Title:	Outdoor lettuce: field resistance to downy mildew (*bremia lactucae*)
Project number:	FV 203b
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Final Report:	March 2001
Previous reports:	None
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Date commenced:	1 April 2000
Date completed:	January 2001
Key words:	outdoor lettuce, downy mildew, partial resistance

The results and conclusions in this report are based on an investigation conducted over one year. The conditions under which the experiment was carried out and the results obtained have been reported with detail and accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore care must be taken with interpretation of the results especially of they are used as the basis for commercial product recommendations.

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Commercial benefits of the project

The project has examined the levels of resistance remaining in a range of outdoor lettuce varieties to downy mildew race BL18, which became prevalent in the UK during 1999. There are large differences between varieties. Some carrying resistance factors to the NL1-16 races were highly susceptible to the new race, whereas others only became slightly infected even towards the end of the growing season. This information will enable growers to target appropriate crop protection methods to minimise the effects of the disease, and maximise the benefits of plant resistance. Varieties showing a higher level of partial resistance may require fewer sprays through the season.

Background and objectives

Major gene, complete resistance to downy mildew (*Bremia lactucae*) is frequently overcome by new variants of the fungus. This occurred in 1998, with the appearance of BL18, which overcame previously effective resistance factors. However, initial grower observation suggested that some varieties even though they became infected by this pathotype did not develop as much disease as others at the same location. This suggests that significant partial resistance was present in some varieties which became evident once major gene resistance was overcome. Partial resistance, probably controlled by many genes, can be a useful factor in disease control, since it can help to reduce the number of sprays applied while still achieving the desired quality. A significant level of partial resistance may also mean that the commercial life of a variety can be prolonged. It is equally important to identify varieties with little or no residual resistance so that growers can be aware of the higher risk posed by them.

Summary of results and conclusions

An isolate of BL18 which originated from a field outbreak in the UK, was used to inoculate lettuce varieties in a field trial at NIAB, Cambridge. The trial was irrigated to promote repeated cycles of infection, ensuring that the inoculum applied constituted the major part of the disease developing on the trial. No natural infection of downy mildew

was seen before inoculation. The plants were scored on four occasions on the basis of the % of the leaf area which showed the characteristic sporulation of downy mildew, using standard scoring diagrams. In addition, plants were lifted late in the season, and the underside basal area scored.

There were statistically significant differences in the levels of downy mildew developing on the varieties. In general, the ranking order of varieties was maintained throughout the season, though disease levels increased to a greater extent on some varieties at the end of the season which had appeared relatively resistant at the start. The range of difference was considerable. For instance, Bacio (NL1-16) showed 8% of its leaf area infected by downy mildew on 15th September, whereas Court, also NL1-16, showed 37% infection. Varieties have been divided into five groups based on the development of disease over the course of the trial as described below:

Group A

Varieties which were highly susceptible to BL18 – these were identifiable from the start of the scoring programme. Disease levels increased very rapidly during September Infection ranged from 63% infection (Ferro) to 32% (Sherwood) on 15th September.

Variety	Resistance factors* claimed
Court	NL1-16
Jaguar	NL1,2, 5-7,14
Dickinson	NL1-16
Roxette	NL1-16
Sonette	
Target	R genes 3 and 11
Triumph	
Diamond	
Silverado	NL 1-16
Ferro	
Delight	NL1,5,7
Swing	NL1-15
Little Gem	
Lincoln	
Sherwood	

Group B

Varieties which were moderately susceptible to BL18 – disease developed a little more slowly than group A types, but still reached high levels. Infection ranged from 30% (Calgary) to 15% (Dynamic) on 15th September

Variety	Resistance factors* claimed
Balance	NL1-16
Dynamic	NL1-16
Match	NL1-16
Set	NL1-16
Talia	NL1-16
Robinson	NL1-7,11,13,15
Calgary	NL1-7,10,16
Iceball	NL1-7,10-16
Saladin	
Kendo	NL1-16, BL19 ,20
Corsair	
Lobjoit Green Cos	

Group C

Varieties which were moderately resistant to BL18 – disease developed slowly, but reached a noticeable level by the end of the season. Infection ranged from 7% (Remus) to 16% (Rubette) on 15th September.

Variety	Resistance factors* claimed
Dublin	NL1-16
Brandon	NL1-7, 10-16
45-39	NL1-16, BL17-21
45-41	NL1-16, BL19, 21
Rubette	NL1-16
Vedette	NL1-16
Bacio	NL1-16
Pinokkio	
Terlana	NL1-16
Remus	
Flamenco	NL1-16, BL19-21
Jaguar	NL1,2,5.7,14

Group D

Varieties which were highly resistant to BL18 – very little disease developed even at the end of the season. Infection levels ranged from 6% (Frisby) to 2% (Frivola) on 15th September.

Variety	Resistance factors claimed
Frivola	Nl 5,16,16, BL 18,21
Bergamo	NL 1-4,6,7,10,13-15
Frisby	
Cherokee	NL1-16, BL19,21
Funly	NL 1-16, BL17-21
Kritair	
Loretta	NL 1-16

GROUP E

Varietes where no disease was recorded throughout the season, and very little basal infection seen at harvest. 0% disease recorded in plots on 15th September

Variety	Resistance factors claimed
Sanguine	NL1-16, BL 19-21
Revolution	NL 1-16
Nika	NL1-16
85-45	NL1-16, BL19, 21
Anthony	NL1-16
Locarno	NL1-16
Malibu	NL1-16
Klausia	NL1-16, BL17-20

* All information on resistance factors is taken from data supplied by breeders.

Action points for growers

- In areas where BL18 pathotypes are predominant, avoid Group A varieties wherever possible. If they are used, monitor carefully and ensure prompt and repeated application of fungicides when disease is forecast. Group B varieties should also be avoided, but disease control may be easier to achieve than with Group A varieties.

- Select Group C or Group D varieties for high risk areas if possible. These will still require protection against downy mildew in most seasons, but spray frequency may be reduced, especially in drier years

- Group E varieties offer the best resistance against BL18, but may still be vulnerable to further new pathotypes, and continued vigilance will be necessary.

Anticipated practical and financial benefits

These results will enable growers to select varieties which show high levels of partial resistance to the BL18 pathotype. This may enable spray costs to be reduced, particularly in years when conditions are only moderately favourable to downy mildew, while maintaining product quality. If it is not possible to select partially resistant types due to commercial requirements, the information provided by this project also identifies more susceptible varieties, which will need particularly close monitoring and effective disease control measures. Further work to characterise partial resistance to new pathotypes as they emerge might be advantageous in the future.

Science section

Introduction

Downy mildew (*Bremia lactucae*) is a major problem in outdoor lettuce, particularly in plantings which come to market in the late summer and early autumn. Genetic resistance to the disease provides some protection, though this is frequently short lived as "major genes" conferring a high level of resistance are rapidly overcome by the increase of virulent pathotypes within the population. However, when major gene resistance is overcome, there may be some partial, "field" or "background" resistance remaining in the variety. This type of resistance can be useful in reducing the rate of disease development, and potentially allowing some reduction in the number of sprays applied to control disease. Recently, a pathotype of downy mildew designated BL18 has been identified in the UK and elsewhere in Europe. The pathotype is capable of overcoming genes giving resistance to the NL races 1-16. There is little information available on the levels of partial resistance in lettuce varieties of commercial interest to BL18, though grower observation has indicated that significant differences do exist (The Grower, October 1998). This work was undertaken with the objective of quantifying levels of partial resistance in a number of varieties of current interest, and comprised a replicated field trial where the BL18 pathotype was deliberately introduced, and disease promoted by irrigation. This generated a uniform and high disease pressure similar to that which could be experienced naturally in a wet season. The variety list was composed with the assistance of members of the Outdoor Salads R&D group.

Materials and methods

Lettuce plants were raised in peat blocks and transplanted on 19 July 2000 into a sandy clay loam soil at NIAB headquarters trial ground. Plots consisted of two rows each 4.2m long, at 35cm centres, with plants at 25cm spacing within rows. There were two plots across the width of a bed and three replicate plots of each variety in a randomised block layout. Three varieties failed to germinate satisfactorily in the blocks and were re-sown as a separate small trial. Results are presented separately for these. Plots were irrigated to

promote establishment as necessary. Treflan and fertiliser were applied to beds on 18th July and the trial protected from slugs by scattering pellets as necessary.

An isolate of BL18, obtained originally in the UK, was increased on susceptible lettuce plants (variety Swing) in a growth room, and the spores washed off using distilled water. 125 ml of spore suspension at a concentration of 10^6 spores /ml was applied to each plot on 21 August 2000, and again on 5 Sepetmber 2000. Plots were irrigated immediately prior to inoculation, then subsequently as necessary in periods of dry weather.

Disease was recorded on 8th, 15th 21st and 26th September by estimating the % of green leaf area showing typical downy mildew symptoms on a whole plot basis (ie examining all the plants in a plot and estimating an overall % cover) The plants were viewed from above, and typical symptoms consisted of yellow patches with occasional sporulation on the upper surface. Periodic checking of these symptoms was carried out to ensure that they coincided with matching sporulation on the lower leaf surface.

On 26 September 10 plants per plot were cut, and assessed as follows:
Icebergs: all trimmed to 1 wrapper leaf, and % basal area infected with downy mildew scored (Dixon *et al*., 1973) then trimmed to produce a disease free head. Trimming scored on a 0-5 scale, where 5 =5 leaves needed to be removed

Leafy and Cos: no initial trimming, basal or underside of head scored for % downy mildew infection, then diseased leaves removed. Trimming scored on 0-5 scale, where 5 = 75% or more leaves needed to be removed
There was insufficient material of the late transplanted varieties to perform the harvest assessment.

Results and Discussion

Disease scores are presented in Table 1 for the plots, and in Tables 2 a, b, and c for the harvest assessment for iceberg, cos and leafy types respectively.

Table 1 % leaf area infected with downy mildew on lettuce varieties

Variety	8 September	15 September	21 September	26 September
Balance	10.0	19.0	20.7	21.7
Dynamic	8.3	15.0	25.0	28.3
Dublin	7.0	13.3	17.3	21.7
Court	23.3	36.7	38.3	45.0
Jaguar	20.0	35.0	40.0	46.7
Match	16.7	28.3	33.3	35.0
Set	15.0	25.0	28.3	31.7
Talia	17.7	25.0	25.0	26.7
Dickinson	15.3	40.0	43.3	48.3
Robinson	16.0	27.3	33.3	43.3
Brandon	8.3	11.3	12.3	12.3
Calgary	15.0	30.0	35.0	35.0
Iceball	11.7	25.7	30.7	31.7
45-39	5.0	8.0	13.3	13.3
45-41	7.3	13.3	18.3	21.7
Roxette	30.0	36.7	43.3	43.3
Rubette	11.7	16.7	16.7	21.7
Vedette	7.0	11.3	18.3	18.3
Sonette	33.3	41.7	48.3	50.0
Target	16.7	41.7	50.0	20.0
Triumph	36.7	50.0	53.3	12.3
Saladin	14.7	28.3	35.0	56.7
Diamond	14.3	32.3	40.0	60.0

Table 1 continued

Variety	8 September	15 September	21 September	26 September
Silverado	25.0	35.0	35.0	38.3
Kendo	6.0	18.3	23.3	46.7
Ferro	26.7	63.3	68.3	38.3
Bacio	3.3	8.3	11.7	26.7
Delight	31.7	58.3	61.7	68.3
Pinokkio	4.7	10.7	13.3	16.7
Swing	33.3	63.3	65.0	65.0
Terlana	8.0	12.3	14.0	18.3
Little Gem	30.0	45.0	48.3	51.7
Lincoln	35.0	48.3	58.3	65.0
Corsair	11.7	20.0	31.7	35.0
Sherwood	21.7	50.0	55.0	58.3
Lobjoit Green Cos	10.0	20.0	25.0	28.3
Remus	4.0	7.3	11.7	18.7
Flamenco	1.3	10.0	10.0	10.0
Frivola	2.3	2.3	4.3	5.0
Sanguine	0.0	0.0	0.0	0.0
Bergamo	0.7	4.0	4.0	4.3
Revolution	0.0	0.0	0.0	0.0
Nika	0.0	0.0	0.0	0.0
Frisby	4.7	6.3	9.0	9.0
85-45	0.0	0.0	0.0	0.0
Anthony	0.0	0.0	0.0	0.0
Cherokee	2.3	5.7	13.3	10.0
Locarno	0.0	0.0	0.3	1.0
Malibu	0.0	0.0	0.0	0.0
Funly	1.0	1.0	2.7	3.3
Klausia	0.0	0.0	0.0	0.0

Kritair	3.3	3.3	4.3	4.3
Lsd (p=0.05)	3.02	7.71	11.29	7.81

Table 1 continued Late transplanted plots

Variety	**8 September**	**15 September**	**21 September**	**26 September**
Jaguar	2.3	6.7	9.3	9.3
Delight	3.7	10.0	15.0	18.3
Loretta	0.7	0.1	2.7	3.1
Lsd (p=0.05)	3.02	7.71	11.29	7.81

Table 2 a Iceberg harvest disease scores (% basal area infected with downy mildew) and trimming index (0-5,where 5 = 5 leaves removed to give disease free head)

Variety	**% basal area infected**	**Trimming index**
Balance	1.1	0.65
Dynamic	3.3	1.68
Dublin	0.0	1.93
Court	2.6	1.48
Jaguar	6.3	2.26
Match	2.8	1.54
Set	1.7	2.31
Talia	0.1	1.40
Dickinson	6.7	2.03
Robinson	19.7	2.61
Brandon	2.6	1.40
Calgary	3.5	2.43
Iceball	0.8	1.68
45-39	0.2	0.57
45-41	2.2	1.91
Roxette	2.8	1.53
Rubette	1.5	1.70
Vedette	0.6	2.10
Sonette	1.8	1.96
Target	1.9	1.60
Triumph	7.6	2.34
Saladin	2.9	2.10
Diamond	3.8	1.97
Silverado	2.2	1.89
Lsd (p=0.05)	9.79	0.997

Table 2b Cos harvest disease scores (% basal area infected with downy mildew) and trimming index (0-5,where 5 = 75% or more leaves removed to give disease free head)

	% basal area infected	Trimming index
Kendo	42.5	4.77
Ferro	24.9	4.40
Bacio	8.6	2.87
Delight	42.2	4.47
Pinokkio	11.4	2.60
Swing	51.5	4.00
Terlana	12.2	3.53
Little Gem	23.3	3.03
Lincoln	50.7	4.27
Corsair	17.0	3.90
Sherwood	25.2	3.47
Lobjoit Green Cos	21.5	4.33
Remus	13.6	2.27
Lsd (p=0.05)	15.20	1.107

Table 2c Leafy types harvest disease scores (% basal area infected with downy mildew) and trimming index (0-5,where 5 = 75% or more leaves removed to give disease free head)

	% basal area infected	Trimming index
Flamenco	14.2	3.20
Frivola	14.7	3.27
Sanguine	1.3	0.53
Bergamo	10.4	2.97
Revolution	0.0	0.27*
Nika	3.0	0.87
Frisby	10.5	3.03
85-45	3.6	0.63
Anthony	3.1	0.47
Cherokee	16.7	2.20
Locarno	3.9	2.13
Malibu	2.7	0.50
Funly	2.6	1.07
Klausia	5.7	0.80
Kritair	7.3	1.30
Lsd (p=0.05)	9.47	1.057

* trimmed to remove Botrytis rot

There were large and significant differences in the reaction of varieties to the BL18 pathotype. In general, the differences were maintained over the scoring period, though some later scores declined due to loss of leaf. Varieties with BL resistances 19, 20 or 21 were resistant or highly resistant, though a little disease did develop on some of them. There was considerable variation in levels of partial resistance in those varieties where only resistance to the NL1-16 races was claimed. Some of these varieties remained relatively disease free, whereas other were quickly infected to a high degree.

The inoculation method used for this trial produced a high and uniform disease pressure across all varieties. Though this was not unusual compared to the levels which can occur naturally, the trial produced a stringent test. In addition, the plots were kept late into the season, and disease continued to increase whereas material would probably have been harvested in most commercial situations. Scores taken on 15th and 21st September probably provide the best indication of levels of partial resistance for practical use, though growers of crops intended for very late harvesting should be aware of the later scores. Where varieties exhibited a significant level of partial resistance, it seems probable that spray frequency could be reduced on these in a commercial situation without reducing the level of disease control required. For more susceptible varieties, careful monitoring and effective spray programmes will be needed.

Conclusions

This work has demonstrated that significant levels of partial resistance remain in varieties when major gene resistance has been overcome. The underlying genetic control of this resistance remains unknown, but breeders can successfully exploit such resistance in order to protect varieties when major genes become ineffective. Partial resistance reduces the rate of disease development, and allows the possibility of reduced spraying.

Technology transfer

The principles of this project were discussed at the HDC-NIAB Lettuce Open Day at Shippea Hill, July 2000. Further technology transfer for the 2001 growing season is proposed to consist of a HDC Fact Sheet and dissemination of results through the NIAB Vegetable Associates Scheme subject to HDC Approval

References

Dixon G R, Tonkin M H and Doodson J K (1973). Colonisation of adult lettuce plants by *Bremia lactucae*. Annals of Applied Biology **74**, 307-313