CALABRESE: CONTROL OF SPEAR ROT AND DOWNY MILDEW

Susan Robertson and Terry Brokenshire

Scottish Agricultural College,
West Mains Road,
Edinburgh,
EH9 3JG
UK

(formerly East of Scotland College of Agriculture)

Report on Project FV8 prepared for the Horticultural Development Council, July 1987-December 1988.
Report prepared June 1992.

For correspondence concerning this report, contact Dr. Rob Harling, Scottish Agricultural College, Edinburgh.

INDEX

1. GENERAL INTRODUCTION

Calabrese is an increasingly popular vegetable in the United Kingdom. In England and Wales the area grown has increased in the past seven years from 750 to 3,734 hectares (1990 figures). Although covering a smaller area, the increase in Scotland during the same period has been even greater, from 250 hectares in 1983 to 837 in 1990. Climatically the east of Scotland is well suited to the production of high quality calabrese. Unfortunately the cooler and wetter conditions also favour two diseases which attack the heads (spears).

Bacterial spear rot is an important disease of calabrese in Scotland. It occurs every year to a greater or lesser extent, depending on the type of growing season. In wet seasons all crops are at risk and large areas are ruined. In drier seasons the disease is seen only on the late harvested crops, from late August to October. Bacterial spear rot has more recently become a significant problem in England in wet seasons. Affected spears usually first have a water soaked appearance which is quickly followed by a soft brown rot (Hildebrand 1986). The shelf life of fresh produce from infected crops is drastically reduced and the freezing quality is poor. Two bacterial species have been consistently isolated from diseased spears in Scotland: *Pseudomonas marginalis* and *Erwinia carotovora* sub sp *carotovora* (Brokenshire & Robertson, 1986). The disease is not restricted to the United Kingdom: it has been recognised in Canada, the United States of America and Australia (Hildebrand 1986; Canaday *et al* 1987, Wimalajeewa *et al* 1987) where *Pseudomonas marginalis* and *Erwinia carotovora* sub sp *carotovora* and *Erwinia carotovora* sub sp *atroseptica* have been isolated from affected spears.

Downy mildew, caused by *Peronospora parasitica*, is a locally serious fungal disease of calabrese causing a significant reduction in produce quality through internal and external blemishes of the spears. The most serious financial losses occur when the full costs of harvesting apparently healthy spears are incurred, only for systemic infection causing internal discolouration to be discovered later. Early infection can also be damaging, resulting in loss of plant vigour and sometimes seedling death.

The Horticultural Development Council funded an eighteen month project from 1987 to 1988 at SAC Edinburgh aimed at the practical control of bacterial spear rot and downy mildew. Building on earlier work within SAC, a wide range of cultivars

has been screened in this current project for the two diseases, and several chemical programmes evaluated. In addition several laboratory and polythene tunnel based experiments were undertaken.

Results from these studies are given in this report.

2. GENERAL MATERIALS AND METHODS

A Spear assessment

Heads were harvested on a weekly basis when they exceeded 10 cm in diameter, or smaller if no further growth was able to take place. When further growth was possible without bolting taking place the spears were left until the following week before being cut. The heads were trimmed to a length of 125 mm and individually assessed for weight, disease, and in the case of variety trials, head shape and compactness. All spears were scored for the extent of downy mildew and spear rot infection.

A.1 Downy mildew assessment

Downy mildew infection of the spears was recorded as being either healthy, slight, severe or systemic depending on the extent of infection. Healthy heads showed no symptoms of infection. Slight infection was recorded when less than 2% of the area of the head was affected by mildew; severe infection when greater than 2% of the head was affected. Spears from plants suffering from systemic downy mildew infection showed a characteristic darkening of the vascular and parenchymatous tissue, revealed when the heads were sliced in half length-wise.

A.2 Spear rot assessment

The incidence and severity of spear rot were recorded based on a visual assessment of the percentage of head area affected. In addition the presence or absence of water soaked tissue was noted in order to determine whether watersoaking was a prerequisite for the development of rot.

Table 1: Abbreviations

H	Healthy
WS	Watersoaked
SR	Spear rot
DM	Downy mildew
SL	Slight
SEV	Severe
SYS	Systemic

B Assessment of downy mildew leaf infection in calabrese cultivars

The leaves of the plants in the 1987 downy mildew variety trial were assessed visually for symptoms of downy mildew infection on three occasions. The individual plots of each variety were scored for incidence of infection, noted as a percentage of infected plants within each plot, and severity as an approximate score within the range 0-20.

C Trial organisation

C.1 Direct- drilled trials

Trials were direct-drilled into raised beds to 4 cm spacing, with rows 46 cm apart. At approximately 2-4 true leaves, the trials were thinned to produce standard plots.

C.2 Transplanted trial

Seeds were sown into module trays (Hassy 308 cell), using SAI seedling module compost. On emergence seedlings were thinned to provide only one plant per module cell. At 2-4 true leaves the module trays were transferred from the glasshouse into a netted enclosure to harden off transplanting into standard design plots.

C.3 Plot design

Field trials were conducted at SAC's Castle Huntly Experimental Field Station near Dundee. Calabrese trials were conducted in raised beds. Each bed was divided into three plots running end to end with narrow access paths in between. Plants, whether direct drilled or transplanted were set into plots of forty eight plants, consisting of four rows of twelve plants. The rows were 46cm apart and plants within rows were approximately 23cm apart. The plot size was 1.84m x 2.76m.

This arrangement gives forty assessable plants with four guards at either end of the plot. At the edges of each trial a single row of guard plants was transplanted or drilled to protect the exposed edges of each plot. All trials treatments were randomised in blocks.

D Seed supplies

The generous assistance of the following seed companies is noted with thanks:

Asgrow International Corporation. 7000 Portage Road, Kalamazoo, MI 49001, USA
Asmer Seeds Ltd. Pinchbeck Road, Spalding, LIncolnshire, PE11 1QG, GB
Breeders Seeds Ltd. Summerwood Lane, Halsall, Ormskirk, Lancs. L39 8RQ. GB
Elsoms Seeds Ltd. (address as Asmer Seeds Ltd)
Nickerson Seeds Ltd. Rothwell, Lincoln, LN7 6DT. GB
Rijk Zwaan BV. PO Box 40, Burgmeester, Crezeelaan 40, 2678KX De Lier, Holland
Royal Sluis BV. PO Box 34, Unit 24, Marathon Place, Mosside Estate, Leyland, Lancs. PR5 3QT. GB
Sluis & Groot BV. PO Box 13, 1600AA, Enkhuizen, Holland
T Sakata & Co. CPO Box Yokohama No11, Yokohama, Japan 220-91
Takii Europe BV. Hoofdweg 19, 1424 PC De Kwakel, The Netherlands
Samuel Yates Ltd. Withyfold Drive, Macclesfield, Cheshire, SK10 2BE. GB

3. ISOLATION OF BACTERIA ASSOCIATED WITH SPEAR ROT

The aim of this experiment was to follow the development of pectolytic bacteria on the leaves and spears as they matured. Initially we planned to quantify the numbers of pectolytic bacteria but because the numbers isolated were very low, detection, rather than enumeration became of more importance.

Materials and Methods

Media

1. Logans media for the isolation of pectolytic microorganisms

a) Basal layer
Simmons citrate agar 23g
CaCl 3g
Crystal violet 0.001g
Distilled water 1l

Heat to dissolve, sterilise 15 minutes at 121^{O}C. When cool adjust pH to 6.8 and pour shallow plates.

b) Overlay
Sodium polypectate 2g

Mix the pectate with a minimum volume of absolute alcohol to produce a smooth paste. Make up to 100ml with distilled water, add EDTA, adjust pH to 7.4 and autoclave 121^{O}C for 15 minutes. When cool pour a thin layer over the citrate agar. Dry overnight prior to use.

2. Stewarts pectate media

a) Basal layer
McConkeys agar 5.2g
CaCl 0.4g
Distilled water 75ml

Heat to dissolve, sterilise 110^{O}C for 10 minutes. When cool pour plates.

b) Overlay
as for Logans medium

3. King's Medium B

Peptone(oxoid) 20g
Glycerol 10g
K_2HPO_4 ..... 1.5g
$MgSO_4.7H_2O$ 1.5g
Agar 15g
Distilled water 1l

Adjust pH to 7.2. Sterilise 15 minutes at 121^{O}C. Pour plates when cool.

4. Tryptone soya agar

Prepared according to the manufacturers instructions.

Plant material

Calabrese leaf material was collected from several sites in Fife and in Chirnside, Berwickshire from approximately the 8 leaf stage to button formation. At head development spears were collected in addition to the leaves.

The leaf/spear tissue was weighed and placed in a Stewards stomacher bag, nine times the fresh weight of quarter strength Ringers solution was added to the sample and the sample was stomached for 4 minutes. Serial ten-fold dilutions of the processed sample were prepared. A range of dilutions were plated onto Logans and Stewarts pectate media for pectolytic bacteria, onto King's medium B for fluorescent *Pseudomonas* and onto tryptone soya agar for a total count of phylloplane bacteria. The plates were incubated for up to five days at 25^{O}C (the pectate media were placed in a sealed polythene bag to maintain high humidity).

Results and Discussion

The prevailing weather conditions, dry and breezy, at the time of harvest led to little spear rot initiation in the monitored crops. Pectolytic *Pseudomonas* and *Erwinia* spp were isolated from occasional spears. Initial biochemical characterisation of the bacterial isolates was carried out to allow a general classification following methods outlined by Lelliot and Stead (1987). The bacteria were identified as *Pseudomonas marginalis* and *Erwinia carotovora* sub sp *atroseptica*.

Example

The set of samples described below yielded a high number of pectolytic bacteria from the microbial isolation, an unusual occurence in the sampling process. The crop was sampled on the 3rd August 1988 and four samples collected:

A Slightly watersoaked
B Initiation of rot visible on some florets
C Established rot
D Established rot

Table 2: Bacteria isolated from calabrese spears

Organisms (colony forming units ml^{-1})		
Sample	Pectolytic	Fluorescent
A	5×10^6 (*Pseudomonas*-type pits)	5×10^6
B	1.1×10^6 (*Erwinia*-type pits) 7.8×10^7 (*Pseudomonas*-type pits)	1.5×10^7
C	1.5×10^8 (*Pseudomonas*-type pits)	1.1×10^8
D	1.5×10^8 (*Pseudomonas*-type pits)	3.6×10^7

Pectolytic, fluorescent *Pseudomonas* spp were isolated from the watersoaked sample (A). Pectolytic *Erwinia* and *Pseudomonas* spp were isolated from the sample showing initial symptoms of spear rot (B). Bacteria from the two rotted spears (C,D) were found to be predominantly pectolytic, fluorescent *Pseudomonas* spp.

In a later experiment, we attempted to establish whether these isolates could cause disease, but the experiment was not successful (see later).

Sample spears taken from several sites showed similarly mixed microbial populations; with pectolytic *Pseudomonas* spp predominating with occasional *Erwinia* spp isolated.

4. SPEAR ROT SUSCEPTIBILITY IN CALABRESE CULTIVARS

Introduction

The two trials described in this section were established to assess variation in the susceptibility of calabrese cultivars to bacterial spear rot in the field. If cultivars with a low susceptibility to disease could be identified, these would be of particular use in areas prone to spear rot and at certain high risk periods during the growing season. Observation of commercial crops by advisers in previous years had indicated that some cultivars, grown in the south east of Scotland area, were badly affected by spear rot. Prior to 1987 there was no specific information available on the varietal susceptibility of calabrese to spear rot.

The study of spear rot development in the field is hampered by the unpredictability of outbreaks of the disease. The disease is more common in early summer and autumn crops when the weather is cool and damp and trials could have been organised around these times but if the weather was dry, spear rot may not develop and trials would be wasted. In order to reduce this risk, and encourage disease development, facilities for overhead irrigation were installed at Castle Huntly and were used throughout the season to maintain adequate soil moisture and to produce a humid environment in the leaves and developing spears.

The calabrese cultivars used in the trial were donated by several seed companies (see General Materials and Methods) and comprised of cultivars commercially available in the UK as well as several breeding lines destined for the UK market. The cultivars screened over the two seasons differed, enabling a larger range of cultivars to be studied. Several identical cultivars were incorporated into both trials in order that more accurate comparisons of the cultivars grown in different trials, and different years, could be carried out.

Results and Discussion

Cultural details of the 1987 and 1988 spear rot cultivar trials are given in Tables 3 and 4. Results from the trials are given in Tables 5,6 and 7.

Table 3: Spear rot field trial 1987: Trial diary

26th June:		5cwt 20:14:14 NPK base dressing.
29th June:		Treflan.
22nd July:		Transplanted modules Birlane granules as spot treatment 2.3-6.7 kg per hectare.
30th July:		Ramrod, Dacthal.
10th August:		Top dressed, 68 units nitrogen
24th August:		Dursban drench 2.1 l/ha in 2250 l/ha water then irrigated 1.5cm (fire brigade action against cabbage root fly)
28th August:		Toppel (caterpillar control).
11th September:		Diptera 80 (caterpillar control)
Harvest dates	1	9th September
	2	15th September
	3	22nd September
	4	28th September
	5	6th October
	6	12th October
	7	19th October
	8	27th October
	9	10th November

Table 4: Spear rot field trial 1998: Trial diary

5th April:		5cwt 20:14:14 base dressing
20th April:		Dursban drench modules
25th April:		Transplanted modules Draza
26th April:		Yaltox Ramrod/Dacthal
24th May:		Top dressed 84 kg N/ha
10th June:		2.5 cm water
15th June:		2.5 cm water
22nd June:		Toppel-blossom beetles.
Harvest dates.	1	21st June
	2	28th June
	3	5th July
	4	12th July
	5	19th July
	6	25th July

Table 5: Spear rot field trial 1987: Susceptibility of calabrese cultivars to Spear rot

Variety	Percentage Incidence		
	Healthy	Watersoaked	Spear Rot
Cape Queen	30	30	40
Citation+	13	36	51
Clipper*	64	33	4
Corvet	34	38	28
Cruiser	24	40	36
Emperor	23	45	32
Futura	27	46	27
Green Belt+	31	23	46
Green Duke	28	36	35
Green Valiant*	57	30	13
Hi Crown*	85	13	2
Kayak	34	28	32
Laser	51	32	16
Marathon	30	29	41
Midas+	27	27	46
Packman	42	37	20
Premium Crop+	8	8	85
Prominence	35	24	41
RS1	22	41	38
Samurai*	58	42	4
SG 1	39	28	32
Shogun	28	65	6
Skiff+	15	39	46
MEAN	35.2	33.5	31.4
SED ±	3.72	2.42	3.97

* Cultivars with a high percentage of healthy heads .
+ Cultivars showing a high incidence of spear rot.

Table 6: Spear rot field trial 1988: Susceptibility of calabrese cultivars to spear rot

Cultivar	Percentage Number of Heads		
	Healthy	Watersoaked	Spear Rot
Bacchus	60	32	8
Charade	97	2	1
Corvet	25	33	42
Dixie	77	21	2
Exp91	69	26	5
Gem	22	30	48
Green Duke	41	24	35
Orion	69	23	8
Parasol	62	11	27
Prima	65	15	20
Pinnacle	71	16	13
Premium Crop	16	9	75
RS8602	45	23	32
Samurai	96	4	0
Shogun	87	3	10
Skiff	41	35	24
Sprinter	37	17	46
SY150	12	40	48
S83.1	63	21	16
Toro	21	31	48
Wintergarden	55	32	13
XPH5168	41	39	20
XPH5167	25	64	11
Zeus	61	21	18
MEAN	52.4	23.8	23.8
SED ±	5.06	2.84	3.93

Spear rot is an important disease in the production of clean, high grade calabrese spears. The disease reduces crop quality and increases the probability of bacterial spoilage occurring during storage, processing and marketing. The presence of water soaked tissue on the surface of the spears will also reduce the quality of the harvested spears. The importance of water soaking in the development of spear rot is not known but it is considered a prerequisite because it can indicate a reduction or loss of the protective wax from the tissue surface, or water infiltration of the sub epidermal tissue - all factors which can predispose the plant to bacterial and fungal infection. In 1987 and 1988 the incidence of spear rot in the trials was high: 70-75% of the spears harvested from the cultivar Premium Crop were affected by bacterial rot. Statistically significant differences were found in the occurrence of spear rot in the distinct calabrese cultivars, indicating that the cultivars vary in their susceptibilities to damage by bacterial spear rot.

Several cultivars produced a higher than average percentage of healthy spears: Clipper, Charade, Dixie, Green Valiant, Hi Crown and Samurai. These cultivars, although yielding a large number of spears which showed no symptoms of rot at harvest, do not have complete resistance to bacterial spear rot: some heads harvested were damaged by bacterial rot and many of the spears were affected by water soaking.

Anecdotal evidence suggested that the susceptibility of calabrese cultivars to bacterial spear rot was related to the shape of the calabrese spear: in particular how domed or flat the spear was. It was suggested that the shapes of the spear would differ in their ability to impede the run-off of water, some shapes retaining moisture therefore increasing the possibility of spear rot damage. In the first season of spear rot trials the heads were scored on a scale of 1-9 (1 = flat head, 9 = extremely domed head). These values were averaged to give each variety a head shape score which could then be related to the incidence of spear rot in the field. Many of the screened cultivars were found to have head shape scores in the range 3-4; only a few showed more pronounced head shapes ie a particularly flat or more domed head. Table 7 below details the more extreme head shape cultivars.

Table 7: The shape of calabrese cultivar spears

Head shape	
Flat (score)	Domed (score)
Orion (2)	Kayak (6)
Premium Crop (2)	Charade (5)
Mercedes (2.5)	Dixie (4)
XPH5168 (2)	Hi Crown (5)
Zeus (3)	Shogun (5)

All of the more domed cultivars showed a lower than average incidence of spear rot. The flatter cultivars varied in their susceptibilities to spear rot ie Orion, below average spear rot incidence; Premium Crop, above average and XPH5168 and Zeus average. These results suggest that the more domed cultivars may be more resistant to spear rot: to be conclusive more very domed cultivars would have to be examined, (this may be more possible now as very domed cultivars are becoming more popular).

The results for the flatter cultivars were inconsistent which may suggest that head shape is only one part of a syndrome which governs spear rot susceptibility.

5. DOWNY MILDEW SUSCEPTIBILITY IN CALABRESE CULTIVARS

Introduction

Peronospora parasitica is a serious fungal pathogen of calabrese capable of causing a reduction in healthy yield through reduced spear quality, reduced seedling vigour and leaf damage.

A range of calabrese cultivars was screened for susceptibility to downy mildew. Two replicated trials were conducted, one trial in each of two seasons (1987 and 1988). In addition an unreplicated trial intended as a demonstration to local growers was conducted in 1988. In addition to spear disease assessment during the first season's trials, the cultivars were visually assessed at regular intervals throughout their development for downy mildew infection of the leaf canopy.

The calabrese cultivars used in these two field trials were donated by several seed companies (see General Materials and Methods) and comprised of cultivars commercially available in the UK and also several breeding lines destined for the UK market. The cultivars screened in the two seasons differed, enabling a larger range to be studied. Several identical cultivars were incorporated into both trials in order that more accurate comparisons of the cultivars grown in different trials, and different years, could be carried out.

Results

Cultural details of the 1987 and 1988 downy mildew cultivar trials are given in Tables 8 and 9. Results from the trials are given in Tables 10, 11 and 12.

Table 8: Downy mildew field 1987: Trial diary

21st July:		Standard base dressing.
23rd July:		Transplanted module raised plants; applied birlane granules. Irrigated 2.5cm water.
30th July:		Ramrod, Dacthal
10th August:		68 units nitrogen; irrigated 2.5cm.
24th August:		Dursdan drench 2.1 litres per hectare in 2250 litres water then irrigated 0.5" (fire brigade action against cabbage root fly)
28th August:		Toppel (caterpillar control)
11th September:		Diptera 80 (caterpillar control).
Harvest dates.	1	9th September
	2	15th September
	3	22nd September
	4	28th September
	5	5th October
	6	12th October
	7	19th October
	8	27th October
	9	5th November
	10	17th November
	11	25th November

Table 9: Downy mildew field trial 1988: Trial diary

27th July:		750 kg/ha 15:15:20 base dressing 33 fl oz Treflan.
24th August:		Modules transplanted after drenching with Dursban. Ramrod/Dacthal. Yaltox. Draza.
2nd September:		Gapped up
14th September:		Toppel
26th September:		60 units N.
Harvest Dates.	1	9th January
	2	23rd January

Table 10: Downy mildew field trial 1987: Susceptibility of calabrese cultivars to downy mildew

Cultivar	Percentage downy mildew incidence H	SL	SEV	SYS
Cape Queen	80	15	4	1
Citation	84	16	0	0
Clipper+	31	32	36	2
Corvet+	40	32	28	0
Cruiser	94	5	1	0
Emporer	71	28	1	0
Futura	89	10	0	0
Green Belt	75	14	10	1
Green Duke	86	14	0	0
Hi-crown	88	12	0	0
Kayak+	15	21	50	14
Laser	93	7	0	0
Marathon	93	7	0	0
Midas	48	45	6	0
Packman	92	8	0	0
Premium Crop	76	21	2	1
Premium Crown	66	33	1	0
Prominence	91	8	1	0
RS1	79	14	3	4
Samurai	83	16	1	0
SG1	79	12	6	3
Shogun	90	10	0	0
Skiff+	13	14	18	54
Mean	72	17	7	3
SED	6.8	5.6	4.3	1.4

+ Cultivars severely infected by downy mildew in the field

Infection key:

H	Healthy
SL	Slight
SEV	Severe
SYS	Systemic

Table 11: Downy mildew field trial 1988: Susceptibility of calabrese cultivars to downy mildew

Cultivar	Percentage disease incidence H	SL	SEV	SYS
Citation	82	10	3	4
Corvet	64	23	14	0
Emperor +	39	28	32	0
Futura +	48	35	17	0
Gem	62	24	14	0
Green Valiant	94	6	0	0
Hi Crown	55	6	6	0
Kayak	61	16	23	0
Laser	60	33	5	2
Marathon	83	11	7	0
Mercedes +	45	19	32	2
Orion	65	24	12	0
Packman	92	8	0	0
Parasol +	36	27	29	2
Prima +	46	45	9	0
Samurai	96	3	1	0
Skiff	73	10	13	3
SY153	66	16	17	0
SY17	85	11	2	1
SY158	64	20	15	0
Zeus	79	14	3	0
MEAN	68	17	12	1
SED	15.9	11	7.8	1.6

+ Cultivars severely infected by downy mildew in the field.

Discussion

In each of the two seasons, the incidence of downy mildew infection was approximately 30% of the total harvested heads. The response of individual cultivars to downy mildew varied from highly susceptible to moderately resistant.

The reaction of some of the more susceptible cultivars in the trials differed over the two seasons, probably due to the different weather and planting conditions: the 1988 trial was slightly later in the year than the 1987 trial. Cultivars found to be heavily infected by downy mildew included the commonly grown cultivars Skiff and Corvet which produced only 13% and 40% healthy spears respectively. The cultivars Kayak, Emperor, Parasol, Mercedes and Clipper were severely affected.

Cultivars of calabrese which were less susceptible to downy mildew were more consistent in their reaction over the two seasons. Marathon, Shogun, Prominence, Packman, Citation and Cruiser showed a low incidence of downy mildew infection in the field trial.

Table 12: Incidence and severity of downy mildew infection of leaves in calabrese cultivars

Variety	Date of assessment 2/9/87 I	S	24/9/87 I	S	19/11/87 I	S	%Healthy Spears
Cape Queen	20	T	100	2	100	38	80
Citation	0	0	50	1	70	2	84
Clipper	100	22	100	12	100	35	31
Corvet	53	3	100	5	100	16	40
Cruiser	86	2	100	5	100	14	94
Emporer	87	8	100	5	100	30	71
Futura	66	1	100	4	100	21	89
Green Belt	100	10	100	3	100	28	75
Green Duke	100	8	100	16	100	12	86
Hi-crown	100	16	100	18	100	50	88
Kayak	92	6	100	9	100	16	15
Laser	50	1	100	3	100	2	93
Marathon	83	2	100	4	100	22	93
Midas	100	8	100	4	100	27	48
Packman	100	2	100	11	100	37	92
Premium Crop	93	2	100	3	100	33	76
Premium Crown	100	9	100	8	100	42	66
Prominence	93	2	100	6	100	17	91
RS1	86	2	100	4	100	43	71
Samurai	100	3	100	4	100	13	83
SG1	78	1	100	4	100	35	79
Shogun	83	6	100	9	100	7	90
Skiff	70	T	100	1	100	11	13

I= Percentage incidence of infected plants
S= Percentage of leaf surface affected by downy mildew
T= Trace: less than 1% of leaf surface affected by downy mildew

The incidence and extent of downy mildew infection and sporulation on the leaves were recorded for the cultivars incorporated in the 1987 trial (Table 12). Studying these parameters showed that some cultivars were very susceptible to leaf infection by *P.parasitica* and suffered extensive leaf canopy damage due to the growth of the pathogen. It became clear, however, that susceptibility to leaf infection did not necessarily mean that the harvested spears would be severely affected by downy

mildew. The canopies of the cultivars Clipper, Green Belt and Hi-Crown were badly infected but only Clipper produced a high proportion of infected spears. Conversely the canopies of some other cultivars were less affected ie Cape Queen, Citation, Laser, Skiff and Futura but Skiff produced very badly infected spears. In general the cultivars which showed less leaf infection did produce more non-infected spears.

Unreplicated cultivar trial 1988

This trial was established as a demonstration to show all the screened cultivars together at one location (Tables 13 and 14), in order that local growers could decide which cultivars could fit the specifications laid down by buyers for calabrese. Unfortunately bad weather delayed planting and the trial maturity was delayed. A single harvest was carried out and then the trial was abandoned because its unreplicated nature limited its use for screening purposes and the low number of plants in each plot added a further restriction. Data should therefore be interpreted with caution.

Table 13: Downy mildew and spear rot unreplicated trial 1988: Trial diary

9th August:		Standard base dressing.
26th August:		Transplanted module raised plants. Ramrod. Dacthal. Yaltox. Draza.
14th September:		Toppel 10 (250ml/ha)]
26th September:		75kg per hectare nitrogen as nitram.
9th January:		Harvested and assessed spears.
Harvest dates	1	9th January

Table 14: Percentage disease incidence and severity in the harvested spears.

Cultivar	No. Heads	Percentage disease incidence: Spear rot H	WS	ROT	Downy mildew H	SL	SEV	SYS
Bacchus	16	100	0	0	50	6	44	0
Cape Queen	12	67	16	17	83	17	0	0
Clipper	16	0	56	44	0	0	38	62
Citation	18	78	16	6	78	22	0	0
Corvet	13	92	8	0	46	54	0	0
Cruiser	14	79	14	7	93	7	0	0
Dixie	16	62	19	19	0	6	69	25
Emporer	13	77	23	0	23	38	38	0
Exp-91	18	89	5	6	100	0	0	0
Futura	16	12	63	25	56	32	12	0
Gem	16	56	6	38	38	50	12	0
Green Belt	15	93	7	0	33	7	60	0
Green Duke	10	40	40	20	60	40	0	0
Gr.Valiant *	7	100	0	0	100	0	0	0
Hi-crown *	7	43	57	0	71	29	0	0
Kayak	9	100	0	0	56	44	0	0
Laser	11	91	9	0	91	9	0	0
Marathon *	2	50	50	0	100	0	0	0
Mercedes	12	83	17	0	50	33	17	0
Midas *	8	100	0	0	100	0	0	0
Orion	9	11	45	44	77	22	0	0
Packman	20	25	55	20	60	25	15	0
Parasol	12	50	33	17	17	58	17	8
Pinnacle	11	73	9	18	18	36	45	0
Prima	17	41	24	35	41	35	24	0
RS1	17	6	29	53	6	41	41	0
RS8602 *	15	100	0	0	40	53	7	0
Samurai *	3	100	0	0	100	0	0	0
Shogun *	11	100	0	0	100	0	0	0
Skiff	5	100	0	0	60	20	20	0
Sprinter	15	7	26	67	20	47	33	0
SY150	19	53	31	16	37	47	16	0
SY1587	15	87	0	13	66	27	7	0
SY17	13	69	16	15	85	8	8	0
XPH5167	20	60	0	40	60	20	20	0
XPH5168	16	81	0	19	88	12	0	0
Zeus	16	69	31	0	69	31	0	0
83.1	18	100	0	0	100	0	0	0
Mean		67	18	14	60	24	14	2
SED		5.0	3.2	2.9	5.0	3.0	3.0	1.8

* Low number of harvested spears

6. CHEMICAL CONTROL OF BACTERIAL SPEAR ROT AND DOWNY MILDEW

A. Control of spear rot

Introduction

The trials reported here involved copper based fungicides which are known to have antibacterial properties. The trials were conducted in 1987 and 1988.

Materials and Methods

All trials were organised as replicated randomised blocks. Table 15 details the chemicals used in both the 1987 and 1988 spear rot and downy mildew trials. Tables 16 and 17 give cultural details from the bacterial spear rot trials. Table 18 gives details of the chemical application times and doses applied to the 1987 bacterial spear rot trial.

Table 15: Chemicals used in trials

Trade name	Active Ingredient	Main Supplier
Cuprokylt	Copper oxychloride (50% w/w)	Unicrop
Fungex	Cupric ammonium carbonate (8.2% w/w)	Hortichem
Kocide 101	Copper hydroxide (50% w/w)	Chiltern
Bronopol	Myacide AS	Boots
Bravo 500	Chlorothalonil (500 g/l)	BASF
Aliette	fosetyl-aluminium (80% w/w)	Hortichem
ESCA88F4	Confidential	
Parasol	Copper hydroxide (50% w/w)	M^{c}Kechnie
Panacide M	Dichlorophen (340 g/l)	Coalite
Polycote trio#	Metalaxyl, Iprodione, gamma HCH	Seedcote Systems
SL291	Metalaxyl/chlorothalonil	
Agral*	Alkyl phenol ethylene oxide (900 g/l)	ICI
Bond*	Synthetic latex (450 g/l)	Newman

* Adjuvants # Seed treatment

Table 16: Chemical control of bacterial spear rot trial 1987: Trial diary

26th June:		Base dressing, 750kg per hectare of 15:15:20 NPK fertiliser.
29th June:		Treflan 1.5 litres per hectare.
30th June:		Corvet direct drilled to a 7.5cm spacing. Birlane granules 70g/100m row.
2nd July:		Ramrod 9 litres per hectare. Dacthal 6 kg per hectare.
6th July:		Irrigated 2.5cm
13th July:		Dursban 1.4 litres per hectare (blossom beetle).
14th July:		Irrigated 2.5cm.
23rd July:		Irrigated 2.5cm.
28th July:		Irrigated 2.5cm.
5th August:		Thinned. Top dressed, 68 units N. Irrigated 2.5cm.
13th August:		Application of 4-6 leaf stage sprays.
27th August:		Application of "14 days later" sprays.
15th September:		Application of "button formation" sprays.
23rd September:		Application of "7 days later" sprays.
Harvest dates.	1	28th September
	2	7th October
	3	14th October
	4	21st October
	5	29th October
	6	12th November

Table 17: Chemical control of bacterial spear rot trial 1988: Trial diary

1st June:		625 kg/ha of 20:14:14 base dressing.
6th June:		Treflan. Direct drilled cv. Corvet 3cm apart, 4 rows 45cm effective. Yaltox (12.5 g per 10 meter row). Draza (5.5 kg/ha)
9th June:		Irrigated 2.5cm.
15th June:		Irrigated 2.5cm.
23rd June:		Irrigated 2.5cm.
29th June:		Application of 4-6 leaf stage spray.
7th July:		Hand weeded. Ramrod/Dacthal
27th July:		Top dressed 100kg N/ha.
5th August:		Toppel.
12th August:		"Button formed" spray.
22nd August:		"7 days later" spray.
Harvest dates.	1	30th August
	2	7th September

Table 18 : Chemical control of bacterial spear rot trial 1987: Chemical application times and doses.

Code	Treatment	Time of application			
		4-6 leaf stage	14 days later	button formation	7 days later
U	Untreated	-	-	-	-
A	Cuprokylt (5 kg/ha)	+	-	+	-
B	Cuprokylt (5 kg/ha)	-	-	+	+
C	Fungex (6.25 l/ha)	+	-	+	-
D	Fungex (6.25 l/ha)	-	-	+	+
E	Fungex (4.25 l/ha + Bond)	-	-	+	+
F	Fungex (6.25 l/ha + Bond)	-	-	+	+
G	Kocide 101 (1 kg/ha)	-	-	+	+
H	Bronopol (0.1%)	-	-	+	+
K	Bronopol (0.5%)	-	-	+	+
L	Aliette (3 kg/ha)	+	+	-	-
M	Aliette (3 kg/ha)	+	+	-	-
	+ Cuprokylt (5 kg/ha)	-	-	+	+

Treatments were applied by knapsack sprayer set at 2 bars pressure, medium nozzle in 600 litres per hectare water. The wetter "Agral" was used at 25 ml/100 litres water except where the sticker "Bond" was used at 100ml per 100 litres water. The trial was arranged as a randomised block with five replicates. For plot size, see General Materials and Methods.

Results

Results from these trials are shown in Tables 19 and 20.

Table 19: Chemical control of bacterial spear rot trial 1987: Incidence of spear rot on treated and untreated harvested spears.

Code	Percentage disease		
	Healthy	Watersoaked	Spear rot
U	5.8	64.4	29.8
A	2.6	73.0	24.4
B	6.2	78.0	15.8
C	2.4	73.2	24.4
D	5.8	74.4	19.8
E	2.6	76.0	21.4
F	1.8	71.6	26.6
G	13.8	66.6	19.6
H	2.6	66.6	30.8
K	1.8	61.2	37.0
L	0.6	68.8	30.6
M	4.8	79.6	15.6
MEAN	4.2	71.1	24.6
SED	4.04	5.65	7.28

Table 20 : Chemical control of bacterial spear rot trial 1988: Chemical application times and doses. Incidence of spear rot on harvested spears

Treatment		time of application			% Disease		
		4-6 leaf	button formed	7days later	healthy	water soaked	spear rot
U	untreated	-	-	-	25	24	51
A	ESCA88F4	-	+	+	49	27	24
B	ESCA88F4	-	+	-	51	13	36
C	ESCA88F4	-	-	+	47	35	18
D	Parasol (3kg/ha)	-	+	+	53	37	10
E	Panacide M (1%)	-	+	+	51	23	26
F	Kocide 101 (2.2kg/ha)	-	+	+	66	23	11
G	Cuprokylt (5kg/ha)	-	+	+	53	37	10
H	SL291 (2l/ha)	+	-	-			
	+Cuprokylt (5kg/ha)	-	+	+	57	23	19
MEAN					50.2	26.9	22.8
SED ±					3.65	2.68	4.54

All sprays: Water rate 600 litres/ha, wetting agent "Agral" at 25ml/100 litres water. Trial organised as a randomised block with 5 replicates.

Discussion

In 1987, when disease pressure was higher than in 1988, a two spray programme (at button formation and seven days later) of Cuprokylt gave a 50% reduction in spear rot, and a two spray programme of Kocide 101 gave a 33% reduction in disease. In 1988, the same programmes each gave an 80% reduction in disease. Parasol was also effective. An additional benefit of these treatments was a reduction in non-systemic downy mildew of the spears.

On the basis of these and earlier SAC trials, a Specific Off-Label Approval was applied for and granted for the use of Cuprokylt in calabrese to control bacterial spear rot MAFF No. 91/0696.

In the 1988 trial it was noted that slight phytotoxic effects (occasional dark flecks) were visible on the spears which had been treated with copper based fungicides. This may have been due to the warm, sunny weather during spear maturity, after the application of the button formation and seven days after button formation sprays.

Several non-copper bactericides were screened with limited success: Panacide M significantly reduced the incidence of spear rot in the 1988 trial but not as effectively as the copper compounds. In further trials in 1989 (results not shown) phytotoxic effects were noted on the plants as a result of Panacide M application.

B Control of downy mildew

Introduction

Downy mildew can affect produce quality through internal and external blemishes of the spear. Early infection of the crop can result in a loss of crop vigour and seedling death. Chemical control of downy mildew infection was targetted at two main stages: protection of the seedling and young plant and later in the maturing crop when the spears are developing. Two trials were conducted, one in 1987 and one in 1988.

Materials and Methods

Tables 21 and 22 give cultural details of the 1987 and 1988 trials. Table 23 gives details of the chemicals applied and the doses used in the 1987 trial.

Table 21: Chemical control of downy mildew, 1987: Trial diary

26th June:		Base dressing.
29th June:		Treflan.
14th July:		Direct drilled cv.Skiff 3" spacing. Birlane granules.
16th July:		Ramrod. Dacthal
12th August:		Thinned Top dressed, 68 units N.
21st August:		Spannet 2 litres per hectare in 1870 litres per hectare water to control cutworm.
24th August:		Dursban drench 2.1 litres per hectare in 2250 l/ha water. Irrigated 1cm (fire brigade action against cabbage root fly).
28th August:		Toppel (caterpillar control)
1st September:		Application of 4-6 leaf stage sprays
15th September:		Application of "14 days after" sprays.
22rd September:		Application of "21 days after" sprays.
29th September:		Application of "28 days after" sprays.
5th October:		Application of "button formation" sprays.
12th October:		Application of "7 days after" sprays
Harvest dates	1	17th November
	2	24th November
	3	30th November

Table 22: Chemical control of downy mildew, 1988: Trial diary

1st June:		625 kg/ha of 20:14:14 base dressing.
6th June:		Treflan.
22nd June:		Direct drilled cv. Skiff.
		Yaltox, Draza, Ramrod/Dacthal
		Irrigated 2.5cm water.
29th June:		"4-6 leaf stage" sprays.
6th July:		"7 days later" sprays.
27th July:		80 Units N.
5th August:		Toppel.
12th August:		"Button formed" sprays.
19th August:		"7 days later" sprays.
14th September:		Toppel
Harvest Dates.	1	15th September
	2	21st September

Table 23: Chemical control of downy mildew, 1987: Chemical application times and doses

Code	Treatment	Time of application					
		4-6leaf stage	Days after 4-6 leaf stage 14	21	28	button formation	7 days later
U	untreated	-	-	-	-	-	-
A	Aliette (3 kg/ha)	+	+	-	-	-	-
B	Cuprokylt (5 kg/ha)	+	+	-	-	-	-
C	SL291 (2 l/ha)	+	+	-	-	-	-
D	Fungex (6.25 l/ha)	+	+	-	-	-	-
E	Kocide 101 (1 kg/ha)	+	+	-	-	-	-
F	Aliette (3 kg/ha)	+	-	-	-	-	-
	+ SL291 (2 l/ha)	-	+	-	-	-	-
G	Aliette (3kg/ha)	+	-	-	-	-	-
	+ SL291 (2 l/ha)	-	-	+	-	-	-
H	Aliette (3 kg/ha)	+	-	-	-	-	-
	+ Sl291 (2 l/ha)	-	-	-	+	-	-
J	SL291 (2 l/ha)	+	-	-	-	-	-
K	SL291 (2 l/ha)	-	+	-	-	-	-
L	Aliette (3 kg/ha)	+	+	-	-	-	-
	+Cuprokylt (5 kg/ha)	-	-	-	-	+	+

All treatments were applied in 600 litres per hectare water using a knapsack sprayer set at 2 bars pressure with a medium nozzle. The spray additive "Agral" was used at 25ml per 100 litres water.

Results

Tables 24 and 25 show the incidence of downy mildew on harvested spears in the 1987 and 1988 trials.

Table 24: Chemical control of downy mildew, 1987: Incidence of downy mildew on harvested spears

Code	Percentage Disease			
	H	SL	SEV	SYS
U	31.2	24.7	16.1	28.1
A	57.0	10.3	11.6	21.1
B	50.2	10.0	19.7	20.1
C	62.1	16.6	12.0	9.2
D	45.1	19.5	11.2	24.3
E	38.5	21.6	21.8	18.1
F	65.3	16.4	8.4	9.9
G	79.9	9.6	7.7	2.7
H	80.7	10.3	8.3	0.7
J	38.5	21.7	15.2	23.9
K	57.7	12.5	15.5	14.3
L	57.2	10.7	11.1	20.9
MEAN	55.3	15.3	13.2	16.1
SED	7.89	4.15	3.94	5.67

Several of the treatments significantly reduced the incidence and severity of downy mildew infection; treatments coded A, B, C, D, F, G, H, K and L. The level of disease in the trial was very high, with 69% of the untreated spears showing symptoms of downy mildew infection; of these 28% were systemically infected. The highest level of control was produced by treatments incorporating Aliette and SL291 (treatments A, C, F, G, H, K, L). The contact fungicides, based on copper compounds, proved less effective under the severe disease pressure.

Table 25: Chemical control of downy mildew, 1988: Incidence of downy mildew on harvested spears

code	seed treatment	treatment	time of application 1	2	3	4	5	%healthy spears
U	nil	nil	-	-	-	-	-	1.7
A	A8005A	nil	-	-	-	-	-	4.4
B	Polycote trio	nil	-	-	-	-	-	1.4
C	A8005A	SL291 (2l/ha)	+	-	-	-	-	32.6
D	Polycote trio	SL291 (2l/ha)	+	-	-	-	-	41.6
E	nil	SL291 (2l/ha)	+	-	-	-	-	34.6
F	nil	Aliette (3kg/ha)	+	-	-	-	-	
		SL291 (2l/ha)	-	-	+	-	-	67.2
G	nil	SL291 (2l/ha)	+	+	-	-	-	
		Cuprokylt (5kg/ha)	-	-	-	+	+	83.3
H	nil	SL291 (2l/ha)	+	+	-	-	-	
		Parasol (3kg/ha)	-	-	-	+	+	92.8

Times of Application:

1 = 4-6 leaf stage
2 = 7 days after 1
3 = pre-button
4 = Button formed
5 = 7 days after 4

In this trial the seed treatments, A8005A and Polycote trio, had no significant effect on the incidence of downy mildew. A single early spray of SL291 (treatments C,D,E) reduced the incidence of downy mildew but not as effectively as either of the spray treatments combining two sprays of SL291 with later sprays of a copper fungicide (treatments G,H). The copper fungicides were applied to control spear rot but had the additional benefit of reducing the severity of downy mildew infection in the harvested heads.

Discussion

Chemical treatments to control downy mildew were very successful. Good protection of the young calabrese plants can be achieved by drenching modules with fosetyl-aluminium (Aliette). To prevent systemic infection of the spears, sprays must be applied at the 4-6 leaf stage and again one week later. Excellent control was obtained with a new co-formulated product based on metalaxyl and chlorothalonil. Overall incidence of downy mildew was lowest where metalaxyl sprays during vegetative growth were followed by applications of copper fungicides during spear development.

Seed treatments had no significant effect on the incidence of downy mildew in the harvested spears when tested in the 1988 trial.

7. POLYTHENE TUNNEL EXPERIMENTS

Introduction

Two experiments were conducted inside polythene tunnels at Castle Huntly. Plot size was 1.35 x 1.8m, consisting of 24 plants in four rows of six plants, at 15 x 45cm spacing.

1. Chemical control of downy mildew

Calabrese cv. Skiff was raised in Hassy modules (sown 14th August 1987, transplanted 24th September, drenched with Dursban prior to planting) and set into smaller plots in the tunnel. This trial involved weekly sprays of Bravo 500 (chlorothalonil) at 3l/ha, in 600l/ha water + Agral at 25ml per 100l water. The aim was to decide the optimum time for the application of chemical treatments to control *Peronospora parasitica* infection. Unfortunately the level of infection in this trial was so high that no variation between treatments could be determined.

2. Induction of spear rot by artificial inoculation

The aim of this experiment was to artificially induce spear rot. The trial was based on inoculation with suspensions of group IV *Pseudomonas* and *Erwinia carotovora* (both isolated from spears naturally infected and exhibiting symptoms of spear rot) onto cv.Corvet grown in the poly tunnel. Spears were initially spayed with water, Agral (25ml per 1000l water) or a suspension of fine carborundum powder. Bacterial suspensions were prepared by growing cultures overnight in nutrient broth, centrifuging at 9000rpm for 10 minutes and resuspending in quarter strength Ringers solution. The pellet was resuspended to produce a suspension of approximately $1x10^9$ cells per millilitre. Spear rot was produced on all the spears in the trial, including controls. Difficulties arose in the poly tunnel because of the inability to maintain constant temperature and humidity over the period of head development following inoculation.

8. THE INFLUENCE OF NITROGEN FERTILISER ON SPEAR ROT AND DOWNY MILDEW INCIDENCE

Introduction

Field observations of calabrese indicated that the application of high levels of nitrogen increased the incidence of disease. In a trial established to investigate this observation three cultivars of calabrese were grown under varied nitrogen regimes: from 125 kg/ha to 325 kg/ha.

Materials and methods

The three cultivars were direct drilled into plots which had received a base dressing of 125kg per hectare nitrogen in the form of an N:P:K fertiliser. Different levels of nitrogen as Nitram were applied as top dressings. The heads were assessed for downy mildew and spear rot at the successive harvests. The results are presented as healthy heads, ie free from both diseases.

Table 26: The influence of nitrogen fertiliser on spear rot and downy mildew incidence: Trials diary

1st June:		625 kg/ha 0f 20:14:14 NPK base dressing.
6th June:		Treflan.
16th June:		Yaltox.
		Draza.
17th June:		Irrigated 2.5cm.
23rd June:		Irrigated 2.5cm.
30th June:		Thinned to produce standard plots.
5th August:		Toppel.
14th September:		Toppel.
Harvest Dates.	1	7th September
	2	12th September
	3	21st September

Results and Discussion

Table 27: The influence of nitrogen fertiliser on spear rot and downy mildew incidence: Percentage healthy spears produced.

	Total Nitrogen Applied(kg/ha)			
	125	175	250	325
Hicrown	52	33	26	30
Premium crop	19	25	0	7
Kayak	0	0	3	2

This trial was affected by wire stem, quite severely in in some patches.

In Hicrown and Premium crop increasing the nitrogen application significantly decreased the percentage of healthy spears harvested. In the cultivar Kayak the disease level was so high that no trend could be observed.

9. SUSCEPTIBILITY OF CALABRESE SEEDLINGS TO DOWNY MILDEW

Introduction

The aim of these experiments was to correlate cultivar susceptibility to downy mildew at the seedling stage with the adult crop. A positive correlation would allow the possibility of screening cultivars at the seedling stage, with the advantages of speed and avoiding field trials.

Materials and methods

1. Isolation and maintenance of the pathogen

Peronospora parasitica was isolated from calabrese in field plots. The mildew was grown under controlled conditions in a cooled illuminated Gallenkamp incubator. The fungus was maintained on 10 day old seedlings of calabrese cv. Skiff grown in John Innes no 3 at 19± 1^{O}C under fluorescent lights and set at a 16 hour day. The mildew was passaged through the calabrese cv.Skiff twice prior to use.

2. Host material

The calabrese cultivars were grown in 6cm plastic pots under the conditions described above for ten days prior to inoculation with the pathogen. At this time the cotyledons of the seedlings had expanded but the first leaves had not emerged. One treatment consisted of five replicate pots of each cultivar, each containing approximately 25 seeds. Fifteen cultivars were screened at any one time, with the fifteen cultivars being randomised within individual plastic seedling propagators. The five propagators were then placed randomly in the incubator.

3. Inoculum preparation

A sporangial suspension was prepared by lightly brushing the sporangiophores off the surface of infected fifteen day old seedlings into sterile distilled water using a fine hair brush. This suspension was filtered through muslin and washed by repeated centrifugation and resuspension of the pellet in sterile distilled water. After three washes the pellet was resuspended to produce a suspension of approximately 1×10^5 sporangia per millilitre.

4. Inoculation of calabrese cultivars

On the day of inoculation the seedlings were misted with distilled water and returned to the propagators for 3 hours, after which time the seedlings were sprayed with the sporangial suspension until the cotyledons were coated with a film of liquid but no run-off had occurred. The pots of inoculated seedlings were then returned to the propagators and the edges of the tray were packed with damp paper tissue, and the propagators were sealed with plastic tape to maintain humidity. The seedlings were incubated for five days, under the previously described conditions, before disease assessment.

5. Disease assessment

The amount of sporulation and necrosis was assessed visually for each cultivar. An average reaction was determined for each pot and an overall mean for each cultivar was determined. Infection was assessed using a 0-4 scale shown in Table 28.

Table 28: Keys to sporulation and necrosis

Sporulation	Necrosis
0 = nil	0 = no symptoms
1 = sparse	1 = discrete necrotic flecking
2 = moderate	2 = small necrotic patches
3 = good	3 = necrotic patches beginning to coalesce
4 = heavy	4 = widespread necrosis

Results

The results are shown in Tables 29-31. Based on these results the responses of a selected range of calabrese cultivars at the seedling stage is compared with their responses from our field trials as adult plants in Table 32.

Table 29: *In vitro* susceptibility of calabrese seedlings: Experiment 1

Cultivar	Sporulation	Necrosis
Citation	2.5	0.5
Clipper	2	3.75
Corvet	2	1.5
EXP 91	2.5	1.25
Gem	2.25	2.5
Hi-crown	2.75	1.5
Parasol	3.5	0.5
Premium Crop	2.5	2.5
Samurai	2.5	2
Shogun	2	2.5
SY 150	3.25	1.5
Toro	2.25	2
XPH 5167	3	2
XPH 5168	0.5	3
83.1	2	1.25
Mean	2.36	1.88
SED±	0.18	0.23

Table 30: *In vitro* susceptibility of calabrese seedlings: Experiment 2

Cultivar	Sporulation	Necrosis
Corvet	2	4
Dixie	2.25	3
Gem	1	4
Kayak	2	3.5
Midas	1.5	3.5
Orion	2	4
Packman	3.5	4
Parasol	2.5	2.5
Prima	3.5	3
Prominence	3.5	2.75
RS 8602	1.5	3
SY 150	1	4
Skiff	2.75	4
Sprinter	1	2.75
Winter Garden	3	2
Mean	2.2	3.3
SED ±	0.23	0.17

Table 31: *In vitro* susceptibility of calabrese seedlings: Experiment 3

Cultivar	Sporulation	Necrosis
Bacchus	2.5	1.5
Cape Queen	2.5	1.5
Charade	1.5	0.5
Emperor	2	1.5
Green Belt	2	0.5
Green Valiant	3	0.25
Laser	3	0.5
Marathon	2	2
Prominence	3	2
SY 17	2.5	2
Zeus	2.5	1.5
Mean	2.4	1.25
SED ±	0.15	0.20

Table 32: A comparison of the response of calabrese cultivars to downy mildew infection at the seedling and adult plant stages

Cultivar	Reaction to downy mildew infection	
	Seedling stage	Adult stage
Laser	Susceptible	Moderately resistant
Parasol	Susceptible	Susceptible
Green Valiant	Susceptible	Resistant
Green Belt	Susceptible	Moderately susceptible
Clipper	Resistant	Susceptible
Corvet	Resistant	Moderately susceptible
Gem	Resistant	Moderately susceptible
Kayak	Resistant	Moderately susceptible
Midas	Resistant	Susceptible

Discussion

Investigations by Kluczewski and Lucas (1983) on the infection of different hosts by *P.parasitica* indicated that in susceptible hosts the pathogen is able to sporulate profusely with little necrosis of the host tissue. In more resistant hosts sporulation of the pathogen is limited and necrosis of the host tissue more widespread.

The calabrese cultivars screened in our experiments showed a range of reaction to downy mildew infection at the seedling stage: from highly susceptible (the cultivars Laser, Parasol, Green Valiant and Green Belt) to resistant (the cultivars Clipper, Corvet, Kayak, Gem and Midas).

Table 32 shows that the susceptibility of seedlings to downy mildew cannot be accurately compared to the incidence of downy mildew in the mature field grown crop, therefore limiting the use of a seedling assay for routine screening of calabrese cultivars.

10. CONCLUSIONS AND SUMMARY

This eighteen month project, funded by the Horticultural Development Council, has provided information on varietal susceptibility to, and the control of, bacterial spear rot and downy mildew in calabrese.

Significant differences in the susceptibility of calabrese cultivars to both spear rot and downy mildew were found. The cultivars Marathon, Shogun, Prominence, Packman, Citation and Cruiser showed a low incidence of downy mildew infection. Some resistance to bacterial spear rot was shown by the cultivars Clipper, Charade, Dixie, Green Valiant, Hi-Crown and Samurai. The cultivars commonly grown in Scotland at the time of the trials, Skiff and Corvet, were susceptible to spear rot and downy mildew in our field trials. The choice of more resistant cultivars by farmers, providing these cultivars met the required quality standards, would reduce the field losses due to bacterial spear rot and downy mildew.

Chemical control of the two diseases was also investigated. Chemical control of downy mildew was effective using Aliette (fosetyl-aluminium) and by using foliar sprays of the experimental product SL291 (metalaxyl/chlorothalonil co-formulation). Copper based fungicides were less effective for downy mildew disease control under high disease pressure. For control of bacterial spear rot we examined copper based fungicides; copper oxychloride (as Cuprokylt) applied as a two spray programme at button formation and seven days later gave 50-80% disease control. On the basis of these HDC funded trials and other SAC trials a Specific Off Label Approval was granted for the use of Cuprokylt to control bacterial spear rot. Other copper based fungicides gave a similar reduction in the incidence of spear rot in the field.

The influence of nitrogen fertiliser rates on disease incidence was briefly studied and it was found that high rates of nitrogen application promoted downy mildew and spear rot.

11. REFERENCES

Brocklehurst, T. F.; Lund, B. M. (1981) Properties of pseudomonads causing spoilage of vegetables stored at low temperature. *J. Appl. Bacteriol.* **50**: 259-266.

Brokenshire, T.; Robertson, N .H. (1986) Control of calabrese spear rot with copper fungicides. *Tests of Agrochemicals and Cultivars* **No7** *Ann. Appl. Biol.* **108**, *Supplement,* pp.52-53.

Canaday, C. H.; Mullins, C. A.; Wyatt, J. E.; Coffey, D. L.; Mullins, J. A.; Hall, T (1987) Bacterial soft rot of broccoli in Tennessee. *Phytopathology* **77**: 1712.

Cooksey, D. A. (1988) Reduction of infection by *Pseudomonas syringae* pv. tomato using a nonpathogenic, copper resistant strain combined with a copper bactericide. *Phytopathology* **78**: 601-603.

Cuppels, D.; Kelman, A (1974) Evaluation of selective media for isolation of soft-rot bacteria from soil and plant tissue. *Phytopathology* **64**: 468-475.

Dong, H.; *et al* (1987) Methods for examining the resistance of chinese cabbage cultivars to soft rot (Erwinia carotovora carotovora). *Scientia Agricultura Sinicia* **20**: 94-95.

Dowson, W. J. (1957) Plant diseases due to bacteria. *University Press, Cambridge.* 231pp.

Dowson, W. J.; Dillon-Weston, W. A. R. (1937) Soft rot of broccoli. *The Gardeners' Chronicle*. July, 1937.

El-Banoby, F. E.; Rudolph, K. (1979) Induction of water soaking in plant leaves by extracellular polysaccharides from phytopathogenic *Pseudomonas* and *Xanthomonas*. *Physiological Plant Pathology* **15**: 341-349.

Graham, D. C.; Harper, P. C. (1966) Effect of inorganic fertilisers on the incidence of potato blackleg disease. *European Potato Journal* **9**: 145.

Greenhalgh, J. R.; Mitchell, N. D. (1976) The involvement of flavour volatiles in the resistance to downy mildew of wild and cultivated forms of Brassica oleracea. *New Phytologist* **77**: 391-398.

Hildebrand, P. D. (1986) Symptomatology and etiology of head rot of broccoli in Atlantic Canada. *Can. J. Plant Pathol.* **8**: 350 (abstract).

Kikumoto, T.; Omatsuzawa, T (1981) Ecological studies on the soft rot bacteria of vegetables (15). Latent infection of chinese cabbage by soft rot bacteria in the field. *Bull. Inst. Agr. Res. Tohuko Univ.*. **32**: 27-35.

Kikumoto, T.(1983) Ecological studies on the soft rot bacteria of vegetables (17). Multiplication and movement of *Erwinia carotovora* subsp. *carotovora* in chinese cabbage cultivars. *Bull. Inst. Agr. Res. Tohuko Univ.*. **34**: 84-91.

Kikumoto, T.(1984) Ecological studies on the soft rot bacteria of vegetables (18). Multiplication of *Erwinia carotovora* subsp. *carotovora* in petioles of susceptible and resistant chinese cabbage cultivars. *Bull. Inst. Agr. Res. Tohuko Univ.*. **35**: 63-73.

Kikumoto, T.(1987) Ecological studies on the soft rot bacteria of vegetables (19). On the first diseased parts in chinese cabbage cultivars caused by the soft rotting bacteria in the field. *Bull. Inst. Agr. Res. Tohuko Univ.*

Kluczewski, S. M.; Lucas, J. A. (1982) Development and physiology of infection by the downy mildew fungus *Peronospora parasitica (Pers. ex Fr.) Fr.* in susceptible and resistant Brassica species. *Plant Pathology*. **31**: 373-379.

Kluczewski, S. M.; Lucas, J. A. (1983) Host infection and oospore formation by *Peronospora parasitica* in agricultural and horticultural Brassica species. *Transacations British Mycological Society*. **81**: 591-596.

Kontaxis, D. G.; Guerrero, P. (1978) Downy mildew epiphytotic on broccoli- a new disease in Imperial Valley, California. *Plant Disease Reporter.* **62**: 170-171.

Lelliot, R. A.; Billing, E.; Hayward, A.C. (1966) A determinative scheme for the fluorescent plant pathogenic pseudomonads. *J. Appl. Bact*. **29**: 470-489.

Lelliot, R. A.; Stead, D. E. (1987) Methods for the diagnosis of bacterial diseases of plants. *Methods in Plant Pathology* **2.** Blackwell Scientific publications. Oxford.

M.A.F.F. (revised 1984) Fire blight of apple and pear. L571

M.A.F.F. (1981) Propagating and transplanting vegetables. RB. 344.

Natti, J. J.; Hervey, G. E. R.; Sayre, C. B. (1956) Factors contributing to the increase of downy mildew of broccoli in New York State and its control with fungicides and Agrimycin. *Plant Disease Reporter.* **40**: 118-124.

Natti, J. J. (1958) Resistance of broccoli and other crucifers to downy mildew. *Plant Disease Reporter.* **42**: 656-662.

Natti, J. J.; Dickson, M. H.; Atkin, J. D. (1967) Resistance of *Brassica oleracea* cultivars to downy mildew. *Phytopathology* **57**: 144-147.

Shah, A.; Srivastava, K. K.; Roy, A. J.; Bora, S. S. (1985) Control of black rot disease of cauliflower by seed treatment. *Prog. Hort.* **17**: 72-74.

Stone, J. R.; Verma, P. R.; Dueck, J.; Westcott, N. D. (1987) Bioactivity of the fungicide metalaxyl in rape plants after seed treatment and soil drench applications. *Canadian Journal Of Plant Pathology.* **9**: 260-264.

Wang, T. M. (1949) Studies on the mechanism of resistance of cruciferous plants to *Peronospora parasitica*. **39**: 541-547.

Wimalajeewa, D. L. S.; Hallam, N. D.; Hayward, A. C.; Price, T. V. (1987) The etiology of head rot disease of broccoli. *Aust. J. Agric. Res.* **38**: 735-742.

Young, J. M. (1984) Effect of water on bacterial multiplication in plant tissue. *N. Z. Journal of Agricultural Research* **17**: 115-119.