	9 (28)	8 (24)	4 (30)	8 (23)	8 (27)
Polygonum persicaria	10 (25=)	2 (29=)	11 (24)	3 (28=)	6 (28=)
Avena fatua	12 (21)	4 (26=)	5 (28=)	1 (31)	6 (28=)
Avena sativa	7 (29)	4 (26=)	5 (28=)	4 (26=)	5 (30)
Triticum aestivum	2 (31)	0 (31)	0 (31)	4 (26=)	1 (31)

The farms surveyed were split into those converted to organic pre-1985 and those converted post-1985. This resulted in 8 farms in the former category and 6 in the latter. Only 24% of fields surveyed had been converted to organic pre- 1985, the remainder had been converted after this date. The data has been ranked and is presented in the ranking order of weed incidence of farms converted pre-1985 (Table 5).

In fields converted to organic farming pre-1985 overall there was a greater weed incidence. *Stellaria media* was still the most frequently occurring weed but was present in 81% of fields converted pre-1985 and only 59% of fields converted after this date (Table 5). The incidence of several weeds was different depending on the length of time in organic farming (Table 6).

Table 5. Effect of length of time in organic farming on weed incidence (mean of 1993-1996)

	Date farms converted to organic			
	Pre-1985		Post-1985	
	% fields with weed present	Rank	% fields with weed present	Rank
No of fields	14		44	
Stellaria media	81	1	59	1
Rumex spp.	62	2	21	9
Veronica persica	60	3	26	6
Poa annua	60	4	46	2
Matricaria spp.	55	5	27	4
Papaver rhoeas	53	6	18	13
Fumaria officinalis	53	7	7	25
Sinapis arvensis	50	8	6	29
Taraxacum officinale	35	9	13	20
Trifolium spp.	35	10	20	11
Galium aparine	34	11	24	8
Ranunculus spp.	34	12	14	18
Veronica spp.	33	13	19	12
Viola arvensis	30	14	21	10
Lamium purpureum	30	15	15	15
Myosotis spp.	29	16	26	5
Sonchus spp.	28	17	27	3
Polygonum aviculare	27	18	24	7
Capsella bursa-pastoris	25	19	14	19
Anagallis arvensis	21	20	6	27
Fallopia convolvulus	20	21	14	17
Geranium spp.	14	22	11	23
Chenopodium album	11	23	15	16
Senecio vulgaris	9	24	12	21
Elymus repens	9	25	7	24
Polygonum persicaria	7	26	6	28
Lolium perenne	7	27	12	22
Avena sativa	3	28	5	30
Triticum aestivum	2	29	1	31
Avena fatua	1	30	7	26
Alopecurus myosuroides	1	31	16	14

Table 6. Effect of length of time in organic farming on incidence of weeds.

Greater incidence in fields converted pre-1985	Incidence was not affected by length in organic farming	Less incidence in fields converted pre-1985
Fumaria officinalis	*Trifolium* spp.	*Avena sativa*
Sinapis arvensis	*Lamium purpureum*	*Senecio vulgaris*
Rumex spp.	*Anagallis arvensis*	*Chenopodium album*
Papaver rhoeas	*Poa annua*	*Lolium perenne*
Veronica persica	*Veronica* spp.	*Avena fatua*
Matricaria spp.	*Capsella bursa-pastoris*	*Alopecurus myosuroides*
Stellaria media	*Galium aparine*	
Taraxacum officinale	*Viola arvensis*	
Ranunculus spp.	*Fallopia convolvulus*	
	Myosotis spp.	
	Polygonum aviculare	
	Geranium spp.	
	Elymus repens	
	Sonchus spp.	
	Polygonum persicaria	
	Triticum aestivum	

Actual weed population data (Table 7) show a greater total number of weeds in fields converted to organic farming pre-1985. In these fields *Papaver rhoeas, Stellaria media,* and *Poa annua* were the top three weeds. In fields converted post-1985 weed populations were much lower and *Alopecurus myosuroides* was greatest in number followed by *Stellaria media,* and *Poa annua*. *Papaver rhoeas* had dropped from 1st to 14th place.

Papaver rhoeas, Stellaria media and *Matricaria* spp. had higher populations in fields converted pre-1985 but *Alopecurus myosuroides* had higher populations in fields converted after this date (Table 7).

Table 7. Effect of length of time in organic farming on weed populations (mean of 1993-1996)

	Date farms converted to organic			
	Pre-1985		Post-1985	
	Plants m^{-2}	Rank	Plants m^{-2}	Rank
Papaver rhoeas	15.4	1	0.6	14
Stellaria media	12.4	2	6.4	2
Poa annua	7.6	3	6.4	3
Matricaria spp.	7.0	4	2.0	7
Sinapis arvensis	4.4	5	1.9	9
Veronica spp.	4.0	6	3.0	6
Veronica persica	3.8	7	1.5	10
Fumaria officinalis	3.3	8	0.0	31
Lamium purpureum	1.5	9	0.4	18
Viola arvensis	1.5	10	0.5	16
Geranium spp.	1.1	11	0.1	27
Galium aparine	1.0	12	0.3	24
Polygonum aviculare	0.9	13	3.0	5
Chenopodium album	0.8	14	0.6	13
Anagallis arvensis	0.8	15	0.1	26
Trifolium spp.	0.7	16	3.8	4
Ranunculus spp.	0.6	17	0.5	15
Rumex spp.	0.5	18	0.1	28
Lolium perenne	0.5	19	1.4	11
Fallopia convolvulus	0.4	20	0.4	17
Triticum aestivum	0.4	21	0.1	30
Capsella bursa-pastoris	0.3	22	0.2	25
Avena sativa	0.3	23	2.0	8
Elymus repens	0.3	24	0.4	21
Myosotis spp.	0.2	25	1.4	12
Senecio vulgaris	0.1	26	0.1	29
Taraxacum officinale	0.1	27	0.3	22
Polygonum persicaria	0.1	28	0.4	20
Avena fatua	0.0	29	0.4	19
Sonchus spp.	0.0	30	0.3	23
Alopecurus myosuroides	0.0	31	8.2	1
Total	69.9		46.6	

The effect of soil texture

Soil types ranged from very light to heavy. The soils selected for organic production are usually the more productive, easily worked soils. The data show that the farms converted pre-1985 were present on light to medium soil types and those converted later encompassed a wider range, from very light through to heavy soils (Table 8). Soil organic matter content was on average 1.1% greater in farms that had been in organic longer; soil nutrient status was similar for the two groups.

Table 8. Soil nutrient status by farm (mean of samples from 5 fields) sampled March 1994.

Farm number	Region	First year in organic Husbandry (exc. Conversion)	Texture class	Texture Group	Soil nutrient status (index)				
					pH	OM (%)	K	P	Mg
Farms converted prior to 1985									
2	North	1949	SL-SZL	L	7.9	5.5	2.4	4.8	2.4
3	South East (Reading)	1981	-	-	8.0	4.8	2.8	2.0	3.0
4	South East (Reading)	1983	SL&CL	M-L	7.3	4.2	1.8	0.6	2.2
6	Midlands and West	1949	CL	M	6.4	2.2	1.2	3.6	3.2
7	South West (Bristol)	1984	ZL-ZCL	L-M	7.8	-	2.2	2.0	2.2
8	South West (Bristol)	1983	SC-SCL	M	7.3	-	3.4	2.2	2.8
9	South East (Wye)	1954	ZL	L	7.8	3.6	0.6	2.0	1.2
13	South West (Starcross)	1983	SCL	L-M	7.5	5.0	0.8	0.8	1.2
Farms converted post 1985									
1	North	1989	SL	L	6.7	5.0	2.2	2.8	5.2
5	Midlands and West	1987	ZCL	M	7.2	2.8	2.0	1.2	2.2
10	South East (Wye)	1991	ZC	H	6.9	4.5	2.6	1.4	3.4
11	East	1989	LS	VL	7.8	1.7	1.0	2.6	0.8
12	East	1988	LS	VL	7.8	1.5	1.6	3.6	1.2
14	South West (Starcross)	1986	SZL	L	8.7	3.2	5.0	3.3	3.5

*VL - Very light, L - Light, M - Medium, H - heavy

LS – Loamy sand, SL – Sandy loam, SZL – Sandy silt loam, ZL – Silt loam, SCL – Sandy clay loam, CL – Clay loam, ZCL – Silty clay loam, ZC – Silty clay

There were similar numbers of fields in each soil textural class. *Poa annua*, *Sonchus* spp., *Stellaria media* and *Veronica persica* occur with similar frequency on all soil types. There was a trend for *Papaver rhoeas* to occur on the lighter soil types and *Trifolium* spp. to prefer the heavier types (Table 10).

Table 10. The effect of soil texture class type on weed frequency (% fields with weed present)

Soil Texture class	Loamy sand	Sandy loam	Sandy silt loam	Silt loam	Sandy clay loam	Clay Loam	Silty clay loam	Silty clay
No of fields	25	19	27	17	15	14	23	12
Alopecurus myosuroides	4	5	0	6	0	7	0	0
Anagallis arvensis	8	0	7	18	7	0	0	0
Avena sativa	4	21	0	0	0	7	4	0
Capsella bursa-pastoris	20	5	15	0	7	14	13	25
Chenopodium album	4	0	0	12	7	0	4	0
Elymus repens	12	11	7	0	13	7	0	0
Fallopia convolvulus	0	11	4	0	7	7	4	0
Fumaria officinalis	0	11	19	29	13	29	17	0
Galium aparine	0	21	15	18	20	7	13	25
Geranium spp.	28	5	4	6	13	14	4	0
Lamium purpureum	0	21	7	24	13	22	4	33
Lolium perenne	8	11	4	0	7	7	9	0
Matricaria spp.	40	0	19	29	0	29	17	25
Myosotis spp.	0	26	15	6	20	14	9	0
Poa annua	32	42	22	41	27	22	26	42
Papaver rhoeas	28	11	15	29	13	22	0	0
Polygonum aviculare	0	0	0	0	7	0	4	8
Polygonum persicaria	0	0	7	0	7	7	4	0
Ranunculus spp.	0	26	15	12	13	14	9	25
Rumex spp.	8	11	19	12	27	36	22	0
Senecio vulgaris	24	11	19	6	7	0	9	17
Sonchus spp.	24	16	11	6	33	14	22	33
Stellaria media	36	32	33	35	40	36	30	33
Sinapis arvensis	0	11	26	29	13	29	9	25
Taraxacum officinale	0	0	11	24	40	14	9	8
Triticum aestivum	0	16	7	0	0	0	0	0
Trifolium spp.	0	11	11	6	20	43	17	33
Veronica persica	36	5	30	29	20	14	17	17
Veronica spp.	0	11	19	12	20	29	9	0
Viola arvensis	16	11	15	6	27	36	26	0

Rotations and cropping

Rotation types were variable but were divided into seven categories (Table 11).

Since there were no occurrences of the combinable breakcrop/root crop/cereal rotation and only one incidence of vegetable/cereal and ley/vegetable/cereal rotation, these data are not shown. The most common rotation was a ley/cereal rotation (Table 12). The most frequently occurring weed was again *Stellaria media* and this occurred in 32-40% of all fields. There appeared to be no effects of rotation on weed populations.

Table 11. Identification of rotation types

Code	Rotation type
1	Vegetables and cereal
2	Ley and cereal
3	Combinable-breakcrop, root and cereal
4	Ley, cereal and root
5	Ley, cereal and combinable break-crop
6	Ley, cereal and vegetables
7	Ley, cereal, root and combinable break-crop

Table 12. The effect of rotation type on weed frequency (% fields with weed present)

	ley cereal	ley/cereal/ root crop	ley/cereal/ combinable breakcrop	ley/cereal/root crop/ combinable breakcrop
No of fields	74	39	22	12
Alopecurus myosuroides	8.3	1.2	18.9	0.0
Anagallis arvensis	10.3	8.0	6.7	4.1
Avena fatua	4.0	1.2	10.0	4.1
Avena sativa	2.3	3.1	5.6	20.4
Capsella bursa-pastoris	9.3	18.5	10.0	10.2
Chenopodium album	9.6	17.3	12.2	10.2
Elymus repens	6.3	6.2	4.4	6.1
Fallopia convolvulus	9.2	16.6	15.5	6.1
Fumaria officinalis	11.3	24.1	7.8	0.0
Galium aparine	17.9	14.2	17.8	18.4
Geranium spp.	9.2	12.3	2.2	6.1
Lamium purpureum	14.6	13.6	4.5	16.3
Lolium perenne	8.3	6.2	12.2	12.2
Matricaria spp.	18.9	34.6	13.3	14.3
Myosotis spp.	15.9	11.7	22.2	28.6
Poa annua	31.5	31.5	18.9	34.7
Papaver rhoeas	17.5	26.6	17.8	6.1
Polygonum aviculare	16.6	20.4	17.8	20.4
Polygonum persicaria	5.0	9.2	4.5	6.1
Ranunculus spp.	15.9	5.6	13.3	18.4
Rumex spp.	23.8	14.8	21.1	24.5
Senecio vulgaris	7.3	14.2	6.7	12.3
Sonchus spp.	18.9	16.0	24.4	20.4
Stellaria media	35.8	39.5	32.2	38.8
Sinapis arvensis	11.3	17.9	2.2	18.4
Taraxacum officinale	17.9	3.7	16.7	6.1
Triticum aestivum	1.0	2.5	1.1	2.0
Trifolium spp.	20.9	11.1	12.2	18.3
Veronica persica	21.2	32.7	24.4	18.4
Veronica spp.	14.6	19.1	16.7	2.0
Viola arvensis	16.2	21.6	21.1	6.1

Foliar disease levels

Between 13 and 19 samples of wheat were received each year for disease assessment. *Septoria tritici* was the most common disease affecting crops in 1993 and 1995 but *S. nodorum* was the most prevalent in 1994 (Table 13). Brown rust was prevalent in 1993, but yellow rust was not detected in any year. *Botrytis* and mildew were the most common ear diseases.

Table 13. Incidence of leaf and ear diseases at GS 75 (mean % crops affected)

	1993			1994			1995		
Disease	Flag leaf	Leaf 2	Ears	Flag leaf	Leaf 2	Ears	Flag leaf	Leaf 2	Ears
S. nodorum	57.1	71.4	28.6	53.9	61.5	7.7	4.8	4.8	4.8
S. tritici	85.7	92.9	0.0	46.2	53.9	0.0	81.0	85.7	0.0
Mildew	21.4	35.7	28.6	46.2	38.5	30.8	19.1	33.3	47.6
Yellow rust	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brown rust	42.9	50.0	-	15.4	23.1	-	9.5	4.8	-
Fusarium blight	-	-	7.1	-	-	0.0	-	-	0.0
Botrytis	-	-	42.9	-	-	15.4	-	-	14.3
F. poae	-	-	14.3	-	-	38.5	-	-	4.8

Septoria tritici was the most severe foliar disease (Table 14). Ear disease incidence and severity were low.

Table 14. Severity of leaf and ear diseases at GS 75 (mean % leaf/ear area affected)

	1993			1994			1995		
Disease	Flag leaf	Leaf 2	Ears	Flag leaf	Leaf 2	Ears	Flag leaf	Leaf 2	Ears
S. nodorum	0.3	0.7	0.1	0.2	1.9	<0.1	0.0	0.0	0.0
S. tritici	2.7	7.7	0.0	0.3	2.2	0.0	2.22	3.8	0.0
Mildew	0.4	0.7	2.0	0.5	0.3	0.3	0.09	0.1	0.7
Yellow rust	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brown rust	3.0	4.4	-	1.9	1.5	-	<0.1	0.0	-
Fusarium blight	-	-	0.2	-	-	0.0	-	-	0.0
Botrytis	-	-	0.1	-	-	<0.1	-	-	<0.1
F. poae	-	-	<0.1	-	-	0.1	-	-	<0.1

Severities of all major foliar diseases, except mildew, were higher in organically grown crops than in conventionally treated crops (Table 15).

Table 15. Comparison of disease levels on leaf 2 at GS 75 in organic and conventionally grown wheat crops (mean % leaf area affected)

	1993		1994		1995	
	Organic	Conventional	Organic	Conventional	Organic	Conventional
S. nodorum	0.7	0.5	1.9	0.3	0.0	<0.1
S. tritici	7.7	4.2	2.2	1.2	3.8	0.8
Mildew	0.7	0.8	0.3	0.4	0.1	0.2
Yellow rust	0.0	<0.1	0.0	<0.1	0.0	0.0
Brown rust	4.4	0.8	1.5	0.1	0.0	0.1

Stem-base disease levels

Eyespot was the most common stem-base disease, affecting between 72 and 92% of crops compared to 72 to 86% of crops affected by fusarium (Table 16).

Table 16. Stem base disease levels (mean % crops affected)

Year	Eyespot	Sharp eyespot	Fusarium
1993	92.9	21.4	85.7
1994	92.3	46.2	84.6
1995	72.0	36.0	72.0

Comparison between incidence of stem-base diseases in organic and conventionally grown crops showed that organic crops were less severely affected in all cases (Table 17).

Table 17. Stem base disease levels at GS 75 (mean % stems affected)

	1993		1994		1995	
	Organic	Conventional	Organic	Conventional	Organic	Conventional
Eyespot	25.43	37.0	18.5	22.2	21.1	24.0
Sharp eyespot	2.6	4.4	4.0	4.8	4.6	9.8
Nodal fusarium	19.7	27.6	11.1	15.4	8.2	11.3
Internodal fusarium	24.85	31.1	15.4	15.2	14.6	20.3

Effect of number of years in organic husbandry on disease levels

Severity of mildew, brown rust and *S. tritici* were higher in wheat crops from fields which had been in organic husbandry for a shorter period of time (Table 18).

Incidence of eyespot was higher in crops from fields which had been in organic husbandry for a longer period of time (Table 19).

Table 18. Effect of number of years in organic husbandry on mean foliar disease levels at GS 75 (% leaf 2 area affected)

1st year of organic production	No. of samples	*Septoria nodorum*	*Septoria tritici*	Mildew	Yellow rust	Brown rust
< 1985	14	1.17	0.97	0.06	0.00	0.01
> 1984	30	0.49	5.38	0.39	0.00	1.49

Table 19. Effect of number of years in organic husbandry on mean eyespot levels at GS 75 (average percent stems affected)

1st year of organic production	No of samples	Eyespot		
		Slight	Moderate	Severe
< 1985	14	14.9	18.0	3.4
> 1984	30	9.2	8.0	0.3

Discussion

Many common agricultural weeds originally colonised natural bare areas. *Chenopodium album*, *Stellaria media* and *Polygonum aviculare* were present in Britain during glacial times. The spread of agriculture during Neolithic times led to the introduction of *Galium aparine* and *Sinapsis arvensis* and suitable habitats for *Rumex* spp. were created. *Fumaria officinalis* was introduced by the Romans. In more modern times *Veronica persica* was first recorded in 1825 (Roberts, 1982). The adoption of widespread herbicide use has provided control of weeds in conventional agricultural crops but organic regulations do not allow their use. Table 20 indicates the overall abundance and ranking order of the main broad-leaved weeds from this survey compared with data from spring assessments in winter cereals in 1967 and 1972 and an autumn assessment in winter wheat and barley in 1989. Whilst these three surveys are from conventional crops the weed spectrum is very similar to that found in the survey of organic crops. The most frequently occurring weeds in all surveys were *Stellaria media, Matricaria* spp., *Polygonum aviculare* and *Veronica persica*. The frequency of these weeds was lower than in the previous surveys and could be associated with a greater weed spectrum at the organic sites providing competition between the weed species themselves. *Rumex* spp. and *Sonchus* spp. had been noted in the 1967 and 1972 surveys but were more abundant in the organic crops, an indication of the problems associated with controlling these prolific-seeding tap-rooted weeds. *Fallopia convolvulus* levels remained similar over the 30-year period, but *Myosotis* spp. has appeared as a weed of organic rotations. The relative abundance of *Stellaria media, Matricaria* spp., *Veronica persica, Galium aparine* and *Sinapis arvensis* was greater in previous surveys than in the organic crops, this could be attributed to the wider range of crops surveyed. *Trifolium* spp. was often included in an organic rotation to improve fertility. Individual weed species were less abundant in organic fields than in the conventional crops, this may be due to less weedy sites being chosen for organic production. The prominence of *Lamium purpureum* and *Viola arvensis* in the 1989 survey was attributed to the switch to winter cropping (Whitehead & Wright, 1989). In organic rotations, where levels of these weeds were lower, many of the crops would be spring sown to allow time for weed control by cultivation and stale seedbed techniques.

Table 20. Percent fields affected and (ranking) of broad-leaved weeds compared with earlier surveys.

	December	Spring	1989[1]	1972[2]	1967[3]
Stellaria media	49 (1=)	77 (1)	94 (1)	89 (1)	77 (1)
Polygonum aviculare	46 (2)	43 (3)	-	52 (5)	46 (5)
Matricaria spp.	36 (3)	39 (4)	67 (3)	53 (3)	52 (2=)
Veronica persica	33 (4=)	47 (2)	72 (2)	55 (2)	52 (2=)
Papaver rhoeas	33 (4=)	30 (7)	18 (11)	20 (8)	-
Rumex spp.	32 (6=)	32 (5)	-	12 (14=)	30 (7)
Sonchus spp.	32 (6=)	28 (9)	-	4 (21=)	11 (14=)
Fallopia convolvulus	31 (8)	23 (15)	-	25 (7)	28 (8)
Trifolium spp.	29 (9)	22 (16)	-	-	-
Myosotis spp.	26 (10)	31 (6=)	-	-	-
Galium aparine	25 (11)	27(13)	58 (4)	52 (4)	49 (4)
Chenopodium album	24 (12)	31 (6=)	13 (13)	13 (13)	18 (9)
Viola arvensis	23 (13)	29 (8)	45 (6)	14 (12)	7 (17=)
Sinapis arvensis	16 (17)	20 (18)	36 (7)	33 (6)	39 (6)
Fumaria officinalis	12 (20)	26 (13)	17 (13)	12 (14=)	30 (11=)
Lamium purpureum	11 (23)	17 (15)	47 (5)	-	-

[1] Whitehead & Wright (1989), [2] Anon (1973), [3] Anon (1968)

Increased years in organic production had encouraged an increase in total weed number and selected out prolific seed producers such as *Papaver rhoeas, Matricaria* spp. *Stellaria media,* and *Sinapis arvensis*. Some of the prolific seeders also have tap roots e.g. *Papaver rhoeas, Matricaria* spp. *Rumex* spp., *Sonchus* spp. and *Sinapis arvensis* which are more difficult to control by cultural methods. Weeds that occurred less frequently

were mainly grasses e.g. *Alopecurus myosuroides* and *Avena* spp., these would be easily controlled in rotations containing grass leys grazed by animals. The incidence of seed production would be virtually nil and the inclusion of spring-sown crops would add to their demise as most germinate in the autumn. In contrast *Poa annua* which can germinate and flower at any time during the year has not been affected by length of time in organic production.

The level of yield loss due to weed infestation can be assessed by using crop equivalents (Wilson, 1989). Weed populations recorded for those weeds considered very competitive or only moderately so were close to the levels where a 2% yield loss would occur (Table 21.). The weeds compete against the crop and the competitive ability of the crop is an important factor, in an organic situation this would be lower than in a conventional system due to the lack of nitrogen applied.

Table 21. Weed populations and crop equivalents (Plants m^{-2}).

	Date farm converted to organic		
	Pre-1985	Post- 1985	Weed population expected to give a crop loss of 2%[1]
Very competitive			
Galium aparine	1.0	0.3	1.6
Avena fatua	0.0	0.4	0.5
Avena sativa	0.3	2.0	0.5
Moderately competitive			
Matricaria spp.	7.0	2.0	1.7
Myosotis spp.	0.2	1.4	6
Alopecurus myosuroides	0.0	8.2	8.3
Stellaria media	12.4	6.4	13
Papaver rhoeas	15.4	0.6	21
Not very competitive			
Lamium purpureum	1.5	0.4	30
Veronica persica	3.8	1.5	32
Viola arvensis	1.5	0.5	109

[1] Wilson 1989

With the exception of mildew, foliar disease incidence and severity were higher in organic wheat crops than in conventionally grown wheat crops. The average severity of brown rust was six times higher and levels of *Septoria nodorum* three times higher than levels recorded in the annual CSL/ADAS national wheat disease survey of conventionally grown crops. These diseases can survive on volunteers and hence be more of a problem in organic cropping systems where volunteers are more prevalent. Conventional farming practices, principally the use of chemical control, resulted in lower levels of foliar diseases than were recorded in organic crops but this difference was least pronounced for *S. tritici*. The crops monitored were less severely affected by stem base-diseases than crops grown by conventional methods, indicating the benefits of sound rotational practice and later sowing in management of diseases such as eyespot.

Levels of brown rust, mildew, and *S. tritici* were higher in crops from fields which had been in organic cropping for a shorter period of time. This may indicate the benefits of extended periods in organic cropping and the establishment of rotations which can lead to a reduction in the levels of volunteers. Time of sowing and avoidance of 'green bridges' which allow diseases to transfer via plants and crop residues to the new crop are important factors in disease control, especially in organic systems. *S. nodorum* was the only foliar disease to

show higher severity in fields which had been in organic production for a longer period of time. *S. nodorum* appears to be less specialised than *S. tritici* and can colonise a wider range of grass genera. Inoculum may therefore build up more readily under long term organic husbandry compared to other more specialised diseases.

Main implications

- The spectrum of the most common weeds of organic crops was very similar to that of conventional crops.
- Long periods of organic farming lead to the build up of specific weeds and the demise of others.
- Weed levels in organic situations were high enough to contribute significantly to economic yield losses.
- The survey was not large enough to form a complete picture of weeds in organic cropping.
- Foliar diseases were higher in organic crops than in conventionally grown crops, whereas incidence of stem-base diseases was lower.
- Extended time in organic farming led to lower severity of *S. tritici*, mildew and brown rust.

Future work

Further surveys of conventional, integrated and organic crops should be undertaken to provide information on the current situation. This would provide data on changes in the national agricultural weed flora and provide an early warning system of the build up of resistance in specific weeds that may not be noticed at a local level. These surveys would also provide invaluable data for comparison of disease incidence and severity under different crop management regimes.

References

Anon, (1968). Broad-leaved weed infestations in winter cereals. Fisons Agricultural Technical information, Spring 1968 pp 21-28

Anon, (1973). Broad-leaved weed infestations in winter cereals. Fisons Agricultural Technical information, Spring 1973 pp 37-41

Anon, (1976). Manual of plant growth stage and disease assessment keys. MAFF publications

Roberts HA, 1982. Weed control handbook: Principles Ed H A Roberts BCPC, Blackwell, London

Wilson BJ, 1989. Predicting cereal weed loss from weeds. *Institute of arable crops Technical note LARS 89/4*

Whitehead R, Wright HC, 1989. The incidence of weeds in winter cereals in Great Britain. BCPC - Weeds, pp107-112.

Scott PR, Hollins T, 1974. Effects of eyespot on the yield of winter wheat. *Annals of Applied Biology* **119**, 1-20