



PROJECT REPORT No. 124

**SURVEY OF SEED-BORNE
PATHOGENS IN CERTIFIED
AND FARM-MADE CEREAL
SEED IN BRITAIN BETWEEN
1992 AND 1994**

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**SURVEY OF SEED-BORNE PATHOGENS IN CERTIFIED
AND FARM-MADE CEREAL SEED
IN BRITAIN BETWEEN 1992 AND 1994**

by

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ABSTRACT

2301 cereal seed samples, drawn from seed stocks of winter wheat and spring and winter barley harvested in England and Scotland in the 3 years 1992-94, were tested for seed-borne pathogens in the Official Seed Testing Station for Scotland. Samples represented both farm-saved seed and seed intended for certification. Tests were made for:

on winter wheat seed -

- *Microdochium nivale* (*Fusarium nivale*)(seedling blight)
- *Septoria nodorum* (seedling blight)
- *Fusarium spp.* (seedling blight)
- *Tilletia caries* (bunt)

on spring and winter barley seed -

- *Microdochium nivale* (*Fusarium nivale*)(seedling blight)
- *Cochliobolus sativus* (seedling blight)
- *Fusarium spp.* (seedling blight)
- *Drechslera graminea* (*Pyrenophora graminea*)(leaf stripe)
- *Drechslera teres* (*Pyrenophora teres*)(net blotch)
- *Ustilago nuda* (loose smut)

The incidence of seedling blight pathogens varied between years. *M.nivale* infection was higher in 1992 and 1993, when more than 40% of certified winter wheat samples had at least 20% of seeds infected, compared to 1994, when only 2% of samples were infected at this level. *S.nodorum* infection was rare in 1992. It was seen in approximately 40% of winter wheat samples in 1993 and 1994, but only occasional samples had more than 20% of seeds infected.

Bunt spores were recorded in between 20% and 60% of certified and farm-saved seed samples over the 3 years of the survey but contamination was usually at low levels. Occasional samples had more than 5 bunt spores per seed. English produced seed was more often contaminated than seed produced in Scotland.

Loose smut infection was higher in winter barley than in spring barley and levels in farm-saved seed were higher than in certified seed. In 1992, 25% of farm-saved winter barley seed samples had more than 0.5% infection. In contrast, in the same year, only 2% of certified spring barley samples were infected at this level.

Leaf stripe was recorded at low levels in both spring and winter barley each year. No more than 2% of samples tested in any year had more than 2% of seeds infected.

The majority of samples tested each year were not infected with seed-borne pathogens at levels that could have been damaging to crop production. Infection at damaging levels could not be determined by visual inspection of the seed and the occasional heavily infected samples could not be predicted by year of production, area of production or category of seed.

A SURVEY OF SEED-BORNE PATHOGENS IN CERTIFIED AND FARM- SAVED CEREAL SEED IN BRITAIN 1992-1994

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CHAPTER 1

INTRODUCTION

For more than 50 years seed-borne fungal pathogens of cereals were controlled by the routine and extensive use of organomercury seed treatment fungicides. Organomercury treatments were readily accepted by cereal growers because they were effective against a number of potentially damaging diseases, were relatively inexpensive (at 1992 prices, £8 per tonne of seed treated/£1.30 per hectare) and easily applied. In 1977 95% of all UK cereal seed was treated with organomercury fungicides (Steed *et al.*, 1979). The seed-borne cereal pathogens that had caused serious damage in the early years of the century such as bunt (*Tilletia caries*) and leaf stripe (*Drechslera graminea* syn. *Pyrenophora graminea*) became so uncommon that most farmers were unfamiliar with the symptoms and damage they could cause.

In response to concerns over the toxicity and persistence of mercury in the environment an EC council directive (Anon., 1979) prohibited its use in agriculture and, in the UK, organomercury was finally withdrawn as a cereal seed treatment in March 1992.

In recent years, some seed-borne cereal pathogens have reappeared as significant causes of loss of yield and/or quality in cereals in the UK. Before the withdrawal of organomercury, strains of *Drechslera graminea* resistant to mercury-based seed treatments (Jones *et al.*, 1989) led to the build up of barley leaf stripe in many stocks of spring barley, especially in Scotland. Yield loss due to leaf stripe was estimated at around two million pounds in the Scottish spring barley crop in 1990 (Cockerell, *et al.*, 1995).

The use of successive generations of untreated, farm-saved seed and a series of dry autumns, which favoured the survival of soil-borne spores of *Tilletia caries*, led to an increase in the incidence of bunt in Eastern England (Yarham, 1993). In addition, there has been a growing awareness in recent years of the importance of seed-borne *Microdochium nivale* (*Fusarium nivale*) as a cause of poor seedling establishment in wheat crops (Cockerell, 1995; Humphreys, *et al.*, 1995).

The knowledge that fungicide resistant strains of seed-borne fungi can occur (eg carboxin resistant *Ustilago nuda*; mercury resistant *Drechslera graminea*) has led to concern that seed-borne diseases might build up rapidly if seed treatment fungicides cease to be effective. Several effective alternative treatments are now available for use on cereal seed and others are likely to be approved within the next few years. Their cost (£30-£40 per tonne of seed treated/£4.80-£6.40 per hectare), relative to organomercury is much higher, but is approximately half the cost of broad spectrum systemic fungicides which give some early foliar pathogen control as well as controlling seed-borne pathogens. These costs have led UK growers and their advisers both to question the need for continued routine cereal seed treatment and to consider the seed treatment most appropriate for their needs.

In trials from 1978 to 1982, Richardson (1986) made over 220 comparisons of spring barley and winter wheat crops grown from untreated and organomercury treated seed. He concluded that seed treatment was not necessary when certified seed was used to produce a grain crop. Sweden and Norway, where most cereal seed is spring sown and the total area is not large, are moving towards a situation where the decision to treat cereal seed depends upon seed health test results (Brodal, 1993). Fungicide treatment is discouraged if disease thresholds are not

passed. On the other hand, cereal seed treatments continue to be used on a routine basis in several countries irrespective of the health of the seed (Rennie & Cockerell, 1994).

Comprehensive, current information on the incidence and distribution of cereal seed-borne pathogens in the UK is limited. The Official Seed Testing Station (OSTS) in Edinburgh has recorded the incidence of seed-borne pathogens in Scottish certified and farm-saved cereal seed (Rennie, 1987; Rennie & Cockerell, 1990; Cockerell, *et al.*, 1995). Reeves & Wray (1994) reported on the incidence of seed-borne cereal pathogens in routine tests made in the OSTs for England and Wales from 1990 to 1993 but a high proportion of their samples probably represented farm-saved seed and some may have been specifically selected from diseased crops. They made no attempt to separate spring and winter barley or certified and farm-saved seed.

The purpose of the work reported here was to determine, over the period 1992-1994, the incidence and distribution of seed-borne pathogens in certified and farm-saved cereal seed in the UK.

This study concentrates on seed of the 3 major cereal crops grown in the UK, winter wheat, winter barley and spring barley. To contain the costs of the study within acceptable limits spring wheat, rye, oats and triticale were not included. For the same reason, only seed-borne pathogens which were considered to be potentially damaging to crop yield or quality were considered. Seed was tested for the following pathogens:

- *Tilletia caries* Winter wheat
- *Microdochium nivale* Winter wheat; winter and spring barley
- *Septoria nodorum* Winter wheat
- *Fusarium spp.* Winter wheat; winter and spring barley
- *Cochliobolus sativus* Winter and spring barley
- *Drechslera graminea* Winter and spring barley
- *Drechslera teres* Winter and spring barley
- *Ustilago nuda* Winter and spring barley

Loose smut of wheat (*Ustilago nuda*) and covered smut of barley (*Ustilago hordei*) are currently very rare in UK seed and neither pathogen was included in the survey.

CHAPTER 2 SAMPLING

2.1 INTRODUCTION

The survey was designed to provide information on the incidence of seed-borne pathogens on winter wheat, winter barley and spring barley. It was intended to compare certified and farm-saved seed for two geographical areas, and for each of the three crops. Initially the survey was to include samples from Scotland and East Anglia but it was extended to include seed crops from other areas of England. The survey was conducted on seed harvested in the three years 1992-1994.

To ensure adequate representation of UK cereal seed a target of 100 samples per category was set with each category relating to;

country Scotland or England,
seed type certified or farm-saved,
harvest year 1992, 1993 or 1994.

Information was requested from seed merchants and growers on: date of harvest; variety; whether the seed was cleaned or as grown; and the treatment applied to the parent seed in the previous generation. Where seed was described as certified information on the generation of seed, e.g., Basic, C1 or C2 was requested.

2.2 MATERIALS AND METHODS

500g samples of certified and farm-saved winter barley, winter wheat and spring barley seed were collected, usually after cleaning but before chemical seed treatment application, from seed processors, operators of mobile seed dressers and growers, after harvest in 1992, 1993 and 1994. Seed samples were collected by Zeneca Crop Protection regional staff and sent to the OSTs in Edinburgh for testing. Where samples were collected before cleaning the seed was shaken over a 2.45mm sieve and the material which passed through was discarded before testing.

2.3 RESULTS

Table 2.1 shows the number and source of samples collected and tested each year. The numbers of samples received from English regions, as defined in figure 1, are given in Table 2.2. Samples collected in 1992 were predominantly from the East of England whereas winter wheat samples collected in 1993 and 1994 came from a wider range of regions. Data are presented according to region where sample numbers are sufficiently high. No analysis of regional influence has been made for English grown winter or spring barley because numbers fell well below the target figure and samples came from a limited area.

Over the three years 99 per cent of samples included information relating to variety but information on the date of harvest was available for less than half the samples tested. Information on seed treatment varied from year to year; it was provided for only 26% of samples in 1992, but for 74% in 1993 and 50% in 1994.

The majority of certified seed samples tested each year were certified seed of the Second Generation (C2) but a small proportion (7%) of all samples tested over the three year period was either First Generation certified seed (C1) or Basic seed.

2.4 DISCUSSION

The number of samples collected for each category was disappointing, with only eight out of 36 reaching the 100 sample target over three years. However, comparisons can be made between seed produced in England and in Scotland for winter wheat and winter barley for all years and for spring barley in 1994. A limited comparison can be made of wheat seed produced in some English regions.

Table 2.1 Number of samples tested in each category

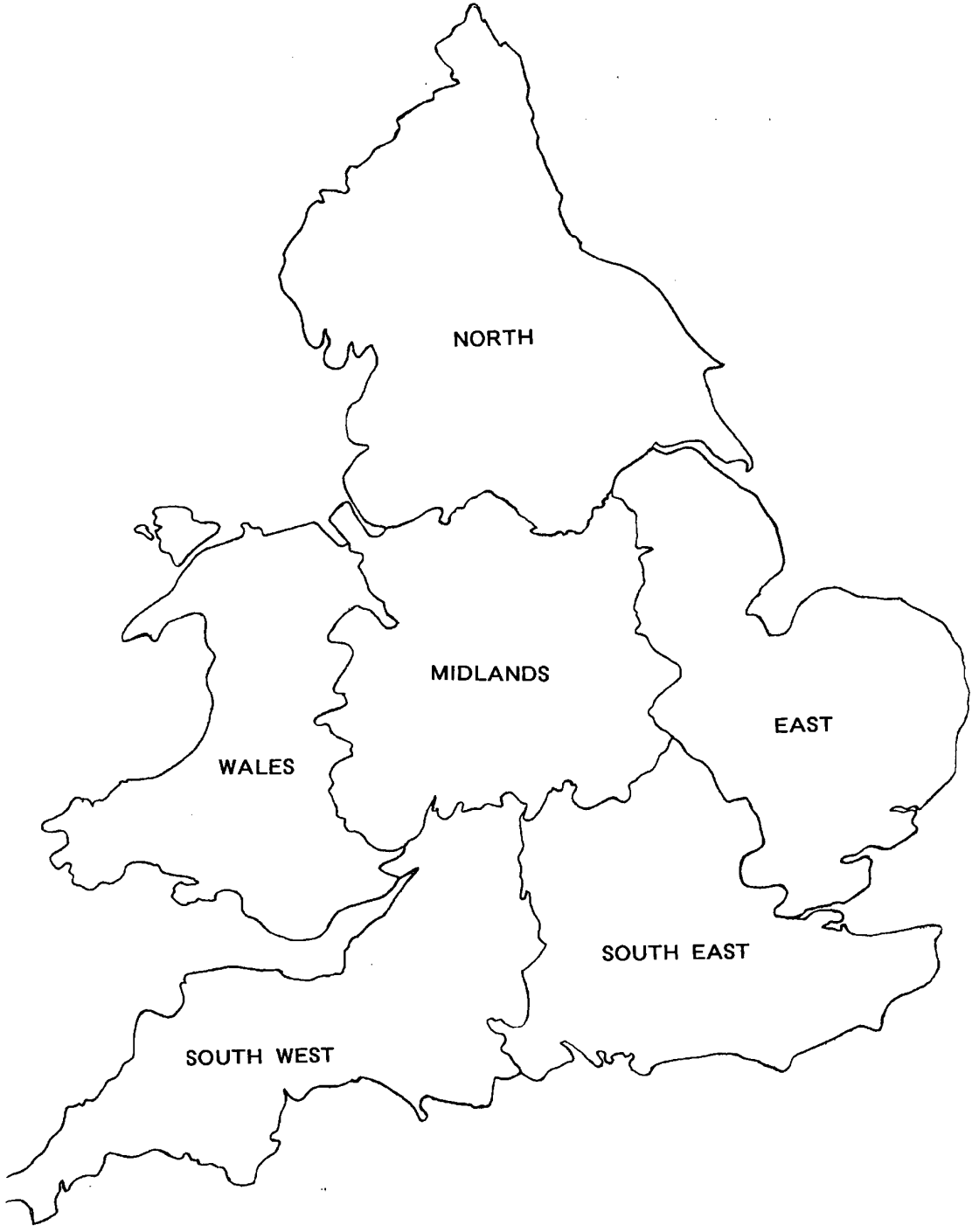
	Certified			Farm-saved		
	1992	1993	1994	1992	1993	1994
Winter Wheat						
Scottish	31	30	30	52	38	49
English	136	176	201	37	147	129
Winter Barley						
Scottish	37	41	41	57	45	26
English	60	68	90	11	52	59
Spring Barley						
Scottish	104	100	110	73	78	61
English	20	26	67	0	3	16

Table 2.2 Number of samples collected from different regions in England and Wales

Area	Certified									Farm-saved								
	1992			1993			1994			1992			1993			1994		
	WW	WB	SB	WW	WB	SB	WW	WB	SB	WW	WB	SB	WW	WB	SB	WW	WB	SB
North	14	10	2	21	6	4	10	6	8	0	1	0	2	3	0	4	2	2
East	42	20	6	34	14	11	78	37	22	37	10	0	91	28	0	53	6	7
South East	8	6	6	48	21	8	41	21	30	0	0	0	17	0	0	5	17	2
South West	2	0	0	11	9	0	26	1	4	0	0	0	23	11	0	15	8	3
Wales	0	0	0	0	0	0	1	1	0	0	0	0	3	2	0	4	2	1
Midlands	3	0	0	15	10	2	13	11	3	0	0	0	10	8	2	8	5	1
Information not provided	67	24	6	47	8	1	32	13	0	0	0	0	1	0	1	40	19	0

WW = Winter wheat
 WB = Winter barley
 SB = Spring barley

Figure 2.1 English and Welsh Sampling Regions



CHAPTER 3

SEED-BORNE PATHOGENS ON WINTER WHEAT SEED 1992-94

3.1 INTRODUCTION

There are few published survey data on the incidence of seed-borne pathogens of winter wheat in the United Kingdom. During the period when organomercury treatments were widely used seed-borne pathogens were adequately controlled and they were of limited practical interest.

Seed-borne *M.nivale* causes pre-emergence blight when heavily infected winter wheat seed is sown untreated (Hewett, 1983). High levels of seed-borne *M.nivale* are associated with cool, wet weather at, or soon after, flowering (Rennie & Cockerell, 1993). During the period 1987 to 1991 *M.nivale* infection on Scottish grown winter wheat seed was relatively high with mean infections reaching 30% in some years (Rennie & Cockerell, 1993). In an earlier survey Hewett (1965) reported much lower levels of infection on English produced seed and high infection was associated with "localised conditions". Hewett's study reported a mean infection of approximately 0.3% with only an occasional sample having more than 5% infection between 1959 and 1962. However, in 1963-64 the average infection in one variety, Capelle-Desprez, was much higher at 5.3%. In contrast, Reeves and Wray (1994) reported between 75% and 95% of samples with more than 5% infection in 1992 and 1993.

Septoria nodorum, like *M.nivale*, can cause pre-emergence death of infected winter wheat seedlings, particularly at low temperatures (Baker, 1970; Hewett, 1975), and the incidence of the fungus appears to be weather dependant; high seed infection is associated with rainfall during seed development (Hewett, 1965). At the time of Hewett's (1965) survey the fungus was common on UK wheat seed. However, in recent years seed infection was only very occasionally recorded in tests at the OSTs, Edinburgh (Cockerell and Rennie, unpublished observations).

A number of *Fusarium* spp. are found on wheat seed (Polley *et al.*, 1990). Some have been considered to have the potential to affect seedling establishment and crop growth and eventually yield but there is little evidence to suggest that seed-borne infection is of much practical importance in the UK. Some *Fusarium* spp. produce mycotoxins which are poisonous to animals if grain is used for feed.

Common bunt (*Tilletia caries*) converts the grain tissues within the pericarp to a mass of black spores, producing bunt balls as the wheat head matures. Bunt causes a direct loss of grain and also spoils grain for milling. Flour can become contaminated as bunt spores release the chemical trimethylamine which has an odour of decaying fish. Bunt balls were recorded in 33% of commercial wheat seed samples tested at the OSTs for England and Wales in 1921. The disease then declined and by 1957 only 0.2% of wheat samples contained bunt balls (Marshall, 1960). Yarham and Jones (1992) reported bunt in wheat crops in East Anglia during the late 1980s. They associated the increase in bunt incidence with an increase in the area sown with untreated farm-saved seed and the ability of the fungus to survive as spores in dry soil between crops. Bunt has only been recorded very occasionally in Scottish wheat crops in recent years (Cockerell, unpublished).

3.2 MATERIALS & METHODS

3.2.1 *Microdochium nivale*, *Septoria nodorum* and *Fusarium spp.*

Working samples were drawn using the hand halving method described in the International Rules for Seed Testing (Anon., 1985) and 2 x100 seed replicates were tested, using a standard agar plate test (Hewett, 1965). Seeds were pre-treated for 10 minutes in sodium hypochlorite, containing approximately 1% available chlorine, and then placed, 5 to a plate, on potato dextrose agar containing 130ppm streptomycin sulphate. Samples were incubated in the dark for 7 days at 20°C. A visual examination was made for colonies of *M.nivale*, *S.nodorum* and other *Fusarium spp.*.

3.2.2 *Tilletia caries*

The submitted seed sample was weighed and a search was made for bunt balls. The percentage by weight of bunt balls was recorded. Three x300 seed replicates were drawn from the sample using the hand halving method described in the International Rules for Seed Testing 1985 (Anon, 1985). The seeds were tested using a modification of the filtration method described by Kietreiber (1984) as outlined below.

Washing procedure

Each 300 seed replicate was placed in a 100ml conical flask and 20ml of 0.1% Tween 20 solution was added and gently shaken for 3 minutes using a mechanical shaker. The resultant solution was decanted into a clean beaker. A further 20ml of Tween 20 solution was added to the seed before shaking for approximately 10 seconds and the liquid was added to the original supernatant. This process was repeated resulting in a total of 60ml of the decanted solution.

Filtration

The decanted solution was filtered through an 8µm cellulose nitrate filter using Büchner filtration apparatus attached to a vacuum. The *T.caries* spores (17-19 µm) were trapped on the cellulose nitrate filter. The filter was then air dried before examination.

Examination

The air dried filter was placed on a drop of water on a microscope slide. The *T.caries* spores were counted at x250 magnification. If the first replicate of a sample contained a high proportion of "debris" which made examination of the filter and recording of spores difficult, three x 100 seed replicates were examined which diluted the effect of the debris and facilitated examination.

The results were recorded as the mean number of spores per seed according to Kietreiber's formula (Kietreiber, 1984).

3.2.3 Statistics

Significance was determined by means of t- tests after applying appropriate transformations to the data.

3.3 RESULTS

3.3.1 *Microdochium nivale* (*Fusarium nivale*) (seedling blight)

The mean *M.nivale* infection recorded for certified and farm-saved seed for each year is given in Table 3.1. There was no significant difference between certified and farm-saved seed in 1993 and 1994, but infection was higher in certified seed in 1992.

Table 3.1 Mean *M.nivale* infection in certified and farm-saved seed and in Scottish and English produced winter wheat seed

	Mean percentage infection					
	Certified	Farm-saved	Significance at $P \leq 0.05$	English	Scottish	Significance at $P \leq 0.05$
1992	19	12	S	19	11	S
1993	22	26	NS	26	14	S
1994	3	3	NS	2	7	S

Ninety-nine per cent of the seed samples tested in 1992 and 1993 had some *M.nivale* infection whereas only 68% of samples were infected in 1994. Infection above 20% was recorded in more than 40% of certified seed samples in 1992 and 1993 but only 2% of samples had this level of infection in 1994 (Figure 3.1). In 1993 57% of farm-saved samples had more than 20% *M.nivale* infection. Nineteen per cent of farm-saved samples were infected above this level in 1992 compared with 2% in 1994.

In 1992 and 1993 seed harvested in England had higher levels of infection than seed harvested in Scotland (Figure 3.2). Approximately 20% of Scottish samples had more than 20% infection in both these years but 41% of English samples exceeded this level in 1992 and 59% of samples exceeded it in 1993. In 1994, however, Scottish seed was more heavily infected than English seed with 7% of samples having more than 20% infection compared to less than 1% of English samples. In both Scotland and England infection was very much lower in 1994 than in 1992 and 1993. There was a significant difference between mean *M.nivale* infection on Scottish and English produced seed in each year (Table 3.1). Data from English samples were divided according to English areas as outlined in Figure 2.1. The mean infection varied from area to area (Table 3.2). Highest infection was recorded in the south-west in both 1993 and 1994.

Figure 3.1 Percentage of winter wheat seed samples with more than 5, 20 and 50 percent *Microdochium nivale* infection

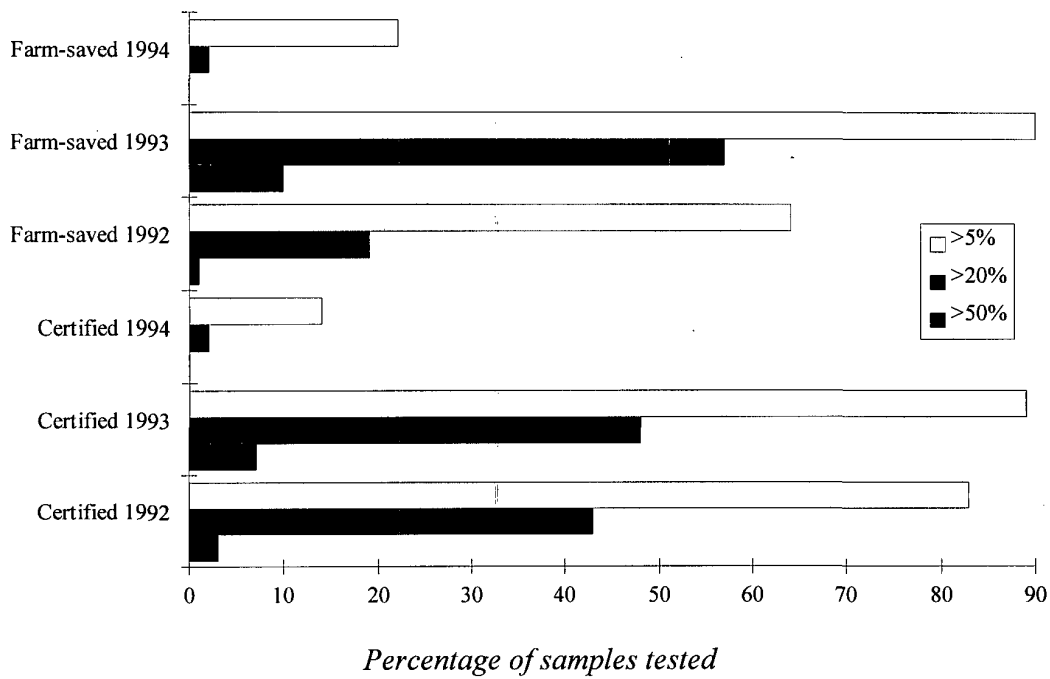


Figure 3.2 Percentage of Scottish and English winter wheat seed samples with more than 20 percent *Microdochium nivale* infection

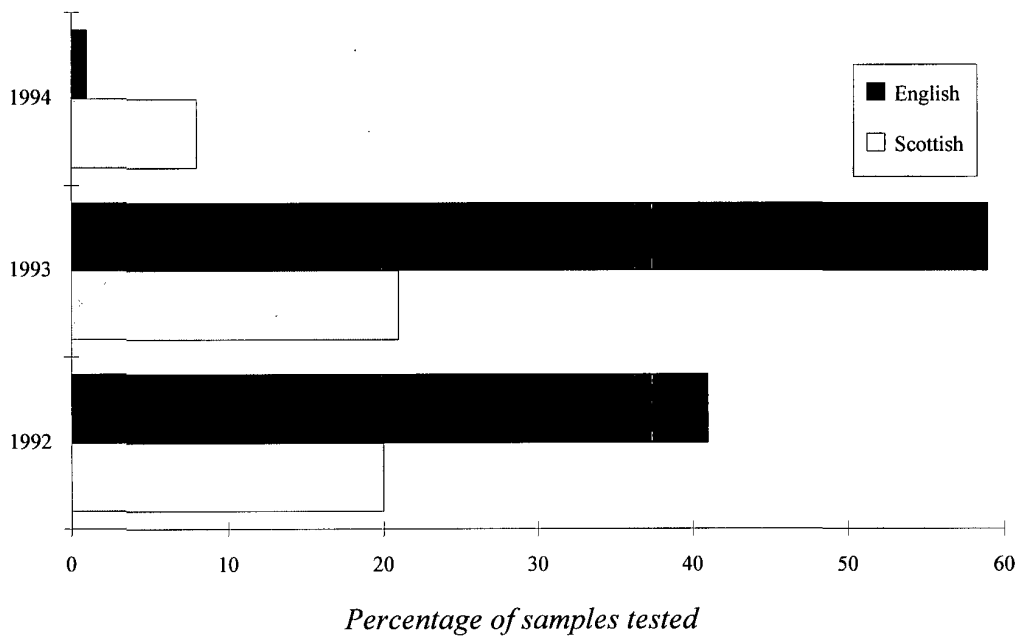


Table 3.2 Mean and range of *M.nivale* in winter wheat samples from English regions (as in Figure 2.1).

Area	YEAR		
	1992	1993	1994
	<i>Percentage infection</i>		
North			
Mean	8	16	3
Range	0 - 32.5	1.0 - 48.5	0 - 10.5
East			
Mean	19	22	0.79
Range	1.0 - 68.0	0 - 62.0	0 - 8.0
South East			
Mean	N/A	29	3
Range	N/A	2.5 - 74.5	0 - 25.5
South West			
Mean	N/A	45	4
Range	N/A	10.0 - 78.0	0 - 29.5
Midlands			
Mean	N/A	22	2
Range	N/A	2.5 - 47.0	0 - 11.0

N/A Data not available, less than 10 samples tested

3.3.2 *Septoria nodorum* (seedling blight)

For both certified and farm-saved seed samples, *Septoria nodorum* infection was more prevalent in seed harvested in 1993 and 1994 than in seed harvested in 1992 (Figure 3.3). Approximately 50% of certified seed samples were infected in 1993 and 1994 compared to only 2% in 1992. In 1993 and 1994 33% and 49% of farm-saved seed carried infection compared to only 1% in 1992. There was no significant difference between mean *S.nodorum* infection in certified and farm-saved seed in 1992 and 1994 (Table 3.3) but infection was significantly higher in certified seed in 1993.

Scottish produced winter wheat had a significantly higher mean infection in 1994 than English produced seed but there was no significant difference in 1992 or 1993 (Table 3.3). Higher levels of infection were recorded on Scottish produced seed in 1994 than on English produced seed (Figure 3.4). In 1994 5% of Scottish samples had more than 20% infection but no English sample exceeded this level of infection. The maximum infection recorded over the 3 years was 39% in a sample of Scottish farm-saved seed in 1994.

Figure 3.3 Percentage of winter wheat seed samples with *Septoria nodorum* infection and percentage of samples with more than 5 and 20 per cent infection

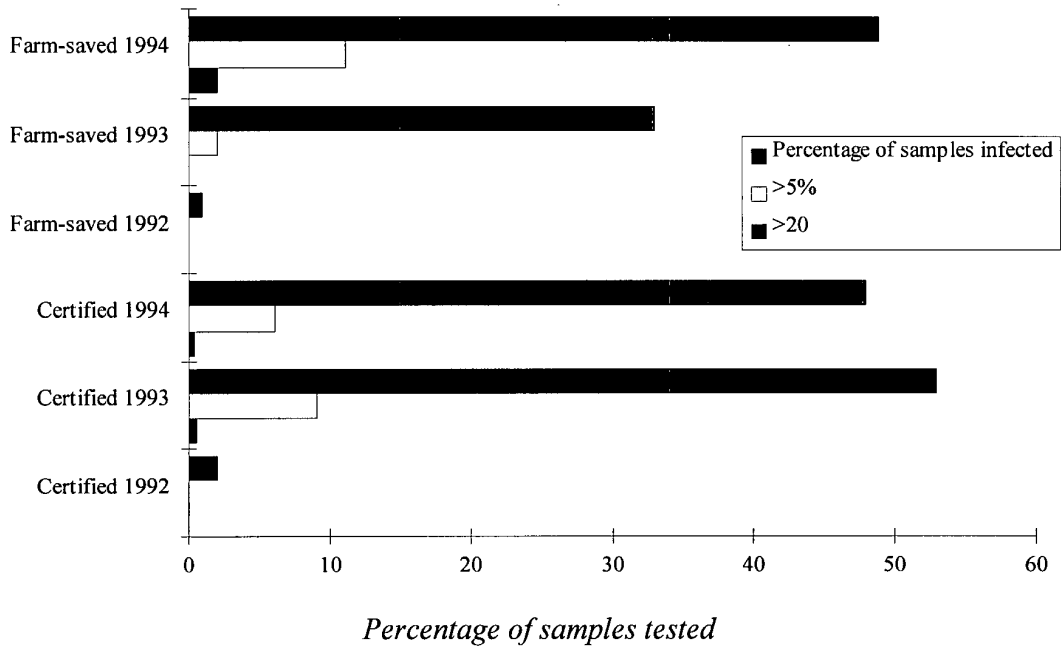


Figure 3.4 Percentage of Scottish and English winter wheat seed samples with more than 5 and 20 per cent *Septoria nodorum* infection

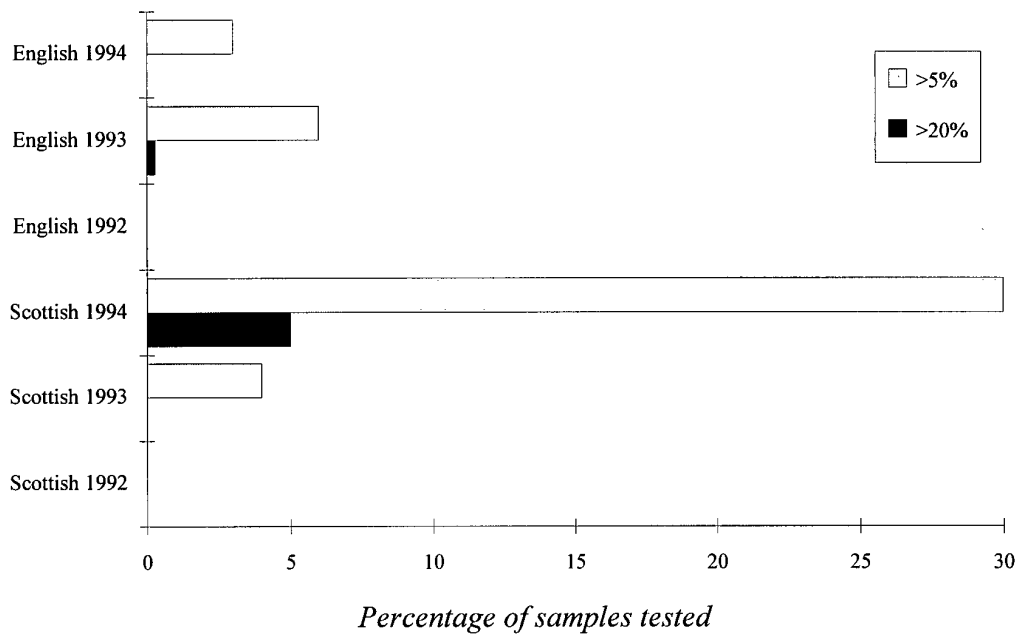


Table 3.3 Comparison of mean *S.nodorum* infection in certified and farm-saved seed and in English and Scottish produced winter wheat seed

	Mean percentage infection					
	Certified	Farm-saved	Significance at $P \leq 0.05$	English	Scottish	Significance at $P \leq 0.05$
1992	<0.1	<0.1	NS	<0.1	<0.1	NS
1993	1.55	0.68	S	1.18	0.93	NS
1994	1.32	2.01	NS	0.82	4.93	S

3.3.3 *Fusarium* spp. (seedling blight)

Fusarium spp. were recorded in over 90% of winter wheat seed samples tested each year, but infection was at relatively low levels (Figure 3.5). There was no significant difference between mean infection in certified and farm-saved seed in any year (Table 3.4).

Twenty-two per cent of Scottish samples had more than 5% infection in 1992 compared to 14% of English samples (Figure 3.6). In 1993 and 1994 infection levels were higher in English seed than in Scottish seed. The maximum infection recorded was 33% in a sample of English certified seed in 1993.

Table 3.4 Mean *Fusarium* spp. infection in certified and farm-saved seed and in English and Scottish produced winter wheat seed

	Mean percentage infection					
	Certified	Farm-saved	Significance at $P \leq 0.05$	English	Scottish	Significance at $P \leq 0.05$
1992	3.27	3.07	NS	2.94	3.75	S
1993	2.79	3.07	NS	3.12	2.02	S
1994	2.65	2.91	NS	2.95	1.96	S

Figure 3.5 Percentage of winter wheat seed samples infected with *Fusarium spp.*, and percentage of samples with more than 5 and 10 per cent infection

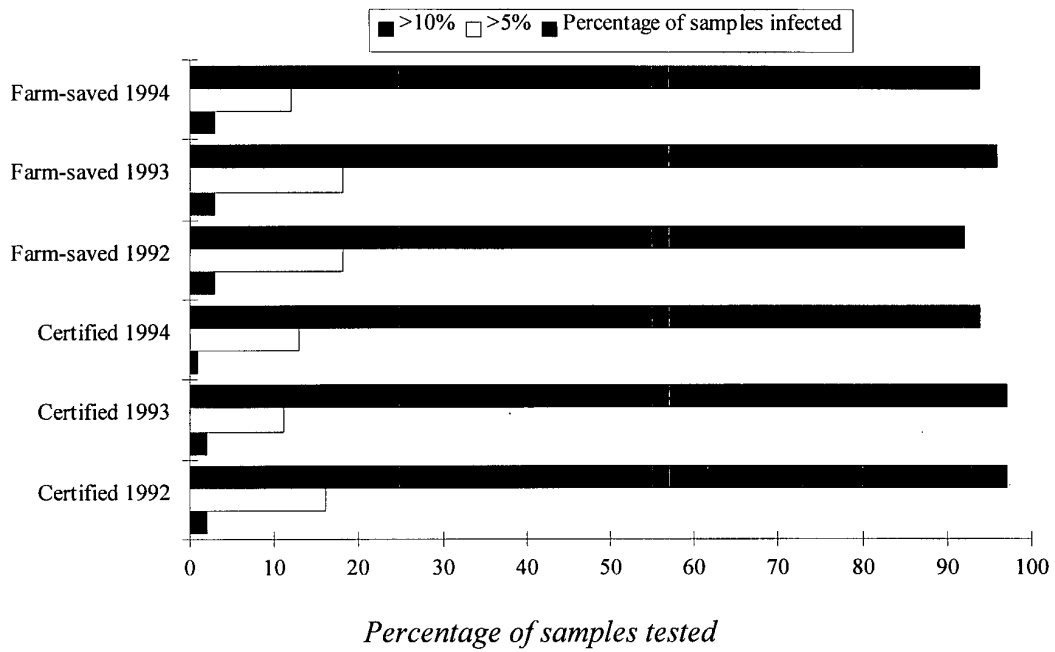
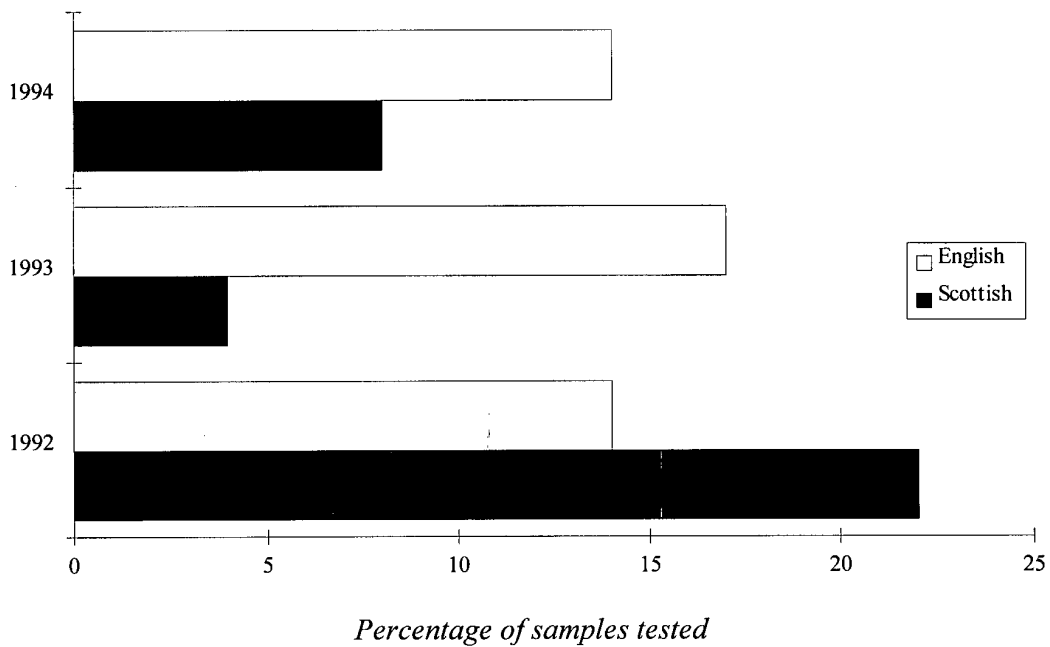


Figure 3.6 Percentage of Scottish and English winter wheat seed samples with more than 5 per cent *Fusarium spp.*.



3.3.4 *Tilletia caries* (bunt)

One broken bunt ball was found in a single sample of English certified seed in 1992. This was the only evidence of bunt balls during the 3 years of the survey. However, spores of *T. caries* were found on 57% of certified seed samples in 1992, on 22% of samples in 1993 and on 34% of samples in 1994 (Figure 3.7). The corresponding figures for farm-saved seed samples were 37%, 43% and 42% respectively. There was a significant difference between mean *T. caries* contamination for certified and farm-saved seed in 1993 and 1994 with farm-saved seed having more contamination than certified seed (Table 3.5).

Table 3.5 Mean *T. caries* contamination for certified and farm-saved seed for English and Scottish produced winter wheat seed

	Certified	Farm-saved	Number of spores per seed		Significance at $P \leq 0.05$	
			English	Scottish		
1992	0.97	1.37	NS	1.58	0.13	S
1993	0.17	0.90	S	0.61	0.06	NS
1994	0.14	0.43	S	0.29	0.20	NS

More than 40% of English farm-saved seed samples were contaminated in each of the 3 years whereas contamination in Scottish farm-saved seed was between 18% and 33%, (Figure 3.8). Contamination in certified seed varied from year to year with 63% of English seed samples contaminated in 1992 and 50% of Scottish certified seed samples contaminated in 1994. Mean contamination of Scottish and English seed was significantly different in 1992 but not in 1993 and 1994 (Table 3.5).

Figure 3.7 Percentage of winter wheat seed samples contaminated with *Tilletia caries* (bunt)

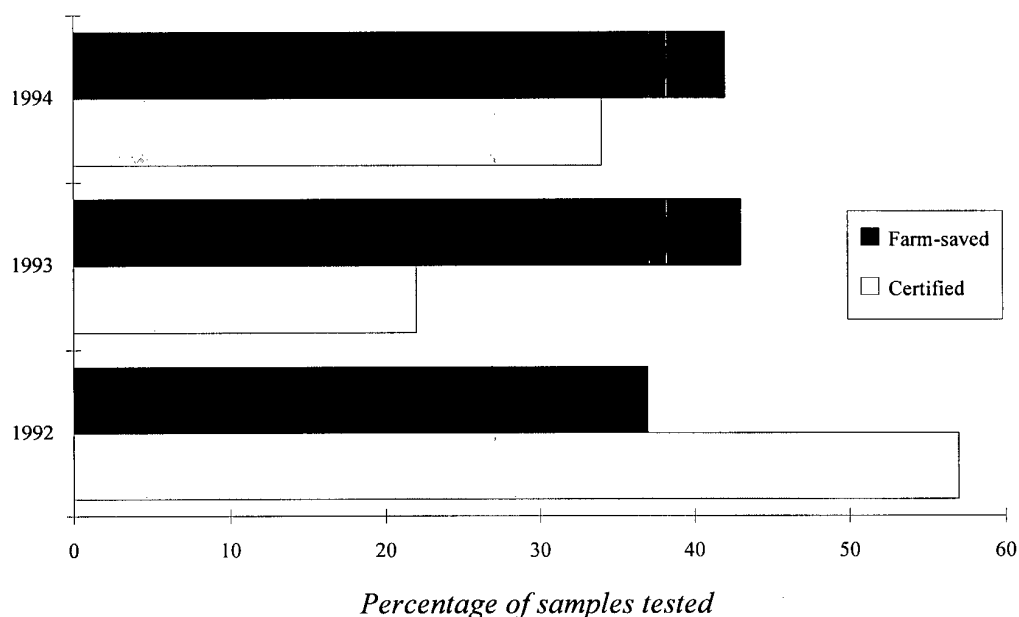


Figure 3.8 Percentage of Scottish and English winter wheat seed samples contaminated with *Tilletia caries* (bunt)

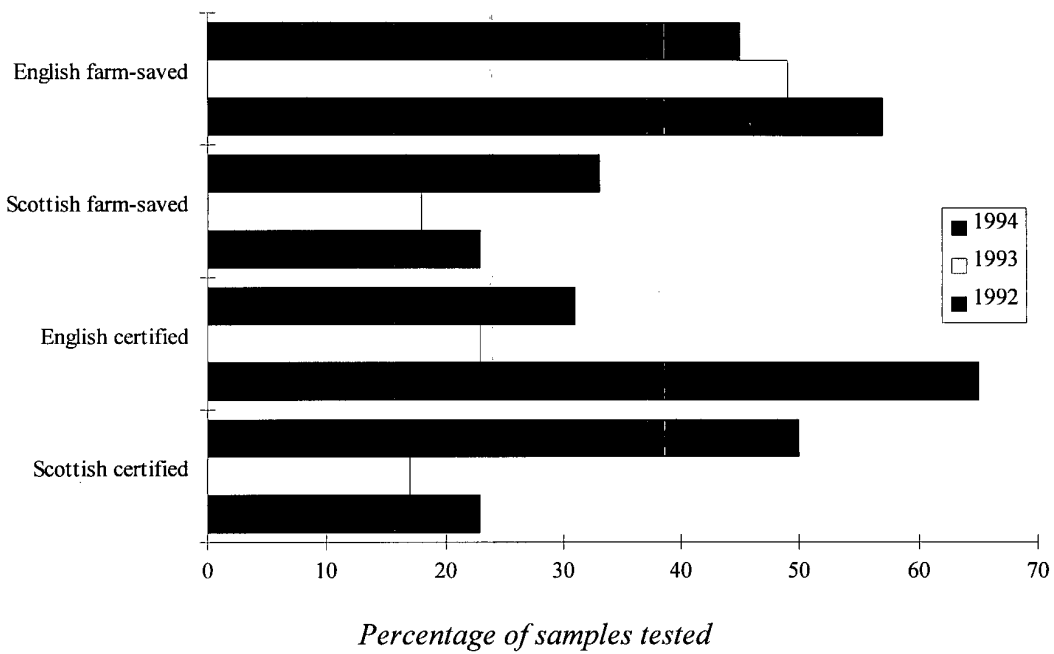
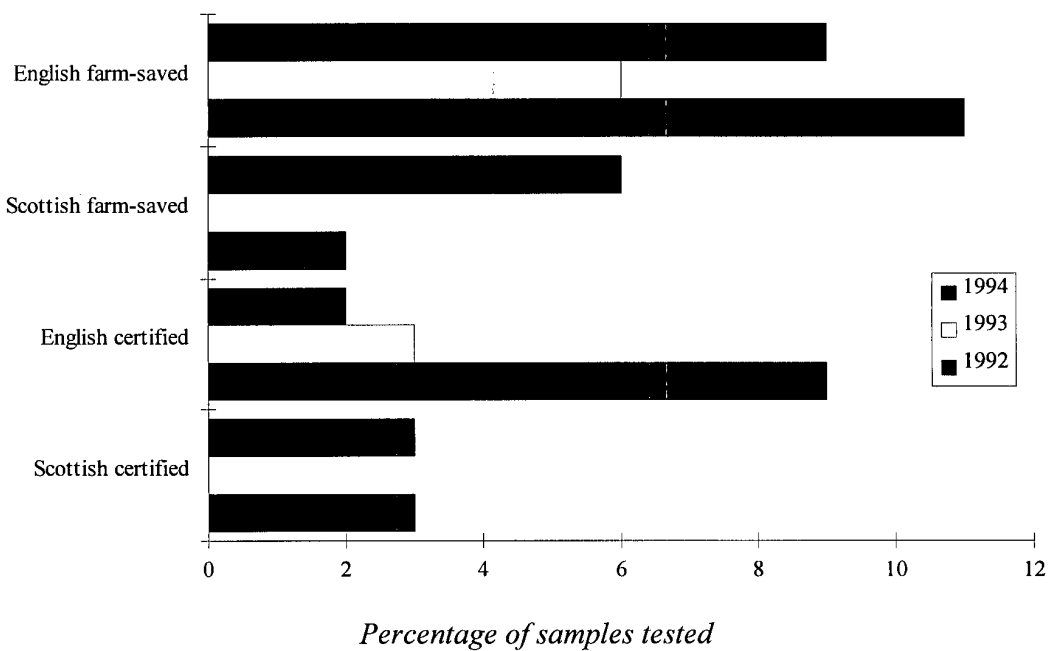


Figure 3.9 Percentage of Scottish and English winter wheat seed samples contaminated with more than one spore of *Tilletia caries* (bunt) per seed



Contamination was generally at low levels (Figure 3.9). In 1992 11% of English farm-saved seed samples carried more than one spore per seed; in 1993 and in 1994 6% and 9% of samples were contaminated at this level. Two English certified seed samples had more than 10 spores per seed in 1992. One sample of English farm-saved seed was contaminated at this level in both 1992 and 1993 and 2 samples reached this level of contamination in 1994. The maximum contamination of 121 spores per seed was recorded in a sample of English farm-saved seed in 1993.

Only 2% of Scottish farm-saved seed samples had more than one spore per seed in 1992; 6% were contaminated at this level in 1994 and no sample of Scottish farm-saved seed had more than one spore per seed in 1993. The number of Scottish certified seed samples with more than 1 spore per seed was very low. Contamination at this level was 3% in 1992, none was recorded in 1993 and 3% of samples were contaminated at this level in 1994. No Scottish seed sample had more than 5 spores per seed in any year.

Within years the mean *T.caries* contamination varied between English regions (Table 3.6). Contamination in any one region also varied from year to year. Mean *T.caries* levels were highest in the East in 1992 and 1993 and in the North in 1994.

Table 3.6 Mean range of *T.caries* contamination in English regions.

Area	YEAR		
	1992	1993	1994
	<i>Number of spores per seed</i>		
North			
Mean	0.45	0.92	0.61
Range	0 - 2.62	0 - 10.37	0 - 7.20
East			
Mean	3.09	1.33	0.17
Range	0 - 91.19	0 - 121.21	0 - 5.56
South East			
Mean	N/A	0.05	0.09
Range	N/A	0 - 0.43	0 - 0.70
South West			
Mean	N/A	0.14	0.05
Range	N/A	0 - 2.07	0 - 0.80
Midlands			
Mean	N/A	0.05	0.30
Range	N/A	0 - 0.27	0 - 5.60

N/A Data not available, less than 10 samples tested

CHAPTER 4

WINTER AND SPRING BARLEY

4.1 INTRODUCTION

As with winter wheat there are relatively few survey data relating to seed-borne pathogens of barley. Seed-borne *M.nivale*, *Drechslera graminea* (leaf stripe), *Cochliobolus sativus* and *Fusarium spp.* were for many years adequately controlled by organomercury seed treatments.

Loose smut (*Ustilago nuda*) was not controlled by organomercury. Infection occurs as a mycelium within seed embryos and as the seed germinates the fungus is carried up in the developing inflorescence which at heading is replaced by a mass of black sooty spores. Gray (1954) reported that it was usual to find between 2 and 15% of plants infected with loose smut in crops of susceptible varieties during the 1940s and early 1950s in the North of Scotland. In 1949 occasional crops of the variety Maja were reported to have as many as 50% of smutted heads. The OSTs for England and Wales recorded loose smut in 84% of Scandinavian bred barley varieties, with infection levels up to 19%, during the period 1954-57. During the same period, English bred varieties were less susceptible to infection, with only 9.5% of samples infected and with a maximum of 4.2% infection (Marshall, 1959). Rennie and Seaton (1975) reported a mean annual incidence of 1% or less in spring barley seed tested between 1959 and 1973 at the OSTs for Scotland.

There are standards in UK Cereal Seeds Regulations for loose smut (Anon., 1993). The maximum permitted infection is 0.5% for seed sold at the EC minimum standard but most UK cereal seed is certified at the Higher Voluntary Standard where the maximum permitted infection is 0.2% for certified seed of the first and second generation and 0.1% for basic seed.

Rennie (1987) found that the incidence of loose smut was more prevalent in samples of Scottish farm-saved seed than in samples intended for certification from 1980 to 1985 although 36% of winter barley samples and 20% of spring barley samples from seed intended for certification had more than 0.2% infection. This confirmed the increased incidence of loose smut infection reported in plots of certified winter barley in England and Wales at this time (Wray & Pickett, 1985) which was associated with strains of the fungus resistant to carboxin. More recently Reeves and Wray (1994) showed an increase, from approximately 10% in 1990 to approximately 30% in 1993, in the percentage of barley seed samples tested at the OSTs for England and Wales which would fail to meet the 0.2% Higher Voluntary Standard for loose smut.

Barley leaf stripe (*D.graminea*) is one of the most damaging diseases of barley. Diseased plants originate only from infected seed. The leaves become systemically infected and the plants senesce early and produce a poor yield of shrivelled seed. Severe outbreaks of the disease were reported in Scotland during the 1930s (Foister, 1961) but the successful treatment of oat seed with organomercury fungicides to control the related species *Drechslera avenae* (leaf spot) led to the extensive use of organomercury seed treatment on barley and for many years leaf stripe was seen only in occasional crops where untreated seed, or inadequately treated farm-saved seed, had been sown (Richardson, 1986). Hewett (1975),

however, described *D.graminea* as being widespread at low levels of infection on spring barley seed samples tested in 1972 and 1973 at the OSTs for England and Wales. Ten per cent of the samples tested during this period were infected, but with a mean infection of less than 1%. However, during this period a sample of Mazurka was reported as having 42% of seeds infected.

During the mid 1980s there were occasional reports of leaf stripe in spring barley crops grown from organomercury treated seed. Jones *et al.*, (1989) confirmed that some strains of *D.graminea* were resistant to organomercury. Cockerell *et al.*, (1995) reported that the incidence of organomercury resistant *D.graminea* was highest in Scottish spring barley in 1989 and 1990, with 69% of samples tested at the OSTs for Scotland infected in 1989 and 82% infected in 1990. In 1990 a sample of spring barley seed had 91% of seeds infected. The introduction of a voluntary Code of Practice significantly reduced infection and by 1992 only 10% of spring barley samples were infected. During the period of their study from 1987 to 1992 Cockerell *et al.*, found that the mean leaf stripe infection on winter barley did not exceed 1%.

Seed-borne *Cochliobolus sativus* infection can reduce seedling emergence in susceptible barley varieties. Hewett (1975) and Whittle and Richardson (1978) noted that high levels of seed-borne infection on the variety Clermont reduced seedling emergence and in their trials Whittle and Richardson also reported a reduction in crop yield. Hewett (1975) reported *C.sativus* in a high proportion of spring barley seed samples but at low levels. Thirteen per cent of Scottish spring barley seed samples, from the 1991 harvest, tested at the OSTs, Edinburgh were infected with *C.sativus* (Cockerell, unpublished data). The variety Atem was most often infected with seed infection levels up to 44%.

In temperate regions *M.nivale* has been reported to cause pre-emergence and post-emergence death of seedlings, and foot rot and ear infection in winter sown barley, wheat and rye (Cristani, 1992). Richardson, *et al.*, (1976) found that spring barley seed infected with high levels of *M.nivale* did not appear to show a reduction in germination but infection was associated with higher levels of seedling disease if the seed was sown untreated. In Scotland high levels of seed-borne *M.nivale* infection are recorded on occasional samples of winter and spring barley in some years but high seed-borne infection has never been associated with reduced germination or emergence (Cockerell, unpublished data).

4.2 MATERIALS AND METHODS

4.2.1 *Ustilago nuda*

Using seed sample dividers, working samples of approximately 120g were taken according to International Rules for Seed Testing (Anon., 1985). The embryo extraction method described by Rennie (1984) was used to detect *Ustilago nuda* infection. Glycerol and water in equal volumes were used to separate chaff and other debris from the embryos; lactophenol was used only to clear the embryos. Approximately 1000 embryos per sample were examined for mycelium of *U.nuda* at x25 magnification and the percentage infection was determined.

4.2.2 *Drechslera graminea*, *Drechslera teres*, *Microdochium nivale*, *Cochliobolus sativus* and *Fusarium spp.*

An agar plate method as described at 3.2.1 was used to determine the percentage infection of *D.graminea* (Rennie & Tomlin, 1984), *D.teres*, *M.nivale*, *C.sativus* and *Fusarium spp.*. A working sample was obtained using seed sample dividers according to International Rules for Seed Testing (Anon., 1985). Two x 100 seed replicates were pretreated for 10 minutes in sodium hypochlorite (containing approximately 1% available chlorine) and then plated 5 to a plate on PDA containing 130ppm streptomycin sulphate. After 7-8 days incubation in darkness at 20°C fungal colonies were examined visually. To confirm the identification of *D.graminea* and *D.teres* colonies, portions of atypical colonies were transferred to filter paper in humid chambers and incubated at 18°C for 2-5 days in cycles of 12 hours NUV light (360nm) and 12 hours darkness and examined at x50 magnification for conidia and conidiospores.

4.2.3 *Statistics*

Significance was determined by means of t-tests after applying appropriate transformations to the data.

4.3 RESULTS

4.3.1 *Ustilago nuda* (Loose smut)

Winter barley

Infection was highest in 1992 and farm-saved seed was more frequently infected, and at higher levels, than certified seed (Figure 4.1). In 1992 20% of certified seed samples and 59% of farm-saved seed samples were infected. In 1994 12% of certified seed samples and 16% of farm-saved seed carried infection.

In 1992 7% of certified seed samples and 37% of farm-saved seed samples were found to have more than 0.2% loose smut infection, the standard for Higher Voluntary Standard (HVS) seed in UK Cereal Seeds Regulations. In 1993 and 1994 5% and 1% respectively of certified seed failed to meet this standard and in the same years 10% and 8% of farm-saved seed was infected above the HVS standard. In 1992 1% of certified seed and 25% of farm-saved seed had more than 0.5% *U.nuda* infection, the maximum permitted in certified seed. In 1993 no sample of certified seed failed this standard but 5% of farm-saved seed was infected above this level. Similarly in 1994, 1% of certified seed and 6% of farm-saved seed failed the 0.5% standard. The mean *U.nuda* infection was significantly higher in farm-saved seed than in certified seed (Table 4.1) in each of the 3 years.

Figure 4.1 Percentage of winter barley seed samples infected with *Ustilago nuda* and percentage of samples with more than 0.2 and 0.5 per cent infection

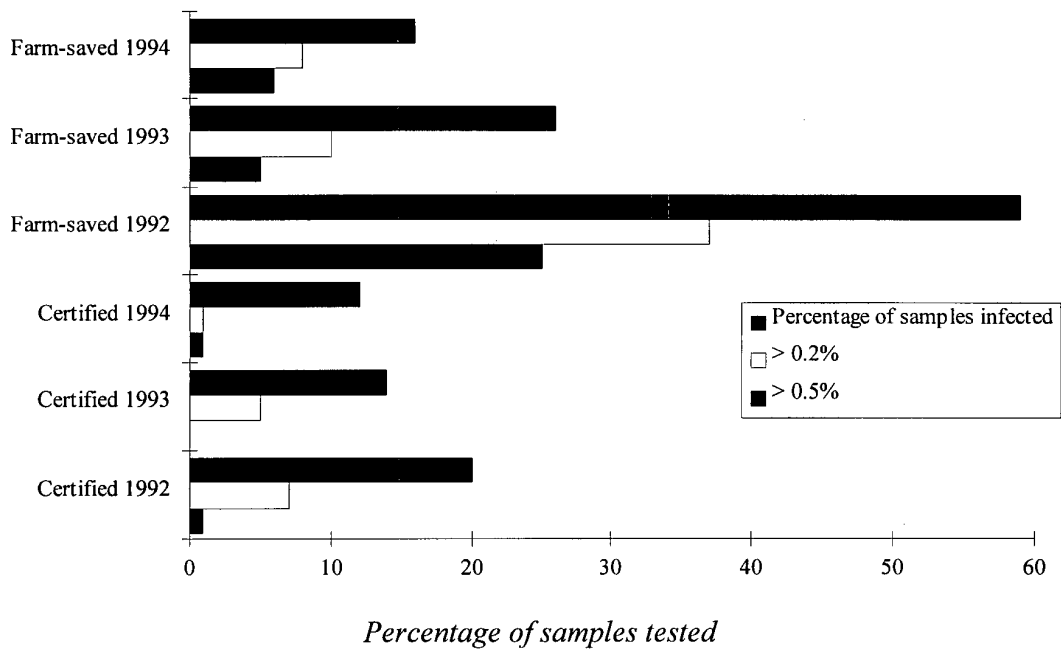


Figure 4.2 Percentage of spring barley seed samples infected with *Ustilago nuda* and percentage of samples with more than 0.2 and 0.5 percent infection

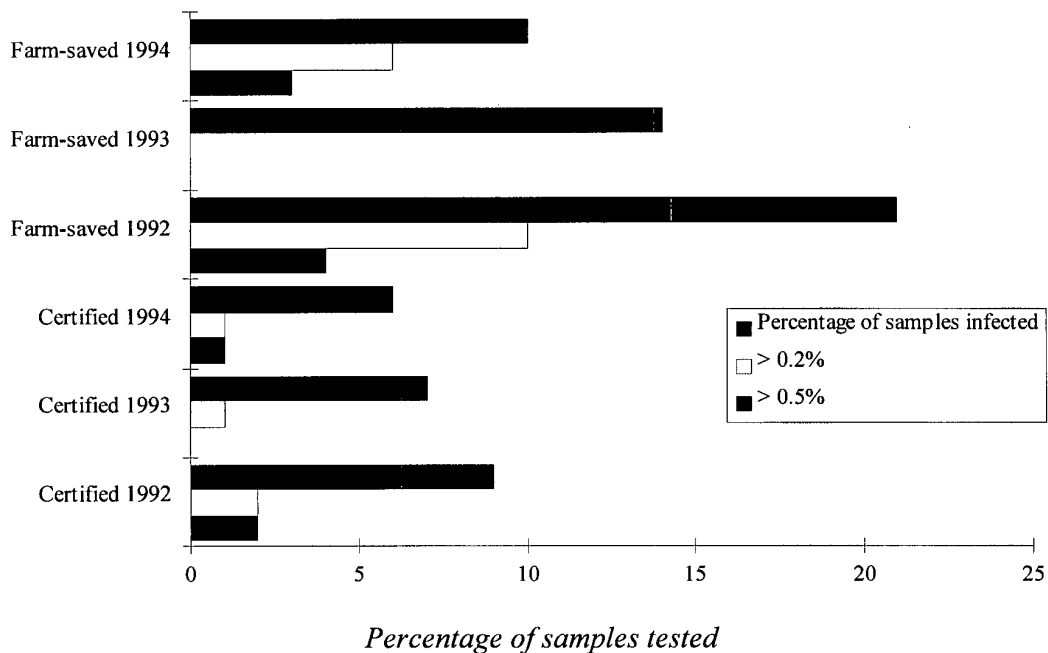


Table 4.1 Mean *U.nuda* infection in certified and farm-saved seed and in English and Scottish produced winter barley seed

	Mean percentage infection					
	Certified	Farm-saved	Significance at $P \leq 0.05$	English	Scottish	Significance at $P \leq 0.05$
1992	0.05	0.75	S	0.13	0.50	S
1993	0.03	0.13	S	0.11	0.02	S
1994	0.02	0.20	S	0.05	0.17	NS

Infection was more frequent in English certified seed and at higher levels than in Scottish certified seed in each year of the survey (Table 4.2). The maximum infection recorded (10.6%) was in a sample of Scottish farm-saved seed in 1994. Only eleven samples of English farm-saved winter barley seed were sampled and tested in 1992 and therefore no data are presented for that year.

There was a significant difference in infection between English and Scottish produced seed in 1992 and 1993 but the difference was not significant in 1994 (Table 4.1).

Table 4.2 Percentage of winter barley samples infected with *U.nuda* and percentage of samples with more than 0.2% and 0.5% infection

	Scottish			English		
	1992	1993	1994	1992	1993	1994
Certified Seed						
Percentage infected	8	5	7	27	19	14
> 0.2%	3	0	0	10	7	1
> 0.5%	0	0	0	2	0	1
Farm-saved seed						
Percentage infected	58	13	15	-	37	17
> 0.2%	35	4	8	-	15	8
> 0.5%	26	2	8	-	8	6

Spring Barley

As with winter barley, infection was higher in farm-saved seed (Figure 4.2) than in certified seed. A decline in infection from 1992 to 1994 was seen in both winter and spring barley and in both certified and farm-saved seed. Nine per cent of certified seed samples and 21% of farm-saved seed samples were infected in 1992. In 1993 7% of certified seed and 14% of farm-saved seed samples were infected while in 1994 6% of certified seed and 10% of farm-saved seed samples were infected.

In 1992 2% of certified seed samples and 10% of farm-saved seed samples had more than 0.2% infection. In 1994 1% of certified seed and 6% of farm-saved seed was infected above this level. In 1992 2% of certified seed and 4% of farm-saved seed failed to meet the 0.5% standard. In 1993 no sample was infected above this level and in 1994 1% of certified seed

and 3% of farm-saved seed had more than 0.5% infection. Differences between certified and farm-saved seed in 1993 and 1994 were not significant but infection in farm-saved seed was significantly higher in 1992. (Table 4.3).

Table 4.3 Mean *U.nuda* infection in certified and farm-saved and in English and Scottish produced spring barley seed

	Mean percentage infection					
	Certified	Farm-saved	Significance at P ≤ 0.05	English	Scottish	Significance at P ≤ 0.05
1992	0.03	0.18	S	-	-	-
1993	0.01	0.02	NS	-	-	-
1994	0.04	0.04	NS	0.09	0.01	NS

4.3.2 *Drechslera graminea* (*Pyrenophora graminea*) (leaf stripe)

Winter Barley

Drechslera graminea was recorded at low levels on 2 to 10% of seed samples during the period of the survey (Figure 4.3). Farm-saved seed was more frequently infected in 1993 and 1994 but certified seed had more infection in 1992. In 1992 and 1994 2% and 1% respectively of certified samples had more than 2% infection (the maximum infection permitted under a Voluntary Code of Practice). In 1993 and 1994 1% and 2% of farm-saved seed samples carried infection above the 2% standard. The highest infection recorded was 24.5% in a sample of English certified Gaelic winter barley in 1994. There was no difference between mean infection in farm-saved and certified seed, or between Scottish and English produced seed in any year (Table 4.4).

Figure 4.3 Percentage of winter barley seed samples infected with *Drechslera graminea* and percentage of samples with more than 2 per cent infection

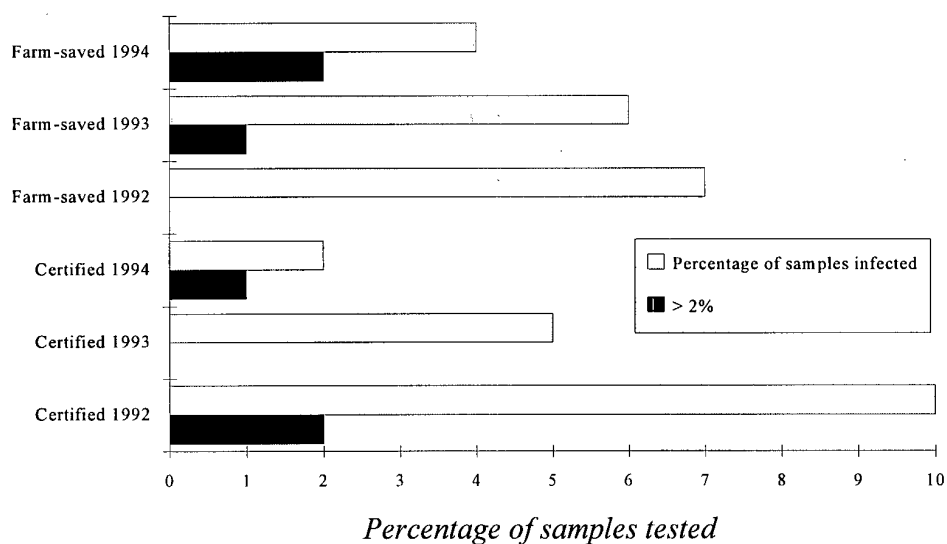


Figure 4.4 Percentage of spring barley seed samples infected with *Drechslera graminea* and percentage of samples with more than 2 per cent infection

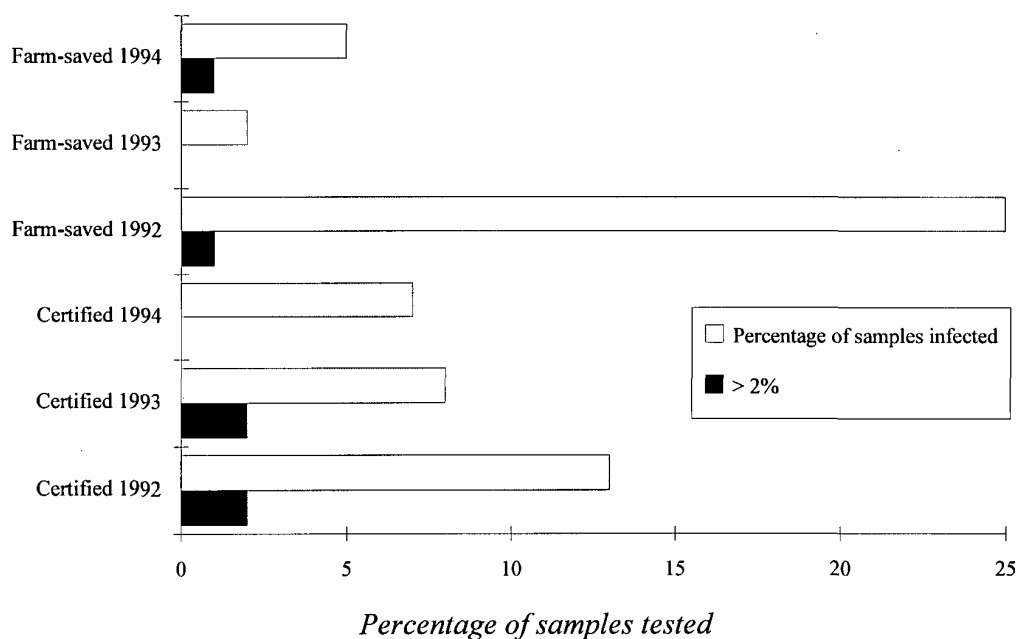


Table 4.4 Mean *D.graminea* infection in certified and farm-saved and in English and Scottish produced winter barley seed

	Mean percentage infection					
	Certified	Farm-saved	Significance at $P \leq 0.05$	English	Scottish	Significance at $P \leq 0.05$
1992	0.17	0.04	NS	0.13	0.11	NS
1993	0.03	0.10	NS	0.10	0.02	NS
1994	0.19	0.18	NS	0.26	0.02	NS

Spring barley

Spring barley seed samples were more frequently infected with *D.graminea* than winter barley samples but infection occurred only at low levels. Thirteen per cent of certified seed samples and 25% of farm-saved seed samples carried *D.graminea* infection in 1992 (Figure 4.4). In 1993 8% of certified seed and 2% of farm-saved seed carried infection and in 1994 7% of certified seed and 5% of farm-saved seed was infected. Infection was greater in farm-saved seed in 1992 but higher in certified seed in 1993 and 1994. In 1992 and 1993 2% of certified seed samples had more than 2% infection but in 1994 no sample of certified seed was infected above this level. In 1992 and 1994 1% of farm-saved seed carried infection at this level but no sample of farm-saved seed had more than 2% infection in 1993. The maximum infection recorded was 13% in a sample of English farm-saved spring barley from the 1994 harvest. There was no difference in infection between certified and farm-saved seed

in 1993 and 1994 but infection levels were significantly higher in farm-saved seed in 1992 (Table 4.5).

Table 4.5 Mean *D.graminea* infection in certified and farm-saved and in English and Scottish produced spring barley seed

	Mean percentage infection					
	Certified	Farm-saved	Significance at $P \leq 0.05$	English	Scottish	Significance at $P \leq 0.05$
1992	0.14	0.29	S	-	-	-
1993	0.09	0.01	NS	-	-	-
1994	0.04	0.19	NS	0.26	0.01	S

4.3.3 *Drechslera teres* (*Pyrenophora teres*) (net blotch)

Winter barley

D.teres was common on both farm-saved and certified winter barley seed (Figure 4.5). Approximately 44% of farm-saved seed was infected compared to 59% of certified seed. The mean *D.teres* infection in certified seed in each of the 3 years was significantly higher than the mean infection of farm-saved seed. (Table 4.6).

In 1993 and 1994 English seed was more frequently infected than Scottish seed and at higher levels. In 1993 10% of English samples had more than 20% infection but no sample of Scottish seed was infected at this level. Thirteen per cent of English samples were infected at this level in 1994 compared to 2% of Scottish samples. A higher percentage of Scottish seed samples was infected in 1992 (Figure 4.6). There was no difference in the mean infection of Scottish and English seed in 1992 but English seed carried a significantly higher mean infection in 1993 and 1994 (Table 4.6).

Table 4.6 Comparison of Mean *D.teres* infection in certified and farm-saved and in Scottish and English produced winter barley seed

	Mean percentage infection					
	Certified	Farm-saved	Significance at $P \leq 0.05$	English	Scottish	Significance at $P \leq 0.05$
1992	2.41	0.53	S	1.44	1.79	NS
1993	5.77	2.72	S	6.24	1.67	S
1994	7.79	2.88	S	7.73	1.68	S

Figure 4.5 Percentage of winter barley seed samples infected with *Drechslera teres*

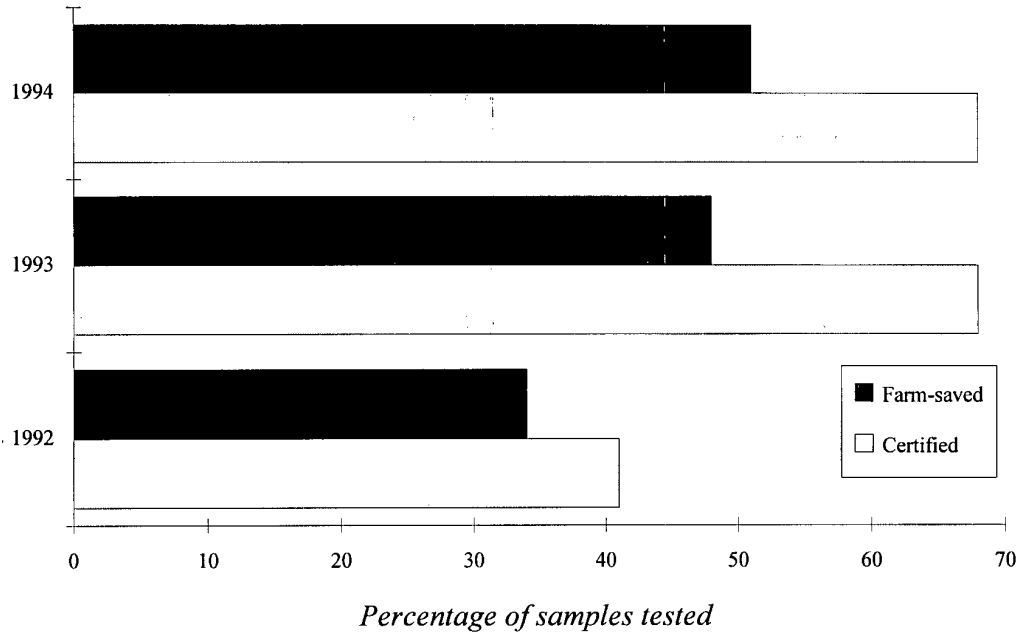
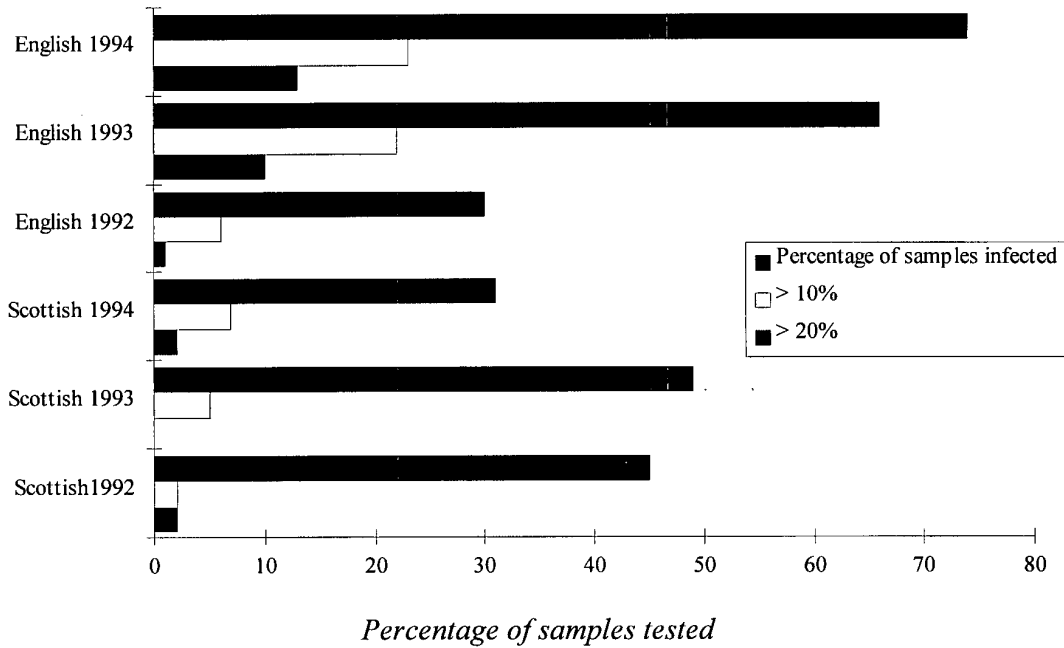


Figure 4.6 Percentage of Scottish and English winter barley seed infected with *Drechslera teres* and percentage with more than 10 and 20 per cent infection



Spring barley

As with winter barley *D.teres* was common on both certified and farm-saved spring barley seed (Figure 4.7). Certified seed samples were more often infected than farm-saved seed in 1993 and 1994 but in 1992 infection was similar in both. More than 50% of certified seed samples were infected in 1993 and 1994 while 41% and 35% of farm-saved seed samples were infected in 1993 and 1994 respectively. Approximately 40% of certified and farm-saved seed was infected in 1992. There was no difference in mean infection between certified and farm-saved seed in 1992 and 1993, but infection in certified seed was significantly higher in 1994. There was no difference in infection between English and Scottish produced seed in 1994 (Table 15).

Figure 4.7 Percentage of spring barley seed samples infected with *Drechslera teres* and percentage with more than 10 and 20 per cent infection

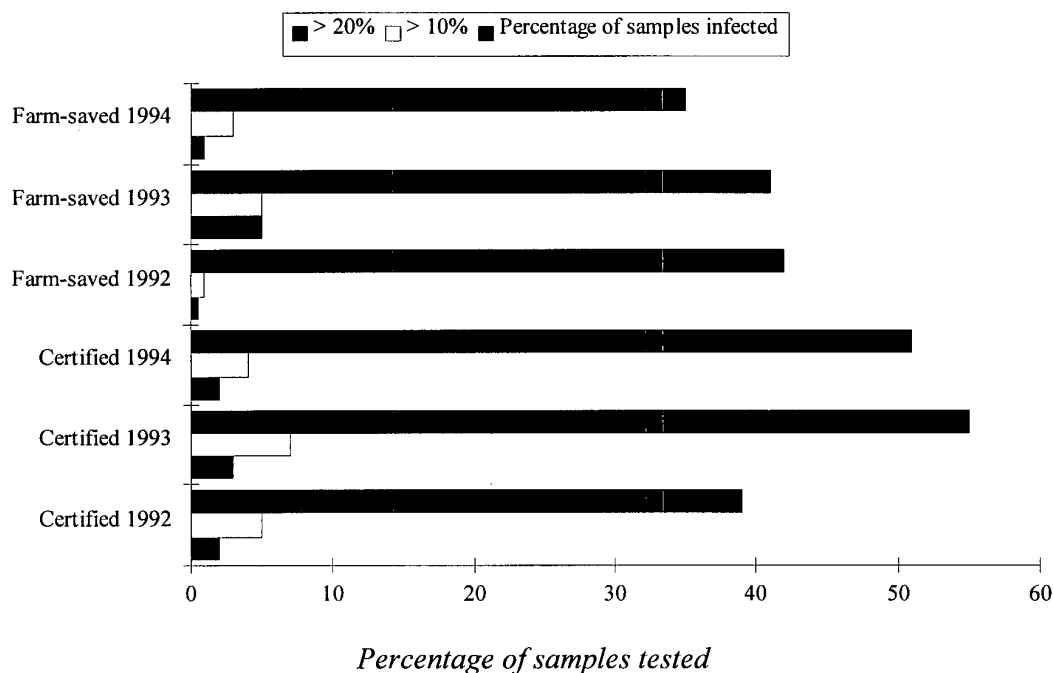


Table 4.7 Mean *D.teres* infection in certified and farm-saved and in Scottish and English produced spring barley seed

	Mean percentage infection		Significance at P ≤ 0.05	English	Scottish	Significance at P ≤ 0.05
	Certified	Farm-saved				
1992	1.57	1.43	NS	-	-	-
1993	2.87	2.72	NS	-	-	-
1994	1.67	0.94	S	1.46	1.44	NS

4.3.4 *Microdochium nivale*, *Fusarium spp.* and *Cochliobolus sativus* (seedling blight)

Winter barley

Microdochium nivale

More than 50% of the winter barley samples tested each year carried *M.nivale* infection at (Figure 4.8) relatively low levels. Six per cent of certified winter barley samples had more than 20% infection in 1993 and 3% of farm-saved samples were infected at this level. Less than 2% of certified seed samples had more than 20% infection in 1992 and 1994 and no farm-saved sample was infected at this level in those years. There was no significant difference between mean *M.nivale* infection in certified and farm-saved seed in any year (Table 4.8).

Seventy seven per cent of English samples were infected in 1992 compared to 68% of Scottish samples (Figure 4.9). The proportion of Scottish samples infected in 1994 was higher than that for English samples. However, there was no significant difference between mean infection in Scottish and English produced seed in any year (Table 4.8).

Figure 4.8 Percentage of winter barley seed samples infected with *Fusarium nivale* and percentage of samples with more than 20 per cent infection

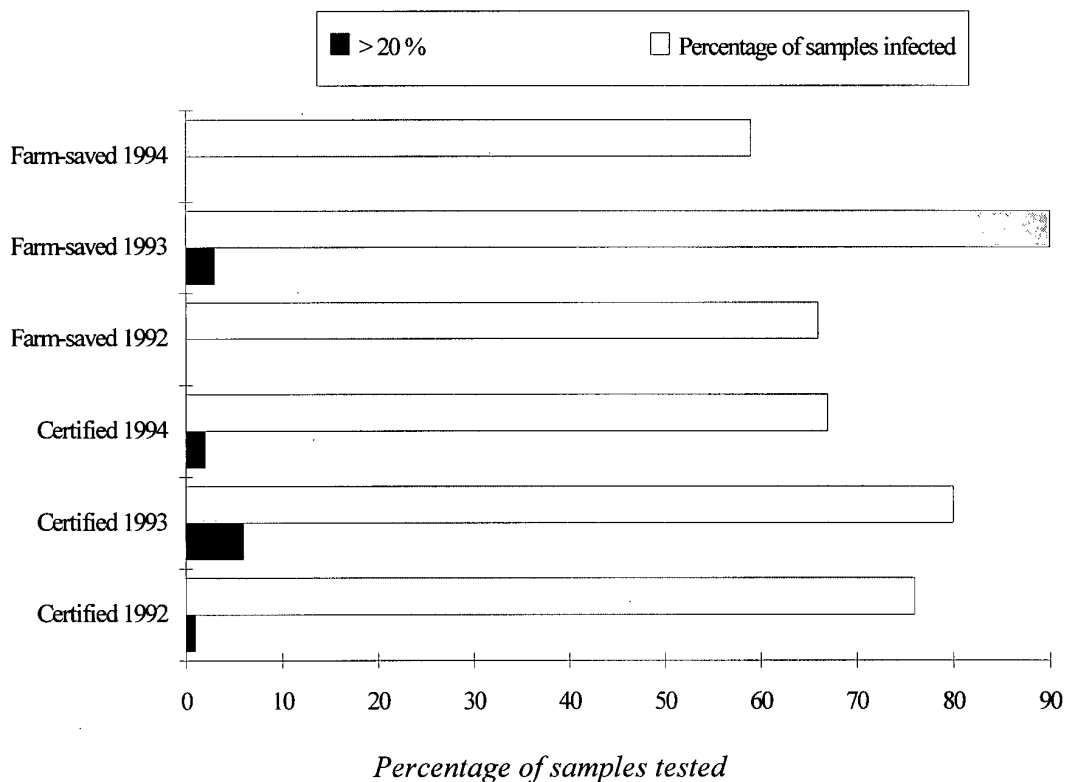


Figure 4.9 Percentage of Scottish and English winter barley samples infected with *Microdochium nivale* and percentage with more than 20 per cent infection

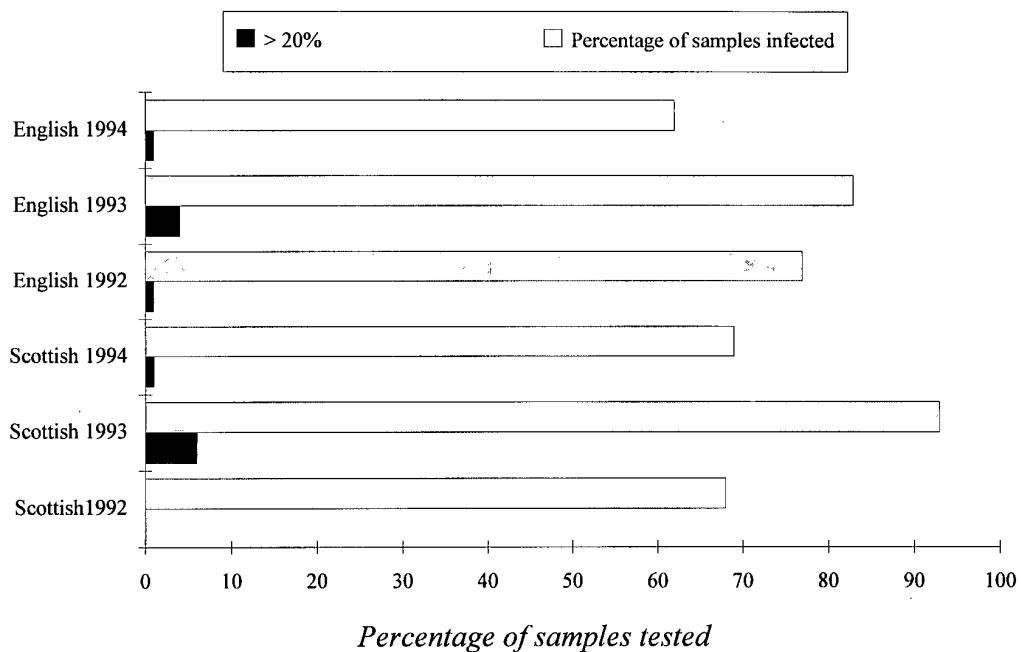


Table 4.8 Mean *M.nivale*, *Fusarium.spp* and *C.sativus* infection in certified and farm-saved winter barley seed and in Scottish and English winter barley seed

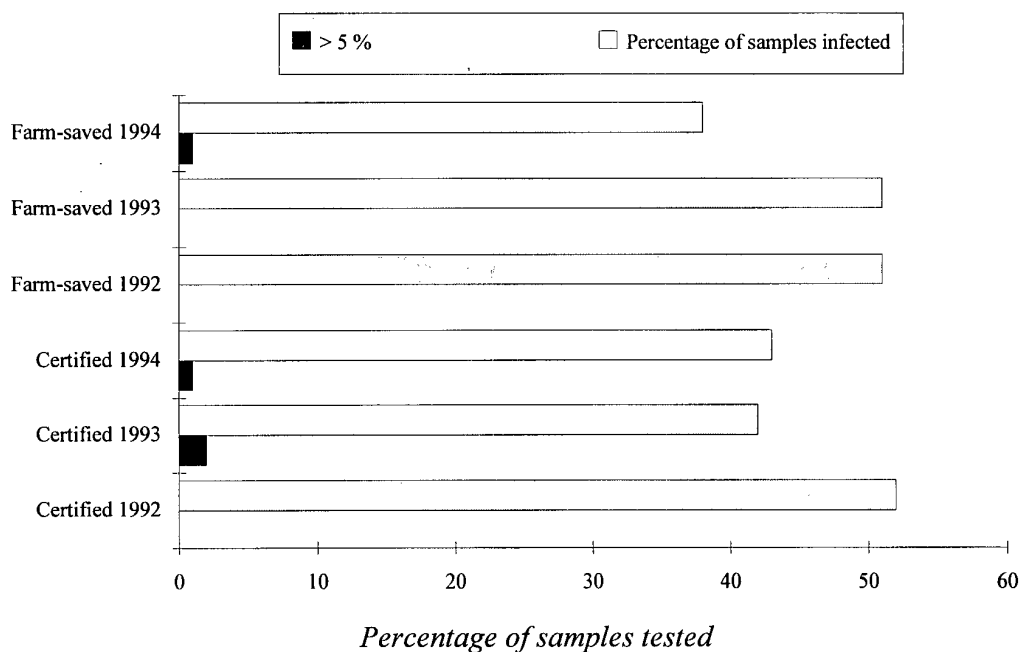
	Mean percentage infection					
	Certified	Farm-saved	Significance at P ≤ 0.05	English	Scottish	Significance at P ≤ 0.05
<i>M.nivale</i>						
1992	2.00	1.36	NS	2.07	1.48	NS
1993	6.52	4.56	NS	4.92	6.55	NS
1994	1.97	1.16	NS	1.46	2.08	NS
<i>F.spp</i>						
1992	0.43	0.50	NS	0.52	0.41	NS
1993	0.61	0.56	NS	0.48	0.73	S
1994	0.47	0.52	NS	0.29	0.93	S
<i>C.sativus</i>						
1992	0.01	0.01	NS	0.02	0.01	NS
1993	0.04	0.03	NS	0.06	0.00	S
1994	0.01	0.01	NS	0.01	0.00	NS

Fusarium spp.

Approximately 40 to 50% of winter barley samples were infected with species of *Fusarium* each year but very few samples had more than 5% infection (Figure 4.10). The percentage of infected certified and farm-saved samples was similar in 1992 and 1994; 52% of certified samples were infected in 1992 and in 1994 43% were infected compared to 51% of farm-saved samples in 1992 and 38% in 1994. The proportion of infected farm-saved seed was higher in 1993 with 51% of samples infected compared to 42% of certified seed samples. However, only 4 samples over the 3 year period had a seed infection level above 5%. There were no significant differences in mean infection between certified and farm-saved seed (Table 4.8).

There was no difference between mean infection in Scottish and English produced seed in 1992 but Scottish seed was more heavily infected than English seed in 1993 and 1994.

Figure 4.10 Percentage of winter barley samples infected with *Fusarium spp.* and



Cochliobolus sativus

The proportion of winter barley samples infected with *C.sativus* was very low (Figure 4.11). Infection was most common in 1993 with 6% of certified seed and 5% of farm-saved seed infected. Two per cent of certified seed and 3% of farm-saved seed was infected in 1992 and 1% of both certified and farm-saved seed was infected in 1994. The mean percentage seed infection did not exceed 1.5% for either certified or farm-saved seed in the 3 year period. There was no difference between mean infection levels of certified and farm-saved seed (Table 4.8).

English seed was more frequently infected than Scottish seed each year (Figure 4.12) with no *C.sativus* being recorded on Scottish winter barley in 1993 and 1994. Overall there was no

significant difference between mean infection in Scottish and English produced seed in 1992 and 1994 but English seed was more heavily infected in 1993 (Table 4.8).

Figure 4.11 Percentage of winter barley seed samples infected with *Cochliobolus sativus*

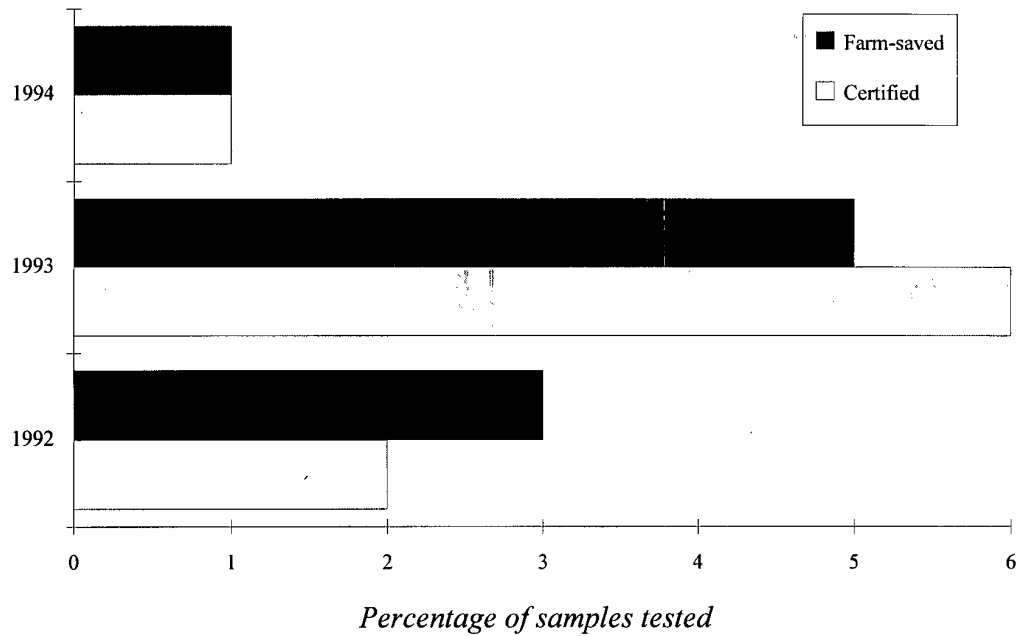
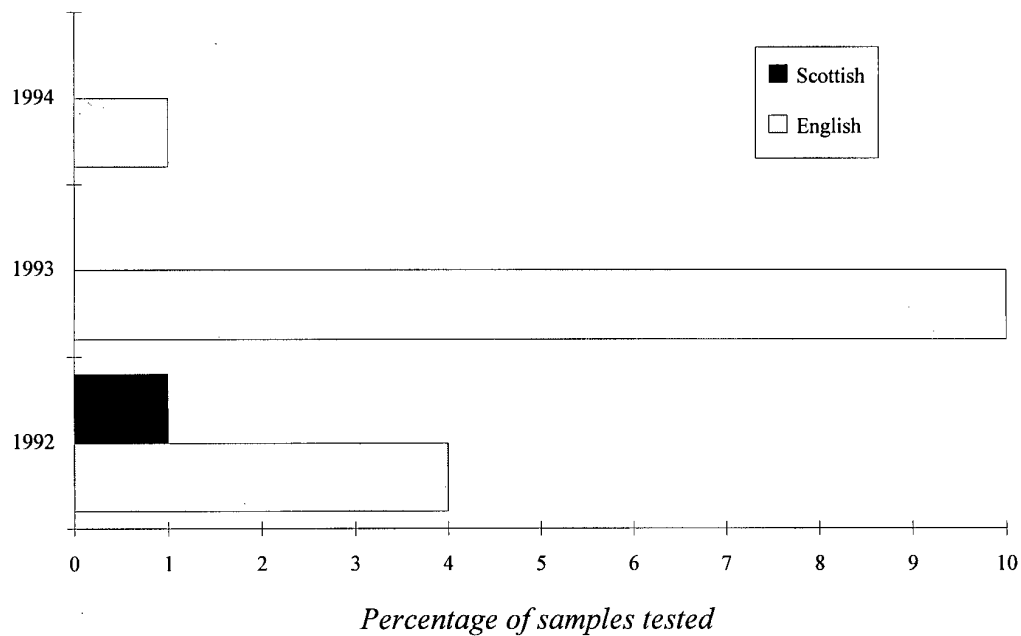


Figure 4.12 Percentage of English and Scottish produced winter barley seed infected with *Cochliobolus sativus*



Spring barley

Microdochium nivale

A high proportion of spring barley samples carried *M.nivale* infection. Certified seed was infected more often than farm-saved seed in each of the 3 years but infection levels were low (Figure 4.13). Ninety four per cent of certified seed samples were infected in 1992 and 1993 compared to 75% and 84% of farm-saved seed. In 1994 73% of certified seed carried infection compared to 65% of farm-saved seed samples. Less than 10% certified seed samples carried more than 20% seed infection in 1992 and 1994 but 14% of certified seed had more than 20% infection in 1993. Five percent of farm-saved seed had more than 20% in 1993 and 1% of farm-saved seed was infected at this level in 1992. No farm-saved seed sample had more than 20% infection in 1994. The mean infection was significantly higher in certified seed than in farm-saved seed in each of the 3 years and Scottish seed had a significantly higher mean infection than English produced seed in 1994.

Table 4.9 Comparison of mean *M.nivale*, *Fusarium* spp. and *C.sativus* infection in certified and farm-saved seed and in Scottish and English produced spring barley seed

	Mean percentage infection					
	Certified	Farm-saved	Significance at P ≤ 0.05	English	Scottish	Significance at P ≤ 0.05
<i>M.nivale</i>						
1992	6.05	3.08	S	-	-	-
1993	8.96	5.03	S	-	-	-
1994	3.27	1.66	S	0.58	3.85	S
<i>F.spp</i>						
1992	2.03	3.12	S	-	-	-
1993	1.90	0.73	S	-	-	-
1994	1.22	2.54	S	1.38	1.74	NS
<i>C.sativus</i>						
1992	0.29	0.57	NS	-	-	-
1993	0.08	0.01	S	-	-	-
1994	0.19	1.31	S	0.27	0.65	S

Fusarium spp.

Spring barley was more frequently infected than winter barley but infection levels were low with approximately 7% of samples having more than 5% seed infection over the 3 years (Figure 4.14). Farm-saved seed was more often infected in 1992 and 1994. Ninety per cent of farm-saved seed was infected in 1992 and 82% was infected in 1994 compared to 85% of certified seed in 1992 and 73% in 1994. A higher proportion of certified seed samples were infected in 1993 (75%) compared with farm-saved seed (57%). Mean *Fusarium*.spp infection was higher in farm-saved seed in 1992 and 1994 but significantly lower than in certified seed

in 1993 (Table 4.9). There was no significant difference between infection levels in English and Scottish seed in 1994.

Figure 4.13 Percentage of spring barley seed samples infected with *Microdochium nivale* and percentage of samples with more than 20 per cent infection

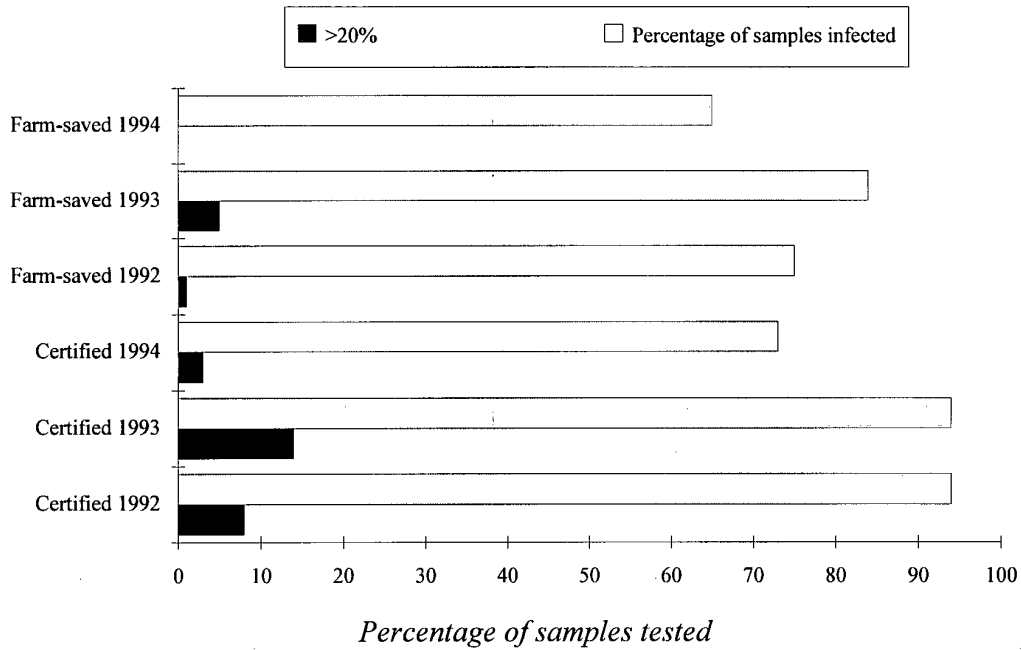
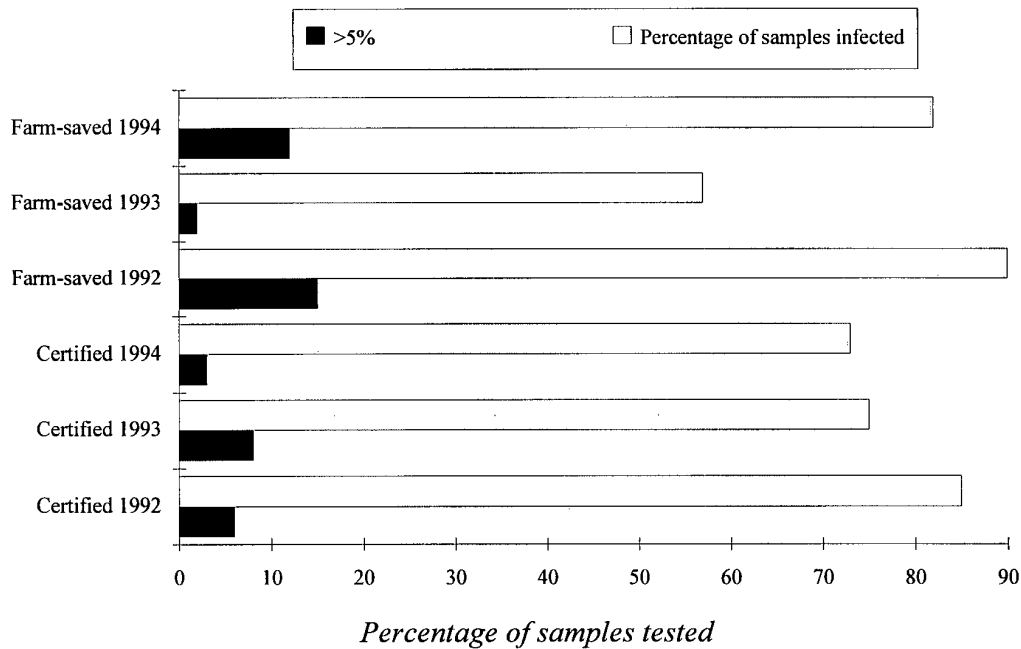


Figure 4.14 Percentage spring barley seed samples infected with *Fusarium spp.* and proportion of samples with more than 5 per cent infection



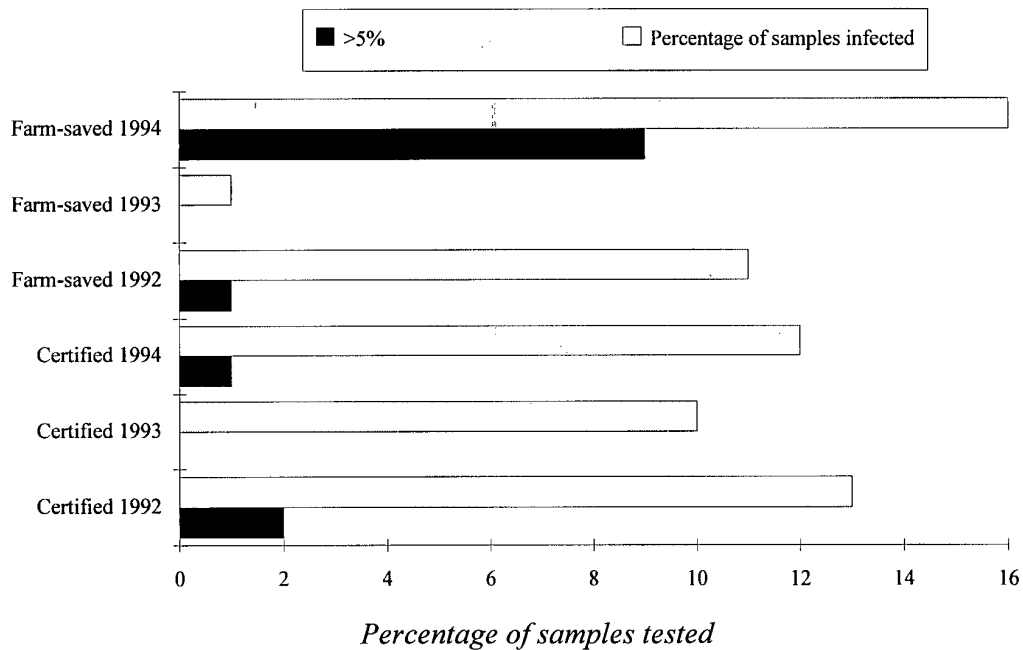
Cochliobolus sativus

Spring barley was more frequently infected with *C.sativus* than winter barley. However, the proportion of samples infected each year was low. Highest infection was recorded in the variety Atem. In 1992 one sample of Atem carried 36.5% seed infection and in 1994 2 samples of Atem had 29% and 41% infection.

A similar proportion of certified and farm-saved seed was infected in 1992 and 1994 (Figure 4.15). Thirteen per cent of certified samples were infected in 1992 and 12% were infected in 1994 compared to 11% of farm-saved samples in 1992 and 16% in 1994. Ten per cent of certified seed samples were infected in 1993 but only 1% of farm-saved samples were infected that year. The proportion of samples with more than 5% infection was highest in farm-saved seed in 1994 with 9% of samples carrying infection above this level.

There was no significant difference in mean *C.sativus* infection in certified and farm-saved seed in 1992 (Table 4.9). Infection was significantly higher in certified seed in 1993 but significantly lower than that of farm-saved seed in 1994.

Figure 4.15 Percentage of spring barley seed samples infected with *Cochliobolus sativus* and proportion with more than 5 per cent infection



CHAPTER 5 DISCUSSION AND CONCLUSIONS

5.1 DISCUSSION

This comprehensive survey reports on the incidence of seed-borne pathogens in UK cereal seed during the period 1992-94. It is the first study to compare the health of farm-saved and certified seed in respect of a wide range of pathogens and to present results separately for cereal seed harvested in England and Scotland.

The pathogens covered by this survey fall in to 2 groups:

1. Those in which the seed-borne phase principally affects seedling establishment (*M.nivale*, *S.nodorum*, *C.sativus*, *Fusarium spp.*) (seedling blights).
2. Pathogens that do not affect seedling establishment but cause damage at a later stage of crop growth (*Tilletia caries*, *Ustilago nuda*, *D.graminea* and *D.teres*)

Seedling blights

Inoculum of these pathogens is usually present in most cereal crops and high seed infection is associated with rainfall during flowering and subsequent seed development. Recent experience suggests that *M.nivale* is the seedling blight pathogen most often recorded in UK cereal seed and that it is the most damaging pathogen, with its effects greatest on the winter wheat crop.

Seedling losses in wheat can be significant if heavily infected seed is sown untreated. Damage is usually greatest in cold seed beds where germination and emergence are slow. Although *M.nivale* can infect barley seed there are few, if any, reports that associate seed infection with seedling losses. *M.nivale* rarely affects barley seed germination when infected seed is assessed in standard tests whereas infection in wheat seed is correlated with reduced germination.

S.nodorum causes a similar pattern of infection and damage to wheat seedlings but in recent years has been much less common than *M.nivale*. It is of no importance as a seedling blight of barley.

C.sativus is very rare on wheat and winter barley seed in the UK, but it has been shown to cause germination and emergence losses in infected spring barley seed lots of susceptible varieties where they have been sown untreated. Other *Fusarium spp.* including *F.culmorum*, *F.avenaceum* and *F.poa* have been regularly recorded on cereal seed harvested in the UK and although *F.culmorum*, especially, is known to be associated with seedling symptoms in warmer soils these species have not been shown to cause the very visible and significant seedling losses associated with *M.nivale* infection in wheat. *M.nivale* and *S.nodorum* are

known to have the potential to cause significant seedling losses when heavily infected wheat seed is sown untreated. The other pathogens are much less important and probably contribute very little to cereal seedling death.

High infection with *M.nivale* and *S.nodorum* has usually been associated with wheat seed produced in the west and north of Britain, in areas where rainfall at flowering is high. Richardson (1986) recorded *M.nivale* infection only at low levels in his 4 year study of stocks of certified seed so confirming the earlier findings of Hewett (1965). *M.nivale* did not become a significant problem in Scottish wheat seed until the area grown increased to 100,000 hectares to meet the needs of distillers and, consequently, interest in producing seed locally increased .

A surprising result of this study is the higher levels of *M.nivale* infection recorded on wheat seed harvested in England in 1992 and 1993 than might have been expected from previous reports and experience (Hewett 1965; Richardson 1986.). Reeves and Wray (1994) confirmed the relatively high levels of infection in wheat seed tested in the OSTs for England and Wales in 1992 and 1993.

In this study *M.nivale* infection was significantly higher on English than on Scottish harvested wheat seed in both 1992 and 1993, when infection levels were generally high, but lower than on Scottish seed in 1994, when levels were much lower. Certified seed appeared to be more heavily infected than farm-saved seed in 1992 but in 1993 and 1994 there was no significant difference. Given that inoculum of *M.nivale* is probably common in cereal crops and that weather at flowering influences seed infection differences would be expected between regions but not between certified and farm-saved seed.

In this survey infection levels were higher than might have been expected for English produced wheat seed. Significant proportions of stocks had more than 20% of seeds infected in 1992 and 1993 (Figures 2 and 3), a level of infection which could have led to seedling losses had seed been sown untreated. In contrast, in 1994 7% of Scottish seed but only 1% of English seed was infected at this level. These differences probably reflect differences in rainfall patterns during seed development.

It is difficult to say at what level of seed infection *M.nivale* will cause significant seedling losses and whether these will result in yield or quality losses. Much will depend on seed bed temperatures, the seed rate and subsequent crop growth. Winter wheat has considerable potential to tiller to compensate for low seedling numbers and many crops may be able to tolerate significant seedling losses.

We have presented data for stocks with more than 5%, 20% and 50% infection. Without seed treatment infection of 50% has been known to cause yield losses when seed has been sown untreated. At 20% infection seedling losses may be significant but in some circumstances may not result in yield loss. At 5% infection seedling loss will probably be negligible.

S.nodorum infection was higher in 1994 and 1993 than in 1992 but a very small proportion of samples had more than 20% of seeds infected in these years. During the period of the survey *S.nodorum* was much less frequent than *M.nivale* as a wheat seedling pathogen. Nevertheless, *S.nodorum* seems to be on the increase. During the 1980s it was very rarely recorded in UK winter wheat seed.

T.caries, *U.nuda*, *D.graminea* and *D.teres*

Inoculum for seed infection usually originates from diseased plants within crops but spores of *D.graminea*, *D.teres*, *U.nuda* and, to a lesser extent, *T.caries* can be transmitted relatively short distances from neighbouring infected crops. Spores of *T.caries* can be transmitted between seed lots in contaminated harvesting and processing equipment.

Plants that develop leaf stripe or loose smut symptoms result only from infected seed. This is usually the case also for *T.caries* but recent evidence suggests that, in some circumstances, infection can also result from soil-borne inoculum. *D.teres*, in contrast, can survive on stubble debris and volunteers, and plants can become infected from wind blown spores. Infection can spread between plants during the growing season and, in practice, seed-borne inoculum of *D.teres* is probably not very significant in terms of disease development compared with other sources of inoculum.

Although controlled by systemic seed treatments and through standards in Seeds Regulations, loose smut has frequently been recorded, at low levels, in UK farm-saved and certified seed. Increases in infection levels have usually been associated with the increased use of susceptible varieties and the development of strains of the fungus resistant to fungicides.

D.graminea and *T.caries* were effectively controlled for very many years by the widespread use of organomercury seed treatments and during the 1970s and 1980s were rare in UK cereals. An upsurge in leaf stripe in 1990, especially in Scottish spring barley, was due to the development of strains of the fungus resistant to organomercury and the increase in bunt in East Anglia was associated with untreated farm-saved seed and, occasionally, with infection from soil-borne inoculum.

In the present study between 25% and 50% of all winter wheat stocks tested each year had some bunt contamination which was, generally, at very low levels and relatively few wheat stocks were sufficiently heavily contaminated for bunt to develop to significant levels in the field if the seed had been sown untreated. English produced seed was more heavily contaminated than Scottish seed in 1992 but there was no difference in 1993 or 1994 and farm-saved seed was more heavily contaminated than certified seed in 1993 and 1994. A single broken bunt ball was found in only one sample and very few samples had more than 10 spores per seed. The relationship between seed contamination and bunt development is not well known principally because, until recent years, bunt has been very rare.

However, the data from this survey show that contamination at low levels is not uncommon. It is not clear whether this seed contamination reflects occasional bunted ears in wheat crops, infected volunteer plants or contamination from harvesting or processing equipment. Bunt has the potential to multiply rapidly between seasons and a significant proportion of these stocks would present risks if the seed were saved and sown untreated in successive years.

Loose smut has been rare in UK wheat for a number of years and tests for *U.nuda* in wheat were not made during this survey. Loose smut was more common in winter barley than in spring barley and infection occurred more often and at higher levels in farm-saved seed than in certified seed. A small proportion of certified seed lots failed to meet the 0.5% standard in seeds regulations but a higher number of farm-saved seed stocks were infected at this level. In 1992 25% of farm-saved winter barley had more than 0.5% infection. Certified seed is

clearly not free from loose smut infection and where infected seed is multiplied on farm without a systemic fungicide there is a risk that infection will increase to a point where yield may be affected. The more often a seed stock is multiplied in the absence of treatment and the more susceptible the variety the greater is the risk of high seed infection.

In this study seed stocks were less often infected with *D.graminea* and infection was at lower levels than Cockerell *et al* recorded in 1990 and 1991 (Cockerell, *et al*, 1995). Spring barley was more frequently infected than winter barley, but there was no consistent pattern suggesting higher infection in farm-saved seed compared with certified seed. Leaf stripe was not recorded at levels that would result in yield loss. Nevertheless, the low levels of infection in a small proportion of stocks highlight the risk of disease multiplication if seed were to be multiplied in the absence of an effective treatment.

5.2 CONCLUSIONS

- Cereal seed-borne pathogen levels have shown no significant increase as a result of the withdrawal of organomercury in 1992.
- The survey data show inoculum of *T.caries*, *U.nuda* and *D.graminea* to be present at low levels on UK cereal seed; there is real potential for these pathogens to cause significant crop losses if they are not properly managed.
- Infection with *M.nivale* is weather dependant and levels vary from year to year and between areas of production reflecting rainfall patterns during seed development.
- *M.nivale* was common on winter wheat seed during the survey period and a significant number of samples were infected at levels that would have affected seedling establishment if the seed had been sown untreated.
- Occasional samples of barley (especially of farm-saved seed) were infected with *U.nuda* at levels that would have affected yield.
- *D.graminea* was not recorded at levels that would have affected crop yield.
- Spores of *T.caries* were present on a significant proportion of winter wheat seed samples. Further work is needed to determine the significance of contamination levels. In the majority of samples tested contamination was not at levels that would have caused significant crop loss.
- *C.sativus* was most often recorded on spring barley; infection was strongly associated with varietal susceptibility.
- The incidence of *S.nodorum* was low during the period of the survey but infection increased in 1994.
- A high proportion of winter and spring barley seed did not carry significant seed-borne infection; sowing these samples untreated would probably not have resulted in economic loss.

CHAPTER 6 REFERENCES

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