Project Title	Evaluating new fungicides for the control of downy mildew on spinach
Project number:	FV 293
Project leader:	Dr Jane Thomas, NIAB
Report:	Final
Previous report	None
Key staff:	Dr Jane Thomas Mr Mike Day Dr Sandra Chapman
Location of project:	NIAB, Cambridge
Project coordinator:	Mr Ian Gillott, Crop Services, Woking, Berkshire
Date project commenced:	1st April 2006
Date completion due:	31st January, 2007
Key words:	Spinach, downy mildew, fungicides, integrated control

The results and conclusions in this report are based on a series of experiments conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with 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 if they are used as the basis for commercial product recommendations.

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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Grower Summary

Headline

- Three new products proved effective in controlling downy mildew (*Peronospora farinosa* f.sp. *spinaceae*) on spinach.
- The most effective products reduced disease incidence to less than 0.5% of plants infected (within an inoculated trial).
- One product 'BUK 98800' (boscalid & pyraclostrobin) increased marketable yield considerably (though the effect was not statistically significant).

Background

At the start of the proposed work, three active ingredients were available for downy mildew control in spinach, all with SOLAs (fosetyl-aluminium, copper oxychloride, and metalaxyl-M). Reliance on these products leaves growers exposed to a high level of risk, both of future non-availability, and potential chemical resistance. There was thus a need to identify potential new products and evaluate their efficacy.

Consultation with the agrochemical industry had already identified several products with potential activity against downy mildew and samples were obtained and tested on some commercial crops in previous work. While enabling observation on crop reactions and providing some indication of efficacy, reliance on natural infection did not expose the products to more uniform and constant disease pressure.

Objectives and expected deliverables

The project aimed to establish a comparative test of a number of new products for effectiveness against downy mildew by inoculating the pathogen in a trial area and encouraging disease development. The results should thus inform growers of the effectiveness of:
1) new products which may become available
2) experimental products in advanced stages of development which could prove useful to the industry.

Table 1. Treatment List

Treatment number	Trade name	Active ingredient	Application rate	Application frequency	Approval status
1	untreated				
2	SL 567 A	metalaxyl-M	1.31/ha	1	SOLA
3	A 12946B	-	0.6 l/ha	1	Not approved
4	CF 303-06	-	1.6 kg/ha	1	Not approved
5	BUK 98800 (now 'Signum')	boscalid + pyraclostrobin	1.5 kg/ha	1	Off label
6	BUK 95160	dimethomorph	0.6 l/ha	1	Not approved
7	EXP 11120 (now 'Infinito')	fluopicolide + propamocarb	1.6 l/ha	1	Not approved
8	EXP 11047 (now 'Previcur Energy')	propamocarb +fosetyl	2.5 l/ha	1	Not approved
9	Folpet	phaltan	1.5l/ha	1	Not approved

Summary of the project

Plots of the variety Toscane were inoculated with downy mildew (Race 6) at the first two true leaf stage and a total of eight products were applied once at the first sign of disease. Plots were scored for disease during the growing season and then harvested and a further disease, yield and quality assessment carried out. Disease developed to a final level of 22% of plants infected at harvest. Significant differences between product efficacy were detected and there was also some effect of one treatment on marketable yield

Main conclusions

New products are available which offer comparable disease control compared to the standard metalaxyl-M included in the trial ('SL 567 A'). The most effective products overall were 'BUK 98800' (boscalid plus pyraclostrobin), now available off label as 'Signum'; 'EXP 11047' (propamocarb & fosetyl-al) and 'Folpet' (phaltan), though differences between products were small, 'BUK 98800' gave the largest improvement in marketable yield.

Financial benefits

Low levels of downy mildew can cause major losses in marketable yield. The results of this work show that several products reduce downy mildew to very low levels and one product increased marketable yield. In areas where genetic resistance to downy mildew has 'broken down' the availability of new active ingredients with improved effectiveness compared to a standard metalaxyl-M will avoid costly losses and provide opportunities for resistance management

Action points for growers

- Use new available products at the first sign of disease (yellow patches on the leaves).
- The products evaluated were used as single sprays to determine efficacy, and appropriate programmes should be used to maximise disease control.
- Monitor varieties with Pfs 1 to 8 resistances carefully. Early indications suggest that resistance to Race 8 may be breaking down in some areas and varieties will require early treatment.
- Keep up-to-date with disease resistance strategies via the Fungicide Resistance Action Group (FRAG) website at: www.pesticides.gov.uk/rags.asp?id=644

Science Section

Introduction

Spinach downy mildew (*P. farinose* f.sp*. spinaceae*) causes considerable losses to UK spinach growers. Crops with low levels of infection may be completely unsaleable, resulting in substantial loss of income. Resistance to the disease is a major component of control options, though it is prone to "breakdown" as new races of the pathogen arise. It is thus essential that effective fungicides are available to protect crops where resistance becomes ineffective, or where known susceptible varieties are grown for specific quality characteristics.

At the time of the project proposal, three active ingredients (a.i.'s), fosetyl-aluminium, metalaxyl-M and copper oxychloride were available for downy mildew control in spinach, all with SOLAs. Reliance on these products leaves growers exposed to a high level of risk, both of future non-availability and potential insensitivity in the pathogen. There is thus a need to identify potential new products and evaluate their efficacy.

Consultation with the agrochemical industry (Ian Gillott, personal communication) has already identified several products with potential activity against downy mildew. This project will access these and others and establish a comparative test for efficacy by inoculating the pathogen in a trial area and encouraging disease development. Effective new products may then be selected for SOLA application.

Materials and methods

Downy mildew Race Pf 6 was obtained from NAKG, The Netherlands, and increased on the variety Toscane by spraying spores on plants with 2-4 leaves and incubating in a growth room at 100% RH for 48h. These were then grown on for 7-10 days and then sporulation was induced by increasing RH to 100%. Spores were either frozen at -20 °C or used fresh to inoculate field plots.

Trial plots (9m long x 4 rows wide) of Toscane were established at NIAB, Cambridge on 12th July 2006 and maintained using standard spinach variety testing procedures with the exception of any fungicide use. Thirty six plots were drilled in 4 replicate blocks of 9 plots. Plants were inoculated on 7th August (early two leaf stage) and again on 10th August. All plants along the rows were sprayed with an aqueous suspension of spores at 10^5 spores ml^{-1}. Spores were applied after light rain, or when light rain was forecast a few hours after spraying with a 300ml volume of inoculum being applied per plot on each occasion.

Fungicides were applied on 15th August when early signs of disease (yellow patches on upper leaf surfaces) were becoming visible. All products were applied in 200l of water/ha. Products, active ingredients and rates are shown in the table below.

Treatment List

Treatment number	Product name	Active ingredient	Application rate	Application frequency	Approval status
1	untreated				
2	SL 567 A	metalaxyl-M	1.31/ha	1	SOLA
3	A 12946B	-	0.6 l/ha	1	Not approved
4	CF 303-06	-	1.6 kg/ha	1	Not approved
5	BUK 98800 (now 'Signum')	boscalid + pyraclostrobin	1.5 kg/ha	1	Off label
6	BUK 95160	dimethomorph	0.6 l/ha	1	Not approved
7	EXP 11120 (now 'Infinito')	fluopicolide + propamocarb	1.6 l/ha	1	Not approved
8	EXP 11047 (now 'Previcur Energy')	propamocarb +fosetyl	2.5 l/ha	1	Not approved
9	Folpet	phaltan	1.5l/ha	1	Not approved

Plots were assessed for incidence of downy mildew on 6th and 15th September by visually estimating % of plants infected per plot. The trial was harvested on 21st September by cutting plants from measured sections of the plots approximately 4m^2 and recording marketable weight, non-marketable fractions (undersize, rots, bolters) downy mildew incidence and any other characteristics (yellowing, browning). Disease and yield data were analysed using analysis of variance.

Results

After initial disease establishment, downy mildew increased relatively slowly on untreated plots (Table 1), but at harvest disease increased in severity and leaf browning was also evident (Table 2). The higher disease levels at harvest were probably due to a combination of ease of recording on harvested plants and late season disease progression. However, the harvest disease scores were more variable over replicates and may reflect original disease foci on lower leaves. Yield of marketable plants was improved considerably by one treatment – 'BUK 98800' (Table 3), though the effect was not significant. There was some evidence of yellowing in the plots treated with the product 'A 12946B', though this tended to be patchy rather than generalised and may not all have been treatment related. No other plant effects were observed. Plot data are given in Appendix 1.

Table 1: Incidence of Downy Mildew in Spinach Plots during Growing Period

Treatment number	Product name	Active ingredient	Downy mildew incidence (% of plants infected)	
			06.09.06	15.09.06
1	untreated	untreated	7.3	6.8
2	SL 567 A	metalaxyl-M	2.4	2.5
3	A 12946B	-	1.1	1.9
4	CF 303-06	-	0.8	1.6
5	BUK 98800	boscalid+pyraclostrobin	0.6	0.2
6	BUK 95160	dimethomorph	2.4	2.1
7	EXP 11120	fluopicolide + propamocarb	1.3	1.1
8	EXP 11047(	propamocarb +fosetyl	1.1	0.6
9	Folpet	phaltan	0.4	1.1
lsd (p=0.05)			2.41	2.30

Table 2: Incidence of Downy Mildew and Leaf Browning in Spinach Plots at Harvest

Treatment number	Product name	Active ingredient	Downy mildew	Leaf browning
			Incidence (%)	Incidence (%)
1	untreated	untreated	21.8	28.1
2	SL 567 A	metalaxyl-M	9.7	18.6
3	A 12946B	-	16.4	20.3
4	CF 303-06	-	16.2	17.5
5	BUK 98800	boscalid+pyraclostrobin	9.6	16.6
6	BUK 95160	dimethomorph	15.4	17.6
7	EXP 11120	fluopicolide + propamocarb	18.4	13.2
8	EXP 11047	propamocarb +fosetyl	9.6	20.6
9	Folpet	phaltan	6.1	5.2
lsd (p=0.05)			ns	10.91

Table 3: Marketable Yield and Non-Marketable Fractions

Treatment	Active ingredient	Marketable	% plants	% plants unmarketable	Yellowing

number		Yield t/ha	marketable				1-9 (9=green)
				undersize	rots	bolters	
1	Untreated	21.2	75.4	23.9	0.7	0.0	6.3
2	metalaxyl-M	21.9	72.5	26.7	0.3	0.5	6.0
3	-	18.9	72.8	27.2	0.0	0.0	5.3
4	-	23.1	64.5	34.0	0.8	0.7	6.5
5	boscalid +pyraclostrobin	27.1	70.5	28.8	0.0	0.7	6.8
6	dimethomorph	21.5	70.6	29.1	0.3	0.0	6.0
7	fluopicolide + propamocarb	22.8	68.4	30.5	0.2	0.9	6.0
8	propamocarb +fosetyl	23.8	72.1	27.7	0.0	0.3	6.5
9	phaltan	20.8	68.3	30.8	0.0	0.9	7.3
lsd (p=0.05)		ns					1.89

Discussion

All of the new products tested gave control of downy mildew at a level better than, or comparable to, the 'SL 567 A' standard during the growing period. The product 'EXP 11120' containing fluopicolide & propamocarb appeared weaker at harvest, though this was largely due to a disease focus in one replicate. One product 'BUK 98800' containing boscalid & pyraclostrobin is now available off label ('Signum'), but growers may wish to consider other products for SOLA application. Only a single spray was used in the experiment to allow clear differentiation between products and levels of disease at harvest were therefore higher than would be expected with commercial fungicide practice. Optimised programmes were not part of the objectives of this work, but repeat applications or sequences of different products should give much lower disease levels at harvest. Considerable leaf browning was evident in the trial and there were treatment effects on this. Some of the browning, though not all, was associated with regular lesions which were identified as *Stemphylium botryosum* infections, and the effect of some of the products used here on *Stemphylium* control would merit further specific investigation. A few lesions were examined microscopically to confirm *Stemphylium* presence and it was noticeable in some of these that shrivelled downy mildew conidiophores and a few spores were present, suggesting that downy mildew infection sites might encourage later infection by *Stemphylium*, though the number of lesions examined was not sufficient to draw any firm conclusions.

Conclusions

The results presented here demonstrate efficacy against spinach downy mildew for a number of new products. One is already available off label (The UK Pesticide Guide, 2007). Availability of a wider range of effective products is highly desirable against the current background of suspected resistance breakdown in some areas of the UK (see Annual Report, FV 284), and growers may wish to consider SOLA applications for the some of the products tested here.

Technology transfer

- General summary of findings included in BLSA conference proceedings.

- One article in *HDC News* due February 2007

References

Thomas J E 2007. Improving the value of downy mildew resistance information for UK spinach growers. Annual report to Horticultural Development Council, FV 284

Appendix I Plot data

Downy mildew incidence scores (% of plants /plot infected)

6th August	R1	R2	R3	R4
Untreated	3	12	7	7
SL 567A	3	0.5	5	1
A 12946B	0.1	0.1	3	1
CF 303-06	0.1	2	1	0.1
BUK 98800	0.1	0.1	2	0.1
BUK 95160	0.5	4	3	2
EXP 11120	2	3	0.1	0.1
EXP 11047	0.1	1	3	0.1
Folpet	1	0.1	0.1	0.5
15th August				
Untreated	5	10	5	7
SL 567A	2	2	2	4
A 12946B	3	0.5	3	1
CF 303-06	5	0.1	0.1	1
BUK 98800	0.1	0.1	0.5	0.1
BUK 95160	5	0.1	0.1	3
EXP 11120	0.1	1	3	0.1
EXP 11047	1	1	0.1	0.1
Folpet	2	0.5	2	0.1

Harvest data plot scores

Rep	treatment	yellowing score (1-9, 9=green)	Marketable	Marketable	Unmarketable (% by no.)			Disease scores (incidence)	
			yield (t/ha)	% (by no.)	undersize	rots	bolters	D.mildew%	browning %
1	Untreated	8	24.73	88.57	8.57	2.86	0.00	12.90	43.55
2		6	23.83	82.83	17.17	0.00	0.00	20.73	28.05
3		7	20.59	65.49	34.51	0.00	0.00	17.57	16.22
4		4	15.68	64.63	35.37	0.00	0.00	35.85	24.53
1	SL 567 A	6	24.68	77.78	21.30	0.00	0.93	10.71	33.33
2		7	23.20	73.26	25.58	1.16	0.00	4.76	17.46
3		6	18.83	62.83	37.17	0.00	0.00	9.86	4.23
4		5	21.08	76.14	22.73	0.00	1.14	13.43	19.40
1	A12946B	6	21.35	64.71	35.29	0.00	0.00	7.58	33.33
2		7	20.45	84.09	15.91	0.00	0.00	8.11	10.81
3		3	14.68	70.11	29.89	0.00	0.00	42.62	22.95
4		5	18.92	72.16	27.84	0.00	0.00	7.14	14.29
1	CF 303-06	5	15.18	48.54	51.46	0.00	0.00	40.00	24.00
2		7	27.30	85.25	14.75	0.00	0.00	3.85	15.38
3		8	30.59	68.69	28.28	3.03	0.00	2.94	7.35
4		6	19.46	55.45	41.58	0.00	2.97	17.86	23.21
1	BUK 98800	7	24.28	70.00	30.00	0.00	0.00	9.52	26.98
2		8	33.78	72.29	27.71	0.00	0.00	15.00	11.67
3		6	26.04	75.26	22.68	0.00	2.06	8.22	16.44
4		6	24.14	64.29	34.82	0.00	0.89	5.56	11.11
1	BUK 95160	7	25.14	79.63	20.37	0.00	0.00	5.81	26.74
2		6	22.16	63.22	36.78	0.00	0.00	7.27	21.82
3		7	25.99	72.94	25.88	1.18	0.00	16.13	14.52
4		4	12.57	66.67	33.33	0.00	0.00	32.50	7.50
1	EXP 11120	6	25.89	77.50	21.67	0.83	0.00	8.60	20.43
2		7	28.92	69.11	29.27	0.00	1.63	12.94	20.00
3		4	15.05	62.35	37.65	0.00	0.00	47.17	5.66
4		7	21.53	64.52	33.33	0.00	2.15	5.00	6.67
1	EXP 11047	5	22.84	72.22	27.78	0.00	0.00	10.77	46.15
2		7	25.00	72.55	27.45	0.00	0.00	16.22	18.92
3		8	26.22	77.17	21.74	0.00	1.09	9.86	14.08
4		6	21.17	66.30	33.70	0.00	0.00	1.64	3.28
1	Phaltan	6	13.51	54.29	45.71	0.00	0.00	14.04	1.75
2		7	22.12	65.09	33.96	0.00	0.94	2.90	4.35
3		8	23.56	72.48	27.52	0.00	0.00	2.53	6.33
4		8	24.05	81.33	16.00	0.00	2.67	4.92	8.20