ANNUAL REPORT YEAR 2

HORTICULTURAL DEVELOPMENT COUNCIL

Calabrese: Factors controlling symptom development in bacterial spear rot (FV/104)

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INDEX

1. PRACTICAL SECTION FOR GROWERS

KEY RESULTS

1. The causal organisms of spear rot in the UK have been identified and confirmed for the first time. The disease is caused by *Pseudomonas* and *Erwinia* bacteria which are naturally present on the surface of the heads.

2. There was no difference in mineral content, including nitrogen and boron, between diseased and healthy heads, thus we could not link disease with nutrient deficiency.

3. A simple method which may be used by growers for the early detection of rot-causing bacteria is under development and has given promising results.

4. Although spear rot incidence is related to the presence of water on the heads, we have found no clear relationship of disease with rainfall. Of greater importance however, is the length of the dew period, and this is a consequence of favourable temperature conditions.

OVERVIEW

Over the years we have tested, and continue to test, various products for spear rot control, some not commercially available in the UK, and we have not found any "wonder cures". The answer to spear rot control lies in a managed approach, and the development of resistant cultivars. In the absence of the latter in the near future, the aim of the project is to examine approaches to disease control which can be implemented now.

For this, it has been necessary to carry out some research into the cause of spear rot in the UK and the effects of the weather on disease; despite the importance of the disease it was not known at the start of the project whether spear rot was really caused by a bacterial pathogen or was physiological - e.g. boron deficiency, as some growers believed. As a result of the HDC work, we now know that bacteria **are** responsible for the disease and this has led us to look at testing the crop for the early presence of disease-causing bacteria. The weather plays a role here too, and it is important to know what conditions lead to disease occurrence. Whilst we are not able to manipulate the weather, if we are able to tell early enough that pathogenic bacteria are present, and that the weather at this time is conducive to disease, then growers can be ready to act by applying copper sprays and harvesting as soon as practicable. We know from previous work at SAC, funded by the HDC, that copper sprays are more effective if applied **early** in head development so that pathogenic bacteria do not get a chance to multiply. Our work in the coming year will be particularly targetted at early detection of disease and at understanding how the environment affects disease - for this we need to analyse the considerable field and laboratory data already collected over two growing seasons - so that growers might be able to forecast if and when disease will occur.

SUMMARY OF RESULTS TO DATE

Spear rot was shown to be caused by two types of bacteria, *Erwinia* and *Pseudomonas*, although the latter is more important. Both are naturally-occurring soil- and water- borne bacteria which contaminate the plants, and ultimately the heads, predominantly by rain splash.

A simple test was developed to determine the presence of these disease-causing organisms in the growing crop. Young spears from commercial crops were kept in tied polythene bags and subjected to an environment with daily periods of high and low temperatures. After around 4 days the spears developed soft rot symptoms if the organisms were present. The results agreed with the subsequent development of the disease in the original crop. Controlled environment experiments and environment records from trial crops had shown that spear rot is favoured by temperature changes which give rise to substantial dew periods. Incubating the spears in polythene bags for alternate periods at two contrasting temperatures e.g. in a domestic refrigerator and a warm kitchen, simulates these conditions. Further work is continuing in order to confirm the reliability of this method as a grower self-use diagnostic.

Questionnaires mailed to growers of calabrese in England and Scotland in 1993 revealed that **Marathon** was the most extensively grown variety in 1992. **Shogun**, **Greenbelt** and **Caravelle** were also popular. There were several points of interest with respect to the incidence of spear rot during the 1992 growing season:

1) Marathon and Greenbelt suffered fewer losses due to spear rot than did Shogun. Caravelle was the most susceptible variety in this survey.

2) In these reported crops, the average loss across the season due to spear rot in England and Scotland was around 29%.

3) Spear rot incidence in 1992 was highest in September and October, and all reported crops in Scotland were affected in October. The levels of disease at this time caused 60% of the reported crops to be lost in both Scotland and England.

4) The incidence of spear rot at these sites was not necessarily associated with increased rainfall, irrigation at heading, higher levels of nitrogen or whether the crop was grown in an exposed or sheltered position.

2. INTRODUCTION

Spear rot is a major disease of calabrese in the UK but despite this, little is known of its biology and the factors which lead to disease. The actual causal organism(s) of the disease in the UK has never been confirmed. Anecdotal evidence from growers suggests that a number of environmental factors can encourage disease such as high temperature, high humidity and nutrient deficiency but there have been no controlled studies on this.

The project aims to identify the causal organism(s) in the UK and to study the factors which initiate and encourage disease. Without some progress in these fundamental areas it will not be possible to design and implement effective control measures.

The research has initially focussed upon the isolation of bacteria from diseased calabrese in the field and the subsequent identification and demonstration of their pathogenicity. To facilitate this, immunodiagnostics have been developed in conjunction with HRI Wellesbourne. The interaction of environment with disease is being studied by monitoring field crops and by controlled environment experiments. A questionnaire was mailed to growers of calabrese in England and Scotland in 1993 requesting information on disease occurrence. Results of these areas of research are presented in this report.

3. MATERIALS AND METHODS

3.1. <u>Isolations of bacteria, isolate identification and response to antisera</u>

Isolations were made from healthy and diseased field grown spears from the 1992 growing season. Initial determinations were made of numbers of fluorescent, non-fluorescent and pectolytic bacterial colonies per gram fresh weight of spear buds. Colonies of differing morphology were selected and grown on plates to confirm purity. Isolates were identified using standard biochemical identification procedures of LOPAT and O/F tests and they were further characterised with respect to their surfactant ability and response to antisera from pathogenic isolates.

3.2. <u>Pathogenicity tests</u>

72 isolates sampled from field grown spears in 1992 and then characterised as in Section 3.1. were also tested for pathogenicity. Sterile lints soaked in either a 10^8 bacterial suspension per ml or sterile distilled water (negative controls) were applied to the surface of glasshouse-grown spears cv Shogun in sterilised 'Magenta GA7' vessels. The sealed vessels, containing sponge collars to support each spear, were incubated at 20°C day/ 10°C night with a 16h photoperiod. Positive controls (a known pathogenic *Erwinia carotovora* subsp. *carotovora* isolate) were also incorporated into each assay. Symptoms on the spear were scored at 5 days after incubation using the following criteria: 0 = healthy; 1 = watersoaked; 2 = watersoaked and soft; 3 = a brown rot; 4 = a black rot.

3.3. <u>Chemical control trials</u>

3.3.1. Field trials, 1992

Plants of cv Skiff were planted out in June 1992 at a site in the Tay valley near Dundee. Plant and row spacings were 25cm and 50cm respectively and plots of 48 plants were replicated 3 times. The trial was treated with fertiliser and pest control chemicals as per normal commercial practice and was irrigated daily from heading. In September, 2 applications, 7 days apart, of either Kasumin liquid, Kasuran WP (bactericides containing the antibiotic Kasugamycin) or Cuprokylt were applied with hand-held sprayers at rates of 2 l/ha , 800g/ha and 5000g/ha respectively in 600 litres of water/ha with wetter (Agral). Control plots were left untreated. The trial was assessed for spear rot symptoms 2 weeks later.

3.3.2. *In vitro* assays

Glasshouse-grown spears, cv Skiff, in 'Magenta' vessels were sprayed to run-off with the following treatments, a) 4 different yeast extracts known to induce immunity to certain plant pathogens, b) oil of Thyme, c) 'Maxicrop' seaweed extract, d) a polymer and e) Cuprokylt. All treatments contained wetting agents. The vessels were incubated for 24h as in Section 3.2. and lints soaked in either a 10^8 suspension of the pathogenic isolate 5038 (IVb, a *Pseudomonas fluorescens-putida* sp.), or sterile distilled water as a control, were then placed on the surface of the spears and the sealed vessels re-incubated and spears scored for spear rot symptoms as in Section 3.2.

3. 3. 3. Field trials, 1993

The treatments in Section 3.3.2. were applied to cv Skiff at the Sustainable Farming Initiative trial site in Elgin. Spears were inoculated using lints and polythene bags were placed over each spear and sealed with rubber bands. Symptoms were scored on 9/8/93.

3. 4. <u>Spear rot development in crops</u>

3. 4. 1. Environmental monitoring of commercial crops

Thermohygrographs were placed in commercial crops at Blairgowrie (Perthshire), Montrose (Angus), Carmyllie (Angus) and Errol (Perthshire). Raingauges were sited at Blairgowrie and Montrose. The thermohygrographs were regularly calibrated on-site and charts from these and the raingauges were collected weekly from 26/4/93 to 19/10/93.

3. 4. 2. Incubation of spears from commercial crops

From the monitored commercial crops (see Section 3.4.1.), a sample of 12 immature spears about 2.5cm in diameter was collected on a weekly basis (starting 2/8/93) and sent by post to arrive at SAC Edinburgh the following day. The spears were incubated in 'Magenta' vessels as in Section 3.2. except that sterile lints soaked only in sterile distilled water were used.

3. 4. 3 Environmental monitoring and spear rot development at a trial site

Breaks of Shogun and Skiff were planted out under cage-netting in May, June, July and August, 1993. The design was of a split-plot type and included a treatment with black polythene mulch to prevent splash-infection from possible soil-borne inoculum. Each split-plot contained 210 plants at 18cm spacings and 34cm between rows. Soil samples were taken for analysis from the trial site before planting. Delta T environmental monitoring equipment was set up in the crop to record surface wetness, air temperature, % relative humidity (RH), wind direction and rainfall. A photographic record was kept of the site. Throughout the growing season the crop was monitored for the appearance of spear rot. After maturity, soil and plant material was removed for analysis of mineral and nitrogen content.

Mature spears in the third break were harvested over 3 weeks, classified as healthy or diseased/ damaged due to spear rot or frost and figures obtained of average spear weight.

3. 5. <u>Controlled environment experiments</u>

Glasshouse-grown spears of Skiff and Shogun were exposed to differing continuous temperature regimes and periods of surface wetness. The spears were supported in sealed 'Magenta' vessels and surface wetness was simulated by the application to the spear surface of sterile lints impregnated either with a bacterial suspension of the pathogenic isolate 5038 or distilled water. After 3 to 6 days the lints were removed and the spears re-incubated in the sealed vessels for a further 48h. Spear rot symptoms were scored as in Section 3.2..

3.6. Grower questionnaire

257 questionnaires (Appendix 1) were sent to growers throughout the U.K. in January and February 1993 with requests for information from the 1992 growing season.

4. RESULTS

4. 1. Isolate identification and characterisation

101 representative isolates were chosen for identification, 72 were fluorescent pseudomonads, 2 were erwinias and 27 remain unidentified non-fluorescent organisms. The majority of the fluorescent pseudomonads belonged to groups IVa (19), IVb (12) and Vb (15). 8 isolates were from the Va group, 1 from the Ia group and the remainder gave atypical responses to LOPAT tests (Appendix 2). The surfactant ability of isolates and also their response to antisera raised to pathogenic isolates 1065 (an atypical *Erwinia carotovora* subsp. *carotovora* from 1991) , 1015 (*Pseudomonas putida*, biotype B, 1991) and 5067 (an *Erwinia carotovora.* subsp. *atroseptica* sp. from 1992) was variable, with no trend with respect to groupings, and with the antisera showing cross-reactivity with erwinias and pseudomonads.

4. 1. 2 Pathogenicity tests

From the 72 isolates characterised in Section 4.1. , 15 were pathogenic giving a brown or a black rot . Eight of these pathogenic isolates belonged to the *fluorescens-putida* complex (IVb group), 3 were from the IVa group, 1 isolate was a Vb, 1 gave atypical LOPAT reactions and 2 were *Erwinia* spp.

Most of the pathogenic isolates were pectolytic and surfactant positive, the exception being the erwinias and 2 other isolates which were pectolytic positive and surfactant negative and one isolate which was negative to both criteria. The antisera showed cross-reactivity with pathogenic and non-pathogenic strains. Two of the IVb isolates which were particularly aggressive, namely 5038 and 5049 were then sent to HRI, Wellesbourne to raise further antisera.

4. 2. Incubation of spears fromcommercial crops

The earlier samples, i.e. end of July, received from commercial crops (Section 3.4.2.) generally developed only watersoaking but toward the end of the season (October) many spears developed full spear rot symptoms. The assays proved effective at a) confirming the presence of pathogenic organisms on healthy heads in a crop already known to have slight disease incidence either in that crop, or in an adjacent crop and, b) demonstrating the presence of potential rot-causing organisms in a crop in which disease then occurred shortly after.

None of the field samples from spears collected at the end of the season gave a positive reaction to antisera in slide agglutination tests with extracted sap.

4. 3. <u>Chemical control trials</u>

4. 3. 1. Field trials, 1992

The results from trials with the antibiotic Kasugamycin are expressed in Table 1 as a percentage of the crop affected.

<u>Table 1</u> <u>Disease (%) on field spears treated with the antibiotic Kasugamycin</u>

Treatment	rot	watersoaking	brown*	Total unmarketable	Marketable
Kasumin liquid	58.3	18.5	2.8	79.6	20.4
Kasuran WP	33.3	21.3	13.9	68.5	31.5
Cuprokylt	25.7	23.1	23.3	72.2	27.8
Control	55.7	18.9	7.3	81.9	18.1
SED +/-	16.96	5.12	8.4	15.53	15.53

* These spears were still turgid and appeared to have dried out after watersoaking

Overall, the addition of copper afforded the best control; plants treated with cuprokylt or kasuran (kasugamycin + copper) had less disease than those from both the untreated control and kasugamycin only (kasumin liquid); here more than 50% of the spears were rotten. Generally, more spears were marketable from the treated plots but not in significantly greater numbers.

4. 3. 2. *In vitro* assays

None of the pre-treatments afforded any protection from subsequent infection by the pathogenic isolate. Micrographs taken using low temperature scanning microscopy (LTSEM) showed that the structure of the spear surface was such that immersion into the polymer was probably necessary for adequate cover.

4. 3. 3. Field trials, 1993.

It was not possible to determine the effect of the pre-treatments in Section 3. 4. 2. in the field. The method of retaining the lints on the spears by enclosing the heads in polythene bags caused overheating which damaged the spears.

4. 4. <u>Spear rot development in crops</u>

4. 4. 1. Monitored commercial crops

In all sites from which environmental data was collected, spear rot was evident towards the end of the season (early October) However, at Montrose and Errol, spear rot also appeared in July and in early August. Work is in progress to analyse the trends in %RH, rainfall and temperature which gave rise to these outbreaks. A comparison will be made with the earlier oubreaks of disease which occurred at the

Montrose site in 1992. Initial assessments suggest that disease develops after, or during, a sustained period of over 90% RH after a temperature inversion which would give a substantial dew period.

4. 4. 2. Trial site

No spear rot occurred on the first planting. Spears of Skiff from this planting showed some slight water-soaking which developed no further when incubated in 'Magenta' vessels and sap from spears in this planting gave negative reactions to antisera.

Spear rot appeared on 27/9/93 on Skiff in the second planting in plots without mulch. Water soaking appeared in Shogun in the unmulched plot 2 days later but rotting was not apparent in this plot until 7/10. This was also the date when spear rot appeared in the mulched plot of Skiff. The spears of Shogun planted through mulch did not show rotting sympoms until 4 days later, i.e. 11/10. The overall incidence of disease was as follows: Skiff (no mulch) 12 rotted heads; Skiff (mulched) 5 rotted heads; Shogun (no mulch) 5 rotted heads; Shogun (mulched) 2 rotted heads. Sap from healthy and diseased/damaged spears in this planting gave a negative response to antisera.

Spear rot appeared in the third planting on 20/10 (Table 2).

Table 2 Spear rot in third planting

Treatment	Total no. of heads	% mature heads	% spear rot [1] mature	% spear rot [1] immature	mean % spear rot
Shogun + mulch	178	30.3	20.4	10.3	15.3
Shogun - mulch	158	14.6	53.2	25.4	39.3
Skiff + mulch	171	2.3	31.2[2]	15.7	23.4
Skiff - mulch	192	0	-[3]	35.3	35.3

[1] using disease index

[2] sample size only 4

[3] no mature heads

Spears grown through mulch matured earlier and there was approx. 50% less spear rot in these plots. Skiff was more susceptible than Shogun and this became more evident as Skiff matured.

The mature heads were harvested from the third planting on 3/11, 11/11 and 17/11/93, and average spear weights from the total harvest were obtained for each variety and treatment (TABLE 3).

Table 3 Total weight of spears (g) harvested from the third planting (totals from 5 rows/treatment)

	SKIFF		SHOGUN	
	+ mulch	- mulch	+ mulch	- mulch
HEALTHY				
total weight	941.23	375.32	636.7	1295.1
(no. of spears)	(20)	(16)	(46)	(49)
Average spear weight	26.87	23.46	35.58	26.4
DISEASED/ DAMAGED				
total weight	3630.68	3092.1	2159.56	1240.72
(no. of spears)	(114)	(116)	(91)	(80)
Average spear weight	31.85	26.66	23.73	15.51
Total yield	4571.91	3467.4	3796.25	2535.77
Overall average spear weight	34.12	26.27	27.71	19.66

Overall, spear weights were low but there was a higher average spear weight from plants that were grown through mulch (Table 3). The majority of the spears of Skiff were diseased with spear rot or damaged due to frost , only 20 out of a total of 134 unmulched were healthy (i.e. only 940g out of a total of nearly 4.6 kg), and only 17 out of a total of 132 mulched were healthy (i.e. 375.32g out of a total of nearly 3.5 kg). On average, about 13% of the total number of spears of Skiff were healthy as against 36% of Shogun.

There was no difference in nitrogen or mineral content of tissue of mulched and unmulched plants of Shogun and Skiff.

Detailed records are available of environmental conditions leading up to these spear rot outbreaks. These are currently being analysed and correlated with environmental data collected from selected commercial crops.

4. 5. Controlled environment experiments

To date, spears have been exposed to constant temperatures of 10, 15, and 20°C whilst in contact for varying lengths of time with lints impregnated with the pathogenic isolate. Spears of Skiff with 2, 3, 4, and 5 days contact with the pathogenic isolate at a constant 20°C had watersoaked tissue which showed some soft rot under the pieces of lint. Spears of Shogun given the same conditions showed watersoaking only after 3, 4 and 5 days. No spears of either variety developed full spear rot symptoms. When spears of Skiff incubated at a constant 15°C were exposed to the pathogenic isolate for 4, 5, and 6 days some developed a brown or a black rot. Watersoaking only was evident on Shogun under these conditions. Of the spears grown at a constant 10°C, only Skiff exposed to the pathogenic isolate for 6 days gave any spear rot symptoms, a brown rot on 2 out of 4 spears. The heads of Shogun remained healthy throughout as did those of Skiff up to, and including, 5 days contact with the pathogen.

4. 6. Growers questionnaire

45 completed questionnaires were received from Scotland (21)and England (24) . The areas represented were Fife (14 replies), Lincolnshire (12), Norfolk (8), Lothians, Borders, Angus, and Perthshire (7) and Lancashire, Derbyshire and Cambridgeshire (4). Overall, this represented around 277 breaks from the 1992 growing season, 101 from Scotland, 176 from England and covered 18 varieties. Marathon was the most extensively grown variety (144 breaks), then Shogun (46), Greenbelt (30) and Caravelle (15). The other varieties represented were Cruiser (8 breaks), Arcadia (6), Regilio and Lazer (5 breaks each), Citation, Corvet, and Packman (3 breaks each), Skiff and Sumosun (2 breaks each) and Dixie, Emerald City, Legend, Southern Comet and Topgreen with one break of each.

The periods when spear rot appeared in crops in Scotland and England and the estimated average loss to spear rot each month is represented in Figures 1 and 2. The disease appeared first in July but losses the following month were the lowest over the spear rot period. Thereafter, disease levels increased until they reached a peak in October with the same percentage loss (approx. 60%) recorded from both Scotland and England (Figures 1, 2). The overall loss to spear rot was 26.7% in England and 32.1% in Scotland giving an average loss of around 29.4%. This equates to a loss last year of around 13,950 t. marketed output with an average value of £9, 577,904 (Basic Horticultural Statistics, 1993, HMSO).

From the figures supplied, Caravelle was the most susceptible variety (mean 37% loss) followed by Shogun (26.3% loss), Cruiser (19% loss) , Arcadia and Marathon where around 14% was lost to spear rot. However, these figures may be influenced by the earliness of each variety.

The average monthly rainfall figures taken from questionnaire returns are given for both Scotland and England in Figure 3. The results show that July and August in England, and August and September in Scotland, were the wettest months.

There was no significant effect on spear rot incidence related to whether the crop was exposed or sheltered. Most crops were reported as being exposed and this did not reduce disease when compared with sheltered crops.

Covers were only used on 9 breaks out of the 277 and were only used in the early part of the season when there was no spear rot (Figures 1, 2).

In England only 22 breaks were irrigated compared to 62 in Scotland. Where crops were irrigated during heading (5 breaks in England, 34 in Scotland), 3 breaks developed the disease in England and 10 in Scotland.

Ten breaks were sprayed with copper in Scotland and complete control was not achieved; the average loss to spear rot in sprayed breaks was 38.2%. In England, 32 breaks were treated; no disease occurred in 7 of these and in the remainder losses due to spear rot averaged around 47.6% .

The amount of nitrogen applied to the crop did not appear to predispose the spears to infection; breaks with disease in Scotland averaged an application rate of around 227.5 kg/ha , those without disease had 206.25 kg/ha of nitrogen applied. In contrast, in England these figures were 200 kg/ha and 216.25 kg/ha respectively.

5. CONCLUSIONS TO DATE

5. 1. The pathogen(s)

The organisms capable of causing spear rot were generally pectolytic and surfactant positive, mostly pseudomonads belonging to the *Pseudomonas putida/fluorescens* complex. In addition to the pectolytic pseudomonads, erwinias were also implicated in the disease. This is in agreement with results from 1991 where a mixture of pseudomonads and erwinias were also found and these included a pathogenic isolate confirmed as *P. putida.* Work is in progress to determine whether any of the remaining non-fluorescent isolates are pathogenic.

5. 2. Diagnostic methods for spear rot

5. 2. 1. Antisera

Presently, the antisera tested have shown cross-reactivity to both pathogenic and non-pathogenic isolates and pseudomonads and erwinias. In addition, because all reactions to sap from spears were negative, it would appear that these at least cannot be used to diagnose the presence of spear rot pathogens. Two new antisera have recently been raised to two aggressive pseudomonads collected in 1992 and these will also be tested.

5. 2. 2. Incubating field spears

Incubating field spears was a good practical indicator of the presence of pathogenic bacteria in the growing crop (Section 4.1.3). The application of this method in a more simplistic form may be a promising diagnostic for self-use by the grower, e.g. incubating spears in sealed polythene bags for about 3 days in a warm place with nightly periods of refridgeration to ensure the presence of free water on the spear surface. If positive, subsequent action would then depend upon knowing whether the environmental conditions conducive for disease development had occurred. Work is now in progress to try to define these conditions.

5. 3. Mulching to reduce the incidence of spear rot and to advance maturity

A black polythene mulch advanced the maturity of spears, increased the average spear weight and reduced the overall incidence of spear rot. The latter suggests that either, a) the organisms responsible may be resident in the soil and/or weed species in the crop, or b) that the spears grown through mulch are less susceptible. This requires further clarification. In addition, further work should determine whether planting through mulch would result in sufficient economic benefit to the grower in terms of a significant yield increase to more than cover the extra costs involved.

5. 4. Environmental conditions conducive to disease

5. 4. 1. Controlled environment experiments

Work to date suggests that a period of dew formation is essential to disease development under normal conditions. Results using constant temperatures, in which dew periods cannot occur, have given variable results. Symptoms were more reproducible in the pathogenicity tests where differing day/night temperatures were used.

5. 4. 2. Field conditions

Work is in progress to describe the environmental patterns that occurred before disease appeared in the crop and no conclusions can be drawn so far.

5. 5. Questionnaire

Growers' answers dispelled some of the anecdotal theories about factors which predispose the crop to disease. Generally, spear rot was more prevalent towards the end of the growing season but at this time the amount of recorded monthly rainfall was declining (Figure 3). Also, whether the crop was irrigated at this time, or had higher levels of nitrogen, or was in a sheltered stand did not seem to unduly influence the outcome. The higher levels of disease in October probably reflected in part, a) the inherent susceptibilty of the particular cultivars in the ground at this time, e.g. Shogun was not shown to be particularly resistant in 1992 (Section 4.6.), and b) the persistence of a film of water on the spear surface which may result from either high rainfall or a temperature inversion leading to dew formation. In the case of crops in 1992 in October, dew formation is the most likely cause of the high incidence of disease.

Copper sprays gave only limited control and growers comments suggested that successful control requires additional information: the presence of the pathogen in the growing crop (self-use diagnostic), and the occurrence or otherwise of periods conducive to disease (analysis of weather data), would ideally contribute towards meeting a set of criteria upon which the timing of sprays could be judged. This would form the basis of an economic integrated control management programme.

NAME: ADDRESS:

TEL:

Field no.	Date of harvest	Variety	Planted or drilled?	Sheltered/ exposed	Covers: yes/no	Total Nitrogen applied: units/acre or kg/ha	Was irrigation applied: 1) after establishment, 2) only at heading, or 3) both	Time of day irrigated (am, midday,pm) and approx daily amount (in or cm)	Were copper sprays applied at heading?	If a wetter was used please state which	Spear rot: yes/no	Estimate % yield loss to spear rot
1												
2												
3												
4												
5												
6												
7												
8												
9												

Rainfall each month:

If you used copper sprays at heading did you consider them worthwhile? YES/NO

Use more sheets if necessary

ISOLATE NUMBER	SOURCE	ID. (LOPAT)	ANTISERUM 1065	1015	5067	SURFACTANT ABILITY	PATHOGENICITY
5000	**Montrose**	**IVb**	S	-	S	+	**3**
5002	Montrose	+ + - + +	S	S	-	+	2
5003	Montrose	+ - + - +	-	-	S	+	1.25
5004	Montrose	IVb	+	-	+	-	1
5006	Montrose	IVb	-	S	-		2.25
5007	**Montrose**	**Vb**	+/S	S	S	+	**3.5**
5008	Montrose	IVa	+/S	-	-	-	1
5009	Montrose	IVb	+/S	-	-	+	2
5012	Montrose	+ - - - -	-	-	-	+	1.75
5013	Montrose	- - - + -	S	-	-	-	1.25
5014	Montrose	- + + - +	-	S	-	-	1
5015	Blairgowrie	Vb	+/S	S	S	+	1.25
5017	**Blairgowrie**	- + - - -	S	S	S	-	**3**
5018	Blairgowrie	IVb	S	S	S	-	2.25
5019	Blairgowrie	Va	-	S	S	++	1
5020	Blairgowrie	Va	-	S	-	-	1.5
5021	Blairgowrie	Ia	S	S	-	-	1
5022	Blairgowrie	IVa	S	-	-	+	2.5
5023	Blairgowrie	IVa	-	S	S	++	1.5
5024	Blairgowrie	Vb	S	+/S	S	++	1
5026	Blairgowrie	IVa	S	S	-	++	2.25
5027	Carmyllie	Vb	-	+	-	++	1
5028	Carmyllie	- - - - -	+	S	+/S	-	1.25
5030	Carmyllie	- + - - -	S	S	S	-	2.25
5031	C. Huntly	IVa	-	S	S	++	1*
5034	C. Huntly	IVa	-	S	-	++	2.75
5035	**C. Huntly**	**IVb**	+	+	+/S	+	**3.75**
5036	C. Huntly	Vb	+	S	+	-	2
5037	C. Huntly	IVa	+	S	+	++	2.25
5038	**Alyth**	**IVb**	+	-	S	+	**4**
5039	Alyth	Va	+/S	S	S	++	2
5040	**Alyth**	**IVa**	-	-	-	+	**3**
5041	Alyth	+ + + - -	S	-	S	+	1.25
5042	Alyth	IVa	-	-	S	+	0.75
5045	Alyth	IVa	-	-	S	+	2.5
5046	Alyth	+ - + - +	S	S	-	-	2
5047	C. Huntly	Va	-	-	S	-	1
5048	C. Huntly	Vb	S	-	-	++	1*
5049	**C. Huntly**	**IVb**	S	S	+	++	**4**
5050	C. Huntly	Vb	S	S	+/S	++	1.25
5051	C. Huntly	IVa	-	-	S	++	2.25
5055	**C. Huntly**	**IVb**	+/S	S	S	+	**4**
5056	C. Huntly	IVb	+/S	S	S	++	1.25
5057	C. Huntly	Vb	+/S	S	S	++	1*
5061	C. Huntly	Vb	+/S	S	S	-	2.5
5062	C. Huntly	- + + + +	+	+	S	+	2.5
5063	C. Huntly	Vb	+	S	+/S	+	2.5
5064	**C. Huntly**	**IVb**	S	-	+/S	++	**3.5**
5066	C. Huntly	+ - - - -	S	S	-	-	1.75
5066ii	**C. Huntly**	**Erwinia sp.**	-	S	-	-	**4**
5067	**C. Huntly**	**Erwinia c. a.**	+	S	+	-	**4**
5069	C. Huntly	Vb	S	-	-	-	1*

cont./

1992 ISOLATES

ISOLATE NUMBER	SOURCE	ID. (LOPAT)	ANTISERUM 1065 1015 5067	SURFACTANT ABILITY	PATHOGENICITY
5072	C. Huntly	IVa	- S -	++	2.25
5073	C. Huntly	Vb	+/S - S	++	2.25
5075	**C. Huntly**	**IVa**	+/S - -	+	**3**
5076	Carmyllie	Va	- - +/S	+	0.75
5077	Carmyllie	Va	S - S	+	1.5
5078	Carmyllie	Va	S S -	+	2
5079	Carmyllie	IVa	S - S	+	1.75
5080	**Errol**	**IVb**	**S - S**	-	**3.25**
5082	Errol	IVa	+/S - S	+	2.25
5083	Errol	IVa	S - -	+	2.25
5085	**Errol**	**IVb**	S - S	+	**3.5**
5086	Errol	Vb	S - -	+	2.25
5089	Errol	Va	S - -	+	1
5090	Errol	+ - - - +	S - S	-	0.75
5091	Errol	Vb	S - -	-	1.5
5093	Bush	IVa	- - -	+	1
5096	Bush	- + + + +	S - -	++	1
5098	**Bush**	**IVa**	- S S	-	**3.5**
5100	Bush	Vb	- S S	+	1
5101	Bush	IVa	- - -	-	1.25