Project Title	Blackberry: evaluation of fungicides for improved control of downy mildew and purple blotch
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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.

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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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TABLE OF CONTENTS

Grower Summary

Headline

Programmes of three to five sprays of Amistar, Folicur and Signum applied in alternation to blackberry between May and December greatly reduced the severity of purple blotch the following year and increased floricane vigour; cane spot was also reduced. Amistar, Cuprokylt, Farm-Fos 44, Paraat and Signum reduced downy mildew.

Background and expected deliverables

UK production of high quality blackberries for fresh fruit sales is increasing rapidly to satisfy the growing consumer desire for health-giving foods and a strong supermarket demand. Some of the major varieties being planted (e.g. Loch Ness, Chester Thornless, Loch Tay) are susceptible to downy mildew (*Peronospora sparsa*). Purple blotch is common on the established varieties Bedford Giant and Silvan, and lesions suggestive of purple blotch have been reported on some new spined varieties (e.g. Driscoll, Carmel, Karaka Black, Obsidian, Black Butte). Both diseases have the potential to devastate crop production. Damaging attacks of downy mildew have occurred in some Spanish tunnel crops. This project aims to evaluate a range of fungicides for control of downy mildew and purple blotch and to devise and test sustainable spray programmes. The industry will benefit through more reliable production of high quality fruit.

Summary of the project and main conclusions

Downy mildew

Evaluation of fungicides for control of downy mildew

In autumn 2007, 10 fungicides were evaluated for control of downy mildew on container plants of the susceptible blackberry cv. Loch Ness. At 7 days after the final spray application, downy mildew affected less than 1% leaf area of untreated plants and there were no significant differences between treatments.

In spring 2008, eight products were evaluated for control of downy mildew on pot grown plants of blackberry cv. Loch Ness. These were Amistar (azoxystrobin), Consento (fenamidone+propamocarb), Cuprokylt (copper oxychloride), Paraat (dimethomorph), Previcur Energy (fosetyl-aluminium + propamocarb hydrochloride), Signum (boscalid+

pyraclostrobin) two experimental products, a foliar fertiliser (Farm-Fos-44) amended with a wetter (Silwet L77 or Omex SW7) and a wetter alone (Omex SW7). Five sprays were applied at 14 day intervals. At 7 days after the final spray application, downy mildew affected around 8% leaf area of untreated plants and was significantly reduced by all treatments (Fig. 1). None of the treatments reduced disease severity by more than 60%, probably due to the high disease pressure and the 14 day interval between spray applications.

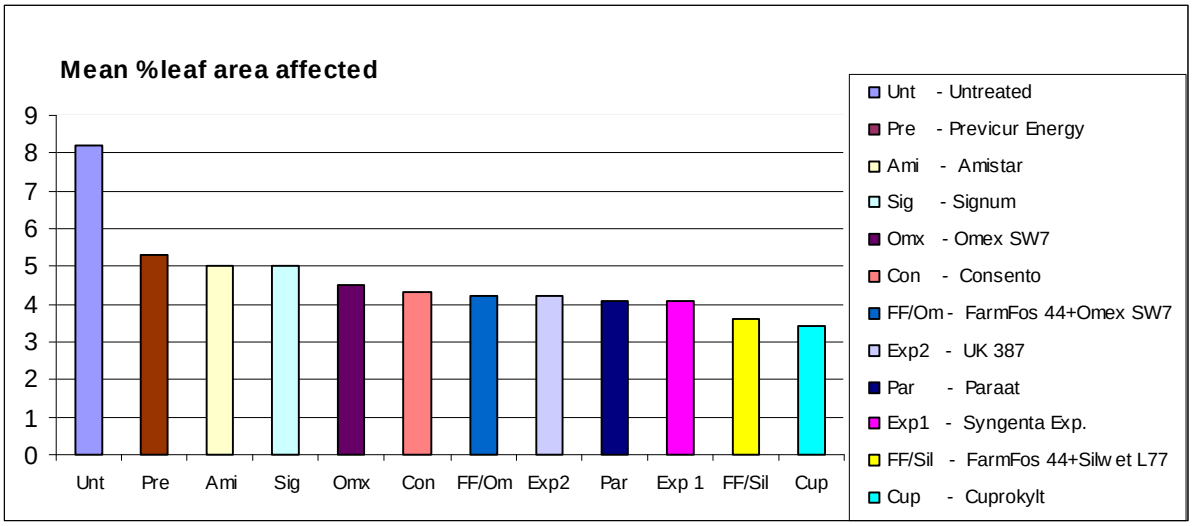

Fig 1: Effect of fungicide treatments on blackberry downy mildew – 24 June 2008 (Experiment 1)

Evaluation of fungicide programmes for control of downy mildew – autumn 2008

Five fungicide spray programmes based on Amistar, Cuprokylt and Signum, a single fungicide drench treatment (Paraat), a foliar fertiliser (Horti-Phyte) amended with a wetter (Omex SW7), a wetter alone (Omex SW7), and a bacterial leaf wash (Sentry P) were evaluated for control of downy mildew on pot-grown blackberry plants. Plants were treated every 14 days in some spray programmes and every 7 days in others.

At 7 days after the final spray application, there were no statistically significant differences between treatments. Downy mildew was greatest on untreated plants (9% leaf area) and least (3%) on plants drenched once with Paraat. A high proportion (≥35%) of untreated plants and plants treated with Sentry P were severely affected by downy mildew (>10% leaf area affected). Less than 3% of plants treated with Paraat or the Horti-Phyte + Omex SW7/Amistar programme fell into this category.

Evaluation of fungicide programmes – 2009

Six programmes based on a Paraat drench in the spring followed by foliar sprays of the fungicides Amistar, Cuprokylt, Folicur and Signum and a foliar fertiliser (Horti-Phyte) plus wetter (Omex SW7) were evaluated for control of downy mildew and cane diseases in a tunnel crop of cv. Loch Ness in Kent. Spray treatments were applied every 2-3 weeks from 15 April to 22 September.

Although the crop was severely affected by downy mildew in 2008, and a trace of the disease appeared by 29 April 2009, it remained at low levels throughout the generally dry summer and autumn. At the final assessment in October, downy mildew affected <1% leaf area on untreated plants. No purple blotch or other cane disease was found on plants.

Effect of leaf wetness duration on downy mildew

In 2007, five leaf wetness durations (0-48 h) were applied weekly for seven weeks to pot-grown plants of cv. Loch Ness. Downy mildew severity remained low (0-2% leaf area affected) with no consistent effect from increasing leaf wetness duration.

In 2008, five leaf wetness durations (0-96 h) were applied weekly for four weeks to pot-grown plants of cv. Loch Ness. Downy mildew severity was reduced with increasing duration that plants were covered with polythene to retain moisture. It is suggested that this unexpected effect was due to high temperatures that resulted from covering plants during sunny weather in May; temperatures above 30^{o}C occurred twice during the experiment. When conditions are moist, spore germination by *P. sparsa* occurs over a wide temperature range up to 26^{0}C; leaf wetness duration has a large effect, with disease incidence increasing very sharply with leaf wetness duration above 4 days.

Purple blotch

Effect of fungicides on germination of Septocyta ruborum spores

Six fungicides were each tested at 2 and 20 ppm a.i. for their effect on germination of *S. ruborum* spores in an agar plate assay. Germination on unamended agar was 88%. Spore germination was reduced by Bravo 500 (chlorothalonil), Signum, Amistar and Folicur (tebuconazole), and not by Cleancrop Curve (carbendazim) or Cuprokylt Fl, at the concentrations tested.

Occurrence of S. ruborum spore production

The effect of temperature and moisture on release of spores from fruiting bodies (pycnidia) of *S. ruborum* was examined in May 2007. Abundant spores were exuded within 3 days when blackberry canes bearing pycnidia of *S. ruborum* were maintained moist, irrespective of temperature (5-20°). No spores were produced when pycnidia were maintained dry for 18 days at 5, 10, 15 or 20°C.

Cane sections affected by purple blotch were collected from a naturally infected crop at intervals from 1 May to 1 August 2007. No spores were visible on any samples at the time of the collections. After moist incubation for 5 days, abundant spore exudation was observed from all lesions during May and June, and from some in July and August. When new season floricane was examined in January 2008, spore exudation was observed after damp incubation. These results indicate a potential for spore release by *S. ruborum* over many months (January – August).

Occurrence of stem purpling and purple blotch on different varieties

Seven blocks of blackberry comprising six varieties on a farm in Norfolk were assessed for stem purpling and purple blotch in June 2007. Canes with sections discoloured purple and bearing fungal spore cases were found at a high incidence in cvs. Silvan (99%), Karaka Black (32%) and Kotata (31%). These symptoms were absent on cv. Loch Tay and at a low incidence on cvs Chester Thornless (1%) and Loch Ness (3-15%). Purple blotch (*S. ruborum*) was confirmed only on cv. Silvan; pycnidia containing a different fungal spore were found in both blocks of cv. Loch Ness. Stem purpling with no evidence of fungal spore cases was common on cvs. Chester Thornless, Kotata and Karaka Black. No canes with wilted shoots were found except on cv. Silvan affected by purple blotch. These results suggest that stem purpling requires microscopic identification of associated fungi before concluding the purple blotch (*S. ruborum*) is the cause of purple lesions.

Development methods for production of purple blotch

In May 2007, pot grown plants of cv. Silvan were inoculated with *S. ruborum* by four methods. In September, plants were treated with half-rate paraquat or stored cold (4°C) for 48h in an attempt to advance the development or purple blotch symptoms. Neither the paraquat nor the cold-shock stress treatment resulted in early development of purple blotch symptoms; the first symptoms appeared in February 2008. By March 2008, purple blotch lesions were confirmed on many green canes, especially those inoculated with mycelium of

S. ruborum, or where cane sections affected by purple blotch were suspended above developing primocanes.

Evaluation of fungicide treatments for control of purple blotch – Experiment 1

In 2007, a field trial was established in Norfolk in a crop of cv. Silvan showing widespread infection by purple blotch. The training system used on the site was to allow primocanes to trail as they grew during the spring, summer and early autumn along the ground to the side of and beneath the floricane. The primocanes to be retained to crop the following year were selected and then tied onto the wires of the crop support trellis during winter, after the old fruiting canes had been cut through at their base and removed from the crop rows. Five fungicides (Amistar, Bravo 500, Cuprokylt FL, Folicur and Signum) each applied as programmes of three sprays were compared with an untreated control. The aim was to protect the primocanes developing in 2007. Sprays were applied when primocanes were 15-30 cm, 60-90 cm and post-harvest. Additionally, three programmes of Folicur applied at different spray timings were evaluated in crops where primocanes were tied-in as they grew, and in one further treatment, floricanes were cut out in spring and a three-spray Folicur programme was applied to tied-in primocanes (i.e. a biennial cropping system).

In January 2008, the disease affected 62% of the surface area of untreated new season floricanes. In areas of crop where primocanes had trailed on the ground, the severity of purple blotch was significantly reduced by Signum and appeared to be reduced by Amistar, Bravo 500 and Cuprokylt FL. Folicur significantly reduced purple blotch when applied to primocanes tied onto wires as they grew, and in a biennial cropping system, but not when applied to the crop where primocanes had trailed on the ground.

In May 2008, the vigour of growth was significantly greater in plots treated with Signum or Folicur the previous year (Fig 2). These two treatments also appeared to reduce the incidence of wilting and dead floricanes at this time.

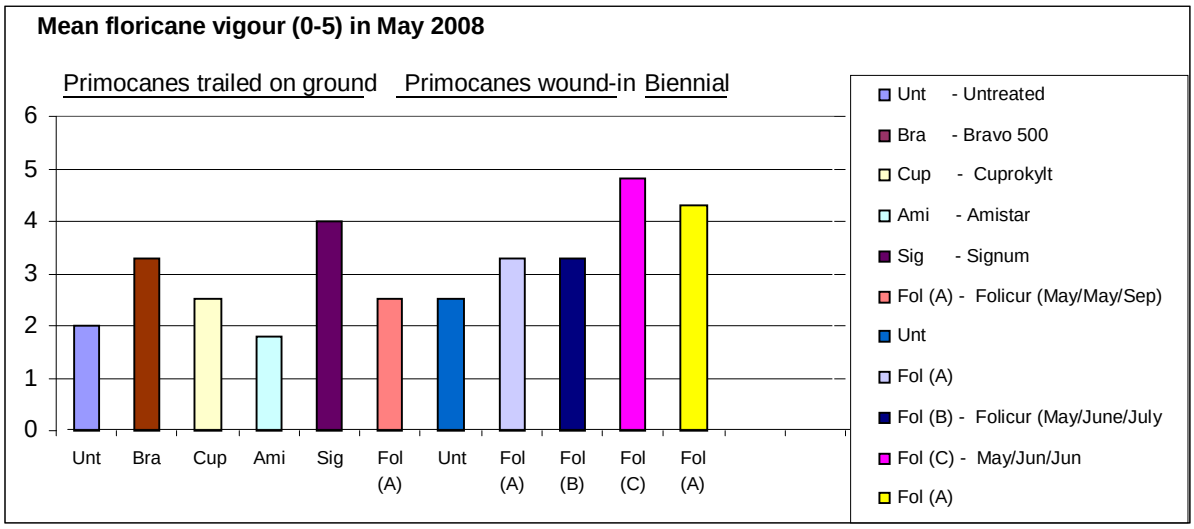

Fig 2: Effect of fungicide and crop management treatments in 2007 on floricane vigour in May 2008.

Evaluation of fungicide treatments for control of purple blotch – Experiment 2

In 2008, a second field experiment was established on cv. Silvan in Norfolk. Three fungicides (Amistar, Folicur and Signum) applied as programmes of up to five sprays were compared with an untreated control. Sprays were applied when primocanes were 15-30 cm (1 May), 60-90 cm (14 May), a week before first pick (10 June), shortly after the final pick (13 August) and after tying-in the new primocanes (26 January). Additionally, the effect of tying-in primocanes during cropping was compared with allowing them to trail on the ground and with removal of the first flush of primocanes.

In May 2009, purple blotch was significantly reduced and crop vigour increased by all the fungicide programmes (Table 1). The five spray fungicide programme appeared slightly more effective than the three and four spray programmes. On crop areas untreated with fungicide, neither early removal of primocanes nor tying-in primocanes as they grew significantly reduced purple blotch. However, where the crop was treated with fungicides, the level of purple blotch control was significantly greater on tied-in than trailed primocanes, probably reflecting better spray coverage. Disease severity was least (10%) where early primocanes were removed, the later primocanes tied-in and a full-season fungicide programme applied.

A low level of cane spot (*Elsinoe veneta*) was significantly reduced by a three spray programme of Amistar, Folicur and Signum.

Table 1: Effect of three crop management practices and some fungicide programmes on control of purple blotch on blackberry – 2008/09

	Cane management and fungicide sprays					May 2009	Cane
	1 May	14 May	10 Jun	13 Aug	26 Jan	Purple blotch % surface area	Vigour (0 - 5)
Primocanes tied-in							
1.	-	-	-	-	-	46	1.3
2.	Signum	Folicur	Amistar	-	-	20	3.8
3.	Signum	Folicur	Amistar	Signum	Folicur	14	3.5
4.	Signum	Folicur	Amistar	-	Folicur	18	4.0
Early primocane removal and primocanes tied-in							
5.	-	-	-	-	-	45	2.5
6.	Signum	Folicur	Amistar	-	-	27	2.5
7.	Signum	Folicur	Amistar	Signum	Folicur	10	3.5
Primocanes trail on floor							
8.	-	-	-	-	-	41	2.0
9.	Signum	Folicur	Amistar	Signum	Folicur	30	3.8
10.	Signum	Folicur	Amistar	-	Folicur	28	4.0

Fungicide products for control of blackberry downy mildew and purple blotch

Fungicides currently (February 2010) permitted for use on blackberry and their activity against downy mildew and purple blotch are summarised in Table 2. Some programmes for control of these two diseases are also suggested (Table 3). Although the efficacy of programmes against downy mildew was not validated in a field experiment in this work due to lack of the disease, the programmes use products with known activity against blackberry downy mildew.

Table 2: Summary of fungicides approved for use on blackberry (February 2010) and their activity against downy mildew and purple blotch.

Product	Maximum rate of use	Approval	Permitted for use		Harvest interval	Active on	
			O	P		DM	PB
Amistar	1 L/ha	1194/95	-	**ü**	10	**ü**	**ü**
Amistar	1 L/ha	0365/03	**ü**	-	7	**ü**	**ü**
Cuprokylt	5 kg/ha	3132/06	**ü**	**ü**	Not stated	**ü**	**ü**
Cuprokylt FL	5 L/1,000 L	3139/06	**ü**	-	Not stated	**ü**	**ü**
Folicur*	0.8 L/ha	2160/08	**ü**	**ü**	14	No	**ü**
Paraat	3 kg/ha	2777/07	**ü**	**ü**	90	**ü**	No
Signum	1.8 kg/ha	0992/08	**ü**	-	3	**ü**	**ü**
Signum	1 kg/ha	-	-	**		**ü**	**ü**

O – outdoor; P – protected; DM – downy mildew; PB – purple blotch.

*One of several products containing tebuconazole that have SOLAs for use on outdoor & protected blackberry.

** SOLA application submitted.

Table 3: Example programmes for downy mildew and purple blotch

Growth stage	Downy mildew	Purple botch	Downy mildew and purple blotch
Open field			
Bud opening	Paraat	-	Paraat
Primocane 15-30 cm	Signum	Signum	Signum
Tunnel covered			
Primocane 60-90 cm	HortiPhyte*	Folicur	Folicur
Around 7 d pre harvest	Amistar	Amistar	Amistar
During harvest	HortiPhyte*	-	HortiPhyte*
During harvest	HortiPhyte*	-	HortiPhyte*
Open field			
After end of harvest	Signum	Signum	Signum
After floricane removal	-	Folicur	Folicur

* Plus wetter

Additional spray treatments before and during fruiting may be justified when downy mildew is active.

Financial benefits

Production of Spanish-tunnel protected high quality blackberries for fresh fruit sales has increased markedly in the last three years to exceed 195 ha in 2008 in order to cope with supermarket demand. The two major diseases of blackberry are purple blotch and downy mildew and both have the potential to devastate production if not adequately controlled. For a tunnel-protected crop of cv. Loch Ness, assuming a yield of 15 t/ha and returns of £8,000/t, the fruit value is around £120,000/ha. Assuming an average annual yield loss of 5% to the combined effects of these diseases, this equates to £6,000/ha; losses for individual plantations could be significantly greater than 10% (e.g. 65-70%). The potential benefit to growers from this project is the identification of treatments that provide effective control of downy mildew and purple blotch with minimum use of fungicides during fruiting, and thereby maintain high quality production without a significant yield loss to these diseases.

Action points for growers

Purple blotch

- Purple areas on blackberry canes can be caused by factors other than the purple blotch fungus, *Septocyta ruborum*. If purple lesions develop on canes, consult an expert to determine if purple blotch is the cause.
- Signum now has a SOLA (0992/08) for use on outdoor blackberry. This fungicide has activity against purple blotch, downy mildew and botrytis. A maximum of two sprays are permitted.

- In a blackberry variety highly susceptible to purple blotch (e.g. Silvan, Bedford Giant), seek to protect the primocanes from infection by treatment with Amistar, Folicur and Signum during the period of rapid cane growth. Alternate fungicide groups for sequential spray treatments in order to reduce the risk of selecting fungicide-resistant pathotypes of the purple blotch fungus, *Septocyta ruborum*.
- Tying-in primocanes as they grew increased the efficacy of four spray or five spray fungicide programmes (using Amistar, Folicur and Signum), compared with allowing primocanes to trail on the ground (until winter) and applying sprays to the trailing primocanes, probably due to improved spray coverage of the target primocanes.
- On crop untreated with fungicides, neither early removal of primocanes nor tying-in primocanes significantly reduced severity of purple blotch when compared with primocanes allowed to trail on the ground until floricane removal.
- Purple blotch severity was least where early primocanes were removed, the later primocanes tied-in and a full-season fungicide programme applied.

Downy mildew

- Consider treating blackberry varieties susceptible to downy mildew (e.g. Loch Ness, Loch Tay, Chester Thornless) with preventative sprays of Amistar, Signum, Cuprokylt and a potassium phosphite fertiliser (e.g. Horti-Phyte + Omex SW7). Note that Signum cannot be used on a protected crop.
- Treat recently planted blackberry varieties susceptible to downy mildew with a drench of Paraat (SOLA 2777/07), before growth commences.

Cane Spot

- Cane spot was reduced by a three-spray programme of Signum, Amistar and Folicur.
- In the absence of fungicide treatment, cane spot was reduced by early primocane removal and by allowing canes to trail on the ground until after removal of old floricanes.

Disease symptoms

- Typical symptoms of downy mildew, purple blotch and cane spot on blackberry are shown in Fig 3.

a) downy mildew on leaves (angular blotches)

b) dryberry caused by downy mildew

c) cane spot

d) cane spot on leaf

e) purple blotch lesion

f) older purple blotch lesion

Fig 3: Typical symptoms of downy mildew, purple blotch and cane spot on blackberry

Science Section

Introduction

Production of Spanish tunnel protected high quality blackberries for fresh fruit sales has markedly increased in recent years in order to cope with the demand from the major UK supermarkets. A range of new varieties are being planted including Loch Ness, Chester Thornless, Karaka Black, Carmel and Obsidian; also Helen and Loch Tay for early harvest. The major varieties at present are Loch Ness (c. 60% of the production area), Chester Thornless (15%) and Loch Tay (15%). Once planted, crops are often grown for 20 years or more. Crops are now generally produced in Spanish tunnels as required by the supermarkets and this allows for early production and harvesting in wet weather.

The two major diseases of blackberry are downy mildew *(Peronospora sparsa)* and purple blotch *(Septocyta ruborum)*. Both have the potential to devastate crop production if not adequately controlled. Downy mildew infects leaves, petioles, canes, flowers and fruit, while purple blotch is a disease of the stems and lateral shoots. In spring, auxiliary buds in sections of cane affected by purple blotch begin to grow normally but later stop growth and die. Also, the presence of purple blotch in a crop can markedly increase winter-kill of floricane.

Recent observations indicate that downy mildew and purple blotch continue to be the main diseases affecting modern varieties both grown in the open and under protection. Purple blotch has occurred on Bedford Giant and Silvan; downy mildew on Loch Ness, Chester Thornless and Loch Tay. Some growers have commented that downy mildew is worse on protected than open field crops. “Dryberry” symptoms caused by downy mildew can affect all the fruit on a lateral.

Until recently, control of downy mildew was largely based on use of Elvaron Multi (tolylfluanid), chlorothalonil products, copper based fungicides and the foliar fertiliser potassium phosphite, although none have specific approval for mildew control on blackberry. However, use of Elvaron Multi was suspended in early 2007 and use of chlorothalonil on blackberry was revoked in September 2007. Sprays for downy mildew are applied to protect new foliage, flowers and developing berries. Only copper fungicides and phosphite can be used during the period the crop is protected; unfortunately, use of the former is restricted to just three applications per year. Sprays of chlorothalonil and potassium phosphite at 14 d intervals did not provide adequate control of downy mildew on Loch Ness grown in Spanish tunnels (T. Chambers; pers. comm.). Control of purple blotch is usually sought using carbendazim. Use of carbendazim, however, is restricted to post-harvest applications,

permitted under SOLA for cane blight control and this approval expires on 30 June 2008. Isolates of *S. ruborum* resistant to carbendazim and copper fungicides have been reported in some plantings, increasing the difficulty in obtaining effective control of purple blotch.

There is an urgent need to identify alternative fungicides which provide effective control of downy mildew and purple blotch on blackberry with minimum risk of leaving pesticide residues in fruit.

In the first year of the project, experimental work on blackberry downy mildew (*Peronospora sparsa*) and purple blotch (*Septocyta ruborum*) showed that:

- Amistar, Bravo 500, Folicur and Signum all have activity against *S. ruborum*, inhibiting spore germination (Bravo 500 is no longer permitted on blackberry)
- Severity of purple blotch was reduced by three-spray programmes of Folicur and Signum
- Purple blotch pycnidia on floricanes have the potential to release spores during wet weather from at least May to August and probably over a longer period
- *S. ruborum* pycnidia containing spores were only found associated with purple lesions on canes of cv. Silvan; purpling on canes of other blackberry varieties may be due to factors other than infection by *S. ruborum*

In the second year of the project, we:

- Identified eight fungicides and a foliar fertiliser that reduced downy mildew on container plants
- Completed a first field experiment, established in 2007, and identified fungicide products that gave control of purple blotch
- Established a second field experiment, evaluating some fungicide programmes and crop management practices, for control of purple blotch

The aim of the work in the third year was:

- To evaluate a range of fungicide programmes for control of downy mildew in a commercial tunnel crop
- To complete the second field experiment evaluating some fungicide programmes and crop management practices for control of purple blotch

1. Evaluation of fungicide programmes for control of downy mildew

Introduction

In recent years damaging attacks of downy mildew have affected leaves and fruit of both outdoor and tunnel crops of blackberry. The disease is sporadic and many growers do not routinely apply preventative treatments. The relative efficacy of different fungicide treatments is unclear. The occurrence of fungicide residues in fruit, even at levels below the MRL, causes adverse publicity. The aim of this work was to evaluate six programmes of fungicides and a foliar fertiliser, designed to be at reduced risk of leaving detectable fungicide residues in fruit, for season-long control of downy mildew.

Materials and methods

Site and crop details

The experiment was located in a Spanish tunnel crop of the susceptible cv. Loch Ness on a commercial farm in Kent. The area of crop affected was severely affected by downy mildew in 2008. There were two rows of crop in the tunnel. Grass pathways between the rows were kept mown short. The experiment was located towards one end of the tunnel, with a 5 m guard at the tunnel end. The trial area was managed as a commercial crop except that no fungicides were applied. A crop diary is given in Appendix 1.

Treatments

Details of fungicides and other products used within treatment programmes are given in Table 1.1. Programmes for control of downy mildew were designed that consisted of:

- A single fungicide drench early in the season, a programme of sprays
- An early season fungicide drench plus fungicide sprays
- An early season fungicide drench plus foliar fertiliser sprays
- An early season fungicide drench plus fungicide sprays for control of both downy mildew and cane diseases
- A fungicide spray programme in response to occurrence of downy mildew symptoms (Table 1.2).

Table 1.1: Details of fungicides and other products used

Product	Active ingredient(s)	Rate of use	Approval on blackberry	Situation for use[a]		Harvest interval (days)
				O	P	
Amistar	azoxystrobin	1 L/ha	SOLA 1194/05	-	ü	10
Amistar	azoxystrobin	1 L/ha	SOLA 0365/03	-	ü	7
Cuprokylt	copper oxychloride	5 kg/ha	SOLA 3132/06	ü	ü	Not stated
Folicur*	tebuconazole	0.8 L/ha	SOLA 2160/08	ü	ü	14
Horti-Phyte	potassium phosphite	4 L/ha	Fertiliser	ü	ü	0
Omex SW7	silicon based wetter	2.5 ml/L	Adjuvant	ü	ü	0
Paraat	dimethomorph	3 kg/ha	SOLA 2777/07	ü	-	90
Signum	boscalid + pyraclostrobin	1.8 kg/ha	SOLA 0992/08	ü	-	3

[a] O – outdoor; P – protected crops

* One of several products containing tebuconazole that have SOLAs for use on outdoor & protected blackberry

Sprays were applied at 1,000 L/ha from both sides of the row. Paraat drench was applied by the grower on 31 March 2009.

Table 1.2: Treatment programmes applied for control of downy mildew on a tunnel crop of Loch Ness- 2009

Treatment	Treatment number and application date											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
	1 Apr	**15 Apr**	**29 Apr**	**13 May**	**26 May**	**10 Jun**	**24 Jun**	**8 Jul**	**21 Jul**	**4 Aug**	**19 Aug**	**22 Sep**
1. Untreated	-	-	-	-	-	-	-	-	-	-	-	-
2. Paraat drench only	Par	-	-	-	-	-	-	-	-	-	-	-
3. Sprays only	-	Sig[a]	HP/O	Ami	HP/O	Sig[a]	HP/O	HP/O	HP/O	HP/O	HP/O	Cup
4. Drench + fungicide sprays	Par	Sig[a]	HP/O	Ami	HP/O	Sig[a]	HP/O	HP/O	HP/O	HP/O	HP/O	Cup
5. Drench + fertiliser sprays	Par	HP/O	HP/O	HP/O	HP/O	HP/O	HP/O	HP/O	HP/O	HP/O	HP/O	HP/O
6. Downy mildew and cane disease programme	Par	Cup	HP/O	Fol	Ami	HP/O	HP/O	HP/O	HP/O	HP/O	HP/O	Fol
7. Response to downy mildew symptoms programme	Par	-	-	Ami	HP/O	Ami	HP/O	HP/O	HP/O	HP/O	HP/O	HP/O

[a] Applied to protected crop under an Administrative Experimental Permit. An application for a SOLA to permit use on a protected crop, at a lower rate (1.0 kg/ha), has been submitted to CRD for assessment.

Experiment design and statistical analysis

The experiment was a randomised block design with fourfold replication, except for treatments 1 (untreated) and 2 (Paraat drench), where there was eightfold replication. Each plot consisted of a 3 m length of row; there were two blocks of treatments in each row. Results were examined by ANOVA.

Assessments

Leaves were examined for symptoms of downy mildew at each visit. At 2 weeks after first occurrence of downy mildew in the crop and two weeks after the final spray treatment, the central 2.5 m of each plot was examined from both sides of the row and the proportion of leaf area affected by downy mildew was estimated separately in the upper, mid and lower leaf canopies. During fruiting fruits were examined for occurrence of 'dryberry', a symptom of downy mildew infection. The plants were also examined for cane diseases (purple blotch, cane spot) at these times.

Results and discussion

Downy mildew was first observed in the crop on 13 May. The disease did not increase above trace levels (<1% leaf area affected), even on untreated plants (Table 1.3). There were no significant differences between treatments in the severity of downy mildew at either assessment. No dryberry symptoms or cane diseases were found.

The most likely explanation for lack of significant levels of downy mildew in the crop is that the environment in the tunnel was not favourable to infection and/or sporulation by *P. sparsa*, the causal fungus. The variety Loch Ness is known to be very susceptible to the disease; indeed, the crop used for the experiment was severely affected by downy mildew in 2008 and it is likely that the fungus was present in plants at the start of treatments. Generally downy mildew was rarely a problem in UK blackberry crops in 2009, a marked contrast to 2008. This is likely due to the lack of wet weather in eastern England during the summer or early autumn in 2009, and consequently there was a reduced occurrence of leaf wetness on crops. Possibly the disease would have been more damaging in the crop if grass pathways had not been mown, likely to result in a more humid environment.

Downy mildew severity on 4 August differed between row sides. Overall, there was a significantly greater (P = 0.001) level of downy mildew on the east side of rows than on the west in both the upper canopy (0.41% vs. 0.07%) and the mid canopy (0.08% vs. 0.01%). At the October assessment, there was a greater level (P = 0.05) on the west side at mid canopy level than on the east site. Possibly these differences were associated with

differences in temperature or leaf wetness duration between the two sides, or they may simply be due to chance.

Table 1.3: Effect of fungicide programmes on downy mildew in a tunnel crop of cv. Loch Ness - Kent, 2009

Treatment	Mean % leaf area affected			
	4 August		15 October	
	Upper Canopy	Mid canopy	Upper canopy	Mid canopy
1. Untreated	0.01	0.01	0.07	0.67
2. Paraat drench only	0.01	0.04	0.0	0.06
3. Sprays only	<0.01	0.02	0.04	0.08
4. Drench + fungicide sprays	0.73	0.01	0.0	0.01
5. Drench + fertiliser spray	0.19	0.50	0.0	0.02
6. Downy mildew/cane diseases	0.16	0.0	0.0	0.01
7. Response to downy mildew	0.81	0.0	0.0	0.13
Significance (21 df)	NS	NS	NS	NS

2. Evaluation of fungicide programmes for control of purple blotch

Introduction

The objective of this work was to determine the effect of some fungicide programmes on control of purple blotch. An experiment was established in 2008 to evaluate programmes of two or more fungicides applied in alternation. The effects of some crop management practices were also examined. Infection by *S. ruborum* occurs on primocanes and symptoms do not appear until the following year, when the primocanes have become floricanes.

Material and methods

Site and crop details

The experiment was done in a commercial crop of cv. Silvan at Terrington St Clement, Norfolk. Purple blotch was obvious throughout the crop at the start of the experiment. A crop diary is given in Appendix 1.

Treatments

Details of products and treatments are shown in Tables 2.1–2.2.

Experiment design and statistical analysis

Treatments were arranged in four randomised blocks, consisting of four adjacent rows (c. 50 m long). Each plot was 3 m long and contained at least 8 fruiting canes. The central 2.5 m of each plot was assessed for disease. Guard areas (3 m long) were left at the ends of rows and thin areas of crop were excluded from the experiment. Results were examined by analysis of variance and regression analysis as appropriate.

Assessment of purple blotch

The incidence of purple blotch lesions on the new season floricanes was determined in January and the proportion of cane surface affected was estimated in May 2009. The number of lesions per cane was counted on the 10 strongest (thickest diameter) canes per plot (5 on each side of the row). The proportion of canes with more than five lesions per cane was also determined. Cane spot (*Elsinoe veneta*) severity on leaves and canes was assessed in August 2008 and January 2009.

Crop growth and management

At each spray application date, the length of 20 primocanes in an untreated area of the crop was measured. Primocanes were wound-in as required at each site visit (see Appendix 1). The first flush of primocanes in treatments 5, 6 and 7 were removed on 29 April, 6 May and 16 May 2008 (i.e. up to first green fruit formation).

Table 2.1: Details of fungicide products evaluated for control of purple blotch – 2008

Product	Active ingredient	Rate of use of product
Amistar	azoxystrobin	1.0 mL/L
Folicur	tebuconazole	0.8 mL/L
Signum	boscalid+ pyraclostrobin	1.8 g/L

Table 2.2: Details of fungicide treatments and crop management practices evaluated for control of purple blotch – Norfolk 2008/09

Treatment	Spray 1 (1 May)	Spray 2 (14 May)	Spray 3 (10 Jun)	Spray 4 (13 Aug)	Spray 5 (26 Jan)
Primocanes tied-up[a]					
1. Untreated	-	-	-	-	-
2. Pre-fruiting programme	Signum	Folicur	Amistar	-	-
3. Full-season programme	Signum	Folicur	Amistar	Signum	Folicur
4. Pre-fruit and clean-up	Signum	Folicur	Amistar	-	Folicur
Early primocane removal and tied-in[b] *(29 April, 6 and 16 May)*					
5. Untreated	-	-	-	-	-
6. Pre-fruiting programme	Signum	Folicur	Amistar	-	-
7. Full-season programme	Signum	Folicur	Amistar	Signum	Folicur
Primocanes trail on floor[c]	-	-	-	-	-
8. Untreated	-	-	-	-	-
9. Full-season programme	Signum	Folicur	Amistar	Signum	Folicur
10. Pre-fruit and clean-up	Signum	Folicur	Amistar	-	Folicur
Primocane length in T1 (cm)	16	66	114	-	240
Growth stage	Start of growth	Early flower	Green fruit	End of fruit pick	After floricane removal

Spray timings: 1 - primocanes 15-30 cm long; 2 - primocanes 60-90 cm long; 3 - around 7 days before the start of fruit picking (to comply with Amistar 7 day harvest interval); 4 - within 7 days of end of fruit picking; 5 - within 7 days of floricane removal and tieing-in of primocanes.

[a]Every 2-3 weeks, primocanes were tied-up in bundles to the top support wire and then outwards and along. Weak primocanes, late-emerging canes, and canes in excess of 8/stool were removed.

[b]All primocanes were removed until the start of fruiting. Thereafter, newly developing primocanes were tied in bundles to the support wire as in treatments 1-4.

[c]Every 2-3 weeks, primocanes trailing on the ground were pushed into rows adjacent to the stools, and held them in position with bamboo canes. These canes were tied-up in January after removal of floricanes. Grass pathway was kept mown so that primocanes on floor could be sprayed.

Results and discussion

Crop growth

The mean length of primocanes at the time of application of sprays 1 and 2 were 16 cm and 66 cm respectively (Table 2.2), in accordance with the experiment requirements of spray application at specific lengths of primocanes (15-30 and 60-90 cm for sprays 1 and 2 respectively). At the third spray, applied around 7 days before first fruit pick, mean primocane length was 114 cm.

Purple blotch

No spores of *S. ruborum* were found on immediate examination of purple blotch lesions examined on 14 May and 11 June; however, abundant spore production was observed after damp incubation in the laboratory for a few days, indicating there was a risk of spores being produced in wet weather and splashed onto the growing primocanes.

In January 2009, a very high proportion of canes (> 90%) were affected by purple blotch in all treatments. The severity of purple blotch was noticeably greatest on canes untreated with fungicide (23 lesions per cane). The disease was significantly reduced by all the fungicide programmes. The full-season programme of five sprays applied to plants where primocanes were tied-in as they grew resulted in least disease (2 lesions per cane). A programme of three sprays applied up to the start of fruiting to plants where primocanes were tied in as they grew, appeared only slightly less effective (3-5 lesions cane) and was not statistically different from the five spray programme. It should be noted that the final spray treatment (the 'clean-up' spray after floricane removal) was done only three days after the assessment in January 2009 and would not be expected to affect purple blotch incidence or severity at this stage. Removal of all primocanes up to the start of fruiting (T5) on plants untreated with fungicide (Table 2.3) appeared to reduce disease but the difference was not significant

Although removal of early emerging primocanes appeared to reduce the mean number of purple blotch lesions per cane (from 23 to 14), the difference was not statistically significant ($P>0.05$) and most canes (88%) still had more than five lesions per cane. In contrast, where the early primocanes were removed and later emerging primocanes were tied-up and treated with fungicide, the proportion of canes with more than five lesions per cane was reduced to around 20-40%. It seems reasonable to assume that where there are fewer purple blotch lesions per cane, the probability of the disease affecting emergence of laterals or resulting in cane death is reduced. The effect of removal of the first flush of primocanes on crop yield was not determined in this project.

In May 2009, the severity of purple blotch was significantly reduced (P <0.001) by all fungicide treatments (Table 2.3). Disease severity was greatest on untreated plants where primocanes were tied-in (T1, 46% cane surface area affected) and least following a full-season fungicide programme where early primocanes had been removed (T7, 10% cane surface area affected). Fungicide programmes were more effective when applied to tied-in primocanes (13-18% surface area affected) than when applied to primocanes on the ground (28-30% surface area affected). Although in January 2009 early removal of primocanes had appeared to reduce purple blotch severity on canes untreated with fungicides (T5) there was no evidence of reduced disease severity on this treatment in May.

In a previous experiment (2007) on plants untreated with fungicide, tying-in primocanes as they grew did not reduce purple blotch compared with allowing canes to trail on the ground (54% and 62% surface area affected respectively). Again in this experiment tying-in primocanes as they grew did not reduce the severity of purple blotch on plants untreated with fungicide compared with primocanes allowed to trail on the ground (46 and 41% surface area affected respectively). In 2007 three sprays of Folicur significantly reduced severity of purple blotch compared with an untreated control when applied to tied-in primocanes but not when applied to primocanes on the ground.

In 2009 control of purple blotch was achieved with four and five-spray programmes of Signum, Folicur and Amistar both on primocanes tied-in as they grew and on primocanes allowed to trail on the ground. When assessed in May 2009 the level of disease control was improved significantly when the four and five-spray programmes were applied to tied-in primocanes (T3 and T4) compared with application to primocanes on the ground (T9 and T10) (Table 2.3). These results confirm that although tying-in of primocanes as they grow does not itself reduce purple blotch, it can improve control of the disease where fungicides with good activity against purple blotch (i.e. Amistar, Folicur, Signum) are applied to the crop.

Where primocanes are allowed to trail on the ground fungicide treatment can still provide control as long as spray coverage of primocanes is not prevented by growth of weeds or grass around the base of plants. Management of blackberry crop growth is significantly easier if old floricanes are removed before the new primocanes are tied in.

Table 2.3: Effect of crop management and fungicide programmes on blackberry purple blotch – Norfolk 2008/09

Treatment	January 2009			May 2009
	Log no lesions/cane	Mean no lesions/cane[a]	% canes with > 5 lesions[b]	% surface area affected
Primocanes tied-up				
1. Untreated	1.38	23.1	90 (6.4)	45.8
2. Pre-fruiting programme	0.58	2.8	28 (9.6)	19.9
3. Full season programme	0.43	1.7	18 (8.2)	13.8
4. Pre-fruit and clean-up	0.66	3.6	45 (10.6)	18.0
Early primocane removal				
5. Untreated	1.17	13.7	88 (7.1)	44.5
6. Pre-fruiting programme	0.78	5.0	40 (10.5)	27.4
7. Full season programme	0.48	2.0	20 (8.6)	10.0
Primocanes trail on floor				
8. Untreated	1.22	15.4	85 (7.7)	40.6
9. Full season programme	0.48	2.0	28 (9.6)	30.2
10. Pre-fruit and clean-up	0.83	5.8	60 (10.5)	28.0
Significance (27 df)	<0.001	-	<0.001	<0.001
LSD	0.273	-	-	12.58

[a] Back transformed from Log_{10} data.
[b] ( ) – standard errors from regression analysis.
[c] Primocanes removed until 16 May (start of fruit formation)

Crop vigour

Fungicide programmes significantly increased (P <0.001) floricane vigour both where primocanes had been tied-in as they grew and where primocanes had trailed on the ground. Floricane vigour in May 2009 was least on untreated canes that had been tied up (T1, index 1.3), and greatest on tied-up and trailed primocanes following the pre-fruit and clean-up programmes (T4 and 10, index 4.0). Low vigour scores were due to a high incidence of dead or part dead canes and to the high incidence of stunted growth of lateral branches. The four-spray 'pre-fruit and clean-up' programme was not inferior to the five-spray 'full season' programme with regard to either purple botch severity or cane vigour in May 2009.

Cane spot

A low level of cane spot occurred on both leaves and canes. When assessed in August 2008, one month after the third fungicide spray timing, there were significant differences between treatments. Cane spot severity was greatest on leaves of untreated plants where the canes had been tied-in (T1, 3.8% leaf area affected) and least following the three spray programme where early primocanes had been removed (T6 and 7, 0.1-0.2% leaf area affected) (Table 2.5). The severity of cane spot was significantly reduced (P <0.001) on plants untreated with fungicide both by early primocane removal (T5) and by allowing primocanes to trail on the ground (T8). A similar pattern of disease severity occurred on the

canes. These results indicate: 1. a three-spray programme of Signum, Amistar and Folicur greatly reduced cane spot severity on both leaves and canes (generally by around 70-80%); 2. in the absence of fungicide treatment, cane spot severity on leaves was reduced by early primocane removal, or by allowing canes to trail on the ground, compared with canes tied-in as they grew.

When assessed in January 2009, there were no significant differences between treatments. However, it is noticeable that cane spot severity was greatest on untreated tied-in primocanes (T1, 7.9 lesions/cane), and least on fungicide treated canes where early primocanes were removed (T6, 1.8 lesion/cane), in accord with the conclusions from the earlier disease assessment (Table 2.5).

Table 2.4: Effect of crop management and fungicide programmes on floricane vigour and winter kill – Norfolk, May 2009

Treatment	Floricane vigour (0-5)	Mean % canes dead or part dead	Mean % canes with stunted branches
Primocanes tied-up			
1. Untreated	1.3	58 (6.5)	44 (7.8)
2. Pre-fruiting programme	3.8	5 (3.2)	10 (5.1)
3. Full season programme	3.5	3 (2.3)	4 (3.4)
4. Pre-fruit and clean-up	4.0	2 (2.1)	4 (3.1)
Early primocane removal			
5. Untreated	2.5	30 (7.6)	24 (7.9)
6. Pre-fruiting programme	2.5	14 (5.1)	24 (7.4)
7. Full season programme	3.5	1 (1.6)	5 (4.1)
Primocanes trail on floor			
8. Untreated	2.0	38 (6.7)	38 (7.9)
9. Full season programme	3.8	7 (3.6)	8 (4.5)
10. Pre-fruit and clean-up	4.0	14 (4.6)	4 (3.1)
Significance (27 df)	<0.001	<0.001	<0.001
LSD	1.24	-	-

Table 2.5: Effect of crop management and fungicide programmes on cane spot – Norfolk 2008/09

Treatment	13 August 2008		January 2009	
	% leaf area affected	% cane area affected	Log. No. lesions/cane	Mean No. lesions/cane[a]
Primocanes tied-up				
1. Untreated	3.8	1.8	0.95	7.9
2. Pre-fruiting programme	0.4	0.3	0.53	2.4
3. Full season programme	0.5	0.6	0.60	3.0
4. Pre-fruit and clean-up	0.9	0.5	0.56	2.6
Early primocane removal				
5. Untreated	1.1	1.0	0.58	2.8
6. Pre-fruiting programme	0.2	0.8	0.45	1.8
7. Full season programme	0.1	0.9	0.53	2.4
Primocanes trail on floor				
8. Untreated	1.5	1.4	0.52	2.3
9. Full season programme	0.6	0.5	0.51	2.2
10. Pre-fruit and clean-up	0.3	0.4	0.44	1.7
Significance (27 df)	0.001	0.04	NS	-
LSD	1.42	1.23	-	-

[a] Back-transformed from Log_{10} data.

Conclusions

Year 1

1. Amistar, Bravo 500, Folicur and Signum all have activity against *S. ruborum*, inhibiting spore germination.
2. Severity of purple blotch was reduced by three-spray programmes of Folicur and Signum; Amistar, Bravo 500 and Cuprokylt FL appeared to reduce disease severity but differences were not quite significant at the 5% probability level.
3. Purple blotch pycnidia on floricanes have the potential to release spores during wet weather from at least May to August and probably over a longer period.
4. *S. ruborum* pycnidia containing spores were only found associated with purple lesions on canes of cv. Silvan; purpling on canes of other blackberry varieties may not be due to *S. ruborum*

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Year 2

1. Eight fungicides (Amistar, Consento, Cuprokylt, Paraat, Previcur Energy, Signum and two experimental products), a foliar fertiliser (potassium phosphite) amended with a wetter (Silwet-L77 or Omex SW7) and a wetter alone (Omex SW7) all significantly

reduced downy mildew on container-grown plants of the susceptible variety Loch Ness in spring 2008.

2. None of five programmes of fungicides and foliar nutrients significantly reduced downy mildew in an experiment in autumn 2008. Downy mildew affected 9% leaf area on untreated plants and was least (3%) on plants drenched once with Paraat.

3. Three out of eight treatments applied in 2007 to a crop of cv. Silvan badly affected by purple blotch significantly increased floricane vigour in May 2008. The treatments were Signum applied in May (x2) and September to plants where primocanes were allowed to trail on the ground, Folicur applied in May, June and September to a crop where primocanes were tied-in, and Folicur applied in May (x2) and September to the vegetative stage of a biennial crop (floricane removed).

Year 3

1. The efficacy of six fungicide and foliar fertiliser programmes in providing season-long control of downy mildew in a tunnel crop of cv. Loch Ness was not established due to lack of the disease at more than trace levels.

2. All seven fungicide programmes applied in 2008 to a crop of cv. Silvan badly affected by purple blotch significantly reduced the severity of the disease in January 2009 and increased crop vigour in May 2009. A programme of three sprays (Signum, Folicur and Amistar) applied up to the start of fruiting, to plants where primocanes were tied in as they grew reduced the number of lesions per cane from 23 to 3; this treatment appeared only slightly less effective and was not statistically different from a five spray programme.

3. On crop areas untreated with fungicides, removal of primocanes until the start of fruiting appeared to reduce purple blotch severity and increase floricane vigour the following spring but differences were not statistically significant.

4. On crop areas untreated with fungicide, tying-in primocanes as they grew did not reduce purple blotch severity or increase floricane vigour, compared with primocanes trailed on the ground. This confirms experimental results obtained in Year 2.

5. A low level of cane spot on leaves and canes was significantly reduced by a three spray programme of Signum, Folicur and Amistar.

6. On blackberry crop areas untreated with fungicide, cane spot severity was significantly reduced by early primocane removal and by allowing primocanes to trail on the ground, compared with primocanes tied-in as the crop grew.

Technology transfer

Presentations

Improved control of blackberry purple blotch and downy mildew. *EMRA/HDC Soft Fruit Seminar* East Malling, November 2008.

Control of blackberry purple blotch and downy mildew. *HDC/NSA Soft Fruit Technical Seminar*, Bedfordshire, December 2009.

Articles

Banishing berry mildew and blotch. *HDC News* **142**, 20-21.

Fungicides assessed on blackberry. *HDC News* **146**, p.10. New reports section

Strategies for purple blotch. *HDC News* **152**, 26.

More control over downy mildew and purple blotch. *HDC Soft Fruit Review Supplement*, *HDC News* **159**, December 2009, p 8.

Improved control of blackberry purple blotch and downy mildew. Technical Up-Date on Soft Fruit Research, East Malling Research Association Members Day Report - November 2008.

Project meeting

13 March 2008, Norfolk

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Reference

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Appendix

Trial diary - Norfolk

Date	Task/comment
17/04/08	Marked out trial plots. Very little growth and no primocanes seen, only growth on floricanes from last season. Some of floricanes appear dead – winter kill?
29/04/08	Primocanes now ranging from 2 – 30 cm in length – mean assessed length = 15.6 cm. Removed primocanes from plots of treatments 5, 6 & 7 as per plan. New growths not yet long enough to tie in. Spray treatment timing 1 aborted due to rain showers.
01/05/08	Applied Timing 1 sprays to plots as per protocol.
06/05/08	Primocanes on treatments 5, 6 & 7 removed. Primocanes on treatments 1, 2, 3 & 4 still not long enough to tie in. Some floricanes tied in to ease spraying.
14/05/08	Applied Timing 2 sprays to plots as per protocol. Crop flowering but still not over-vigorous. Primocanes measured, range 45 – 95 cm, mean length = 65.7 cm. Most primocanes not quite reaching the wires so few tied in. Sent excised slivers of blotch lesions for T O'N to process.
16/05/08	Primocanes on treatments 5, 6 & 7 removed.
27/05/08	Primocanes tied in on all plots (blocks 1 & 2) as per protocol. Floricanes flowering and fruiting now.
28/05/08	Primocanes tied in on all plots (blocks 3 & 4) as per protocol.
09/06/08	Primocanes tied in on all plots (blocks 1 & 2) as per protocol.
10/06/08	Primocanes tied in on all plots (blocks 3 & 4) as per protocol. Applied Timing 3 sprays to all plots as per protocol. Primocanes measured, range 91 – 148 cm, mean length = 113.6 cm. Crop still flowering but good fruit set. Fruit mainly green but just turning to red.
11/06/08	Sent excised slivers of blotch lesions
03/07/08	Primocanes tied in on all plots (block 1 only) as per protocol.
08/07/08	Primocanes tied in on all plots (block 2 only) as per protocol.
15/07/08	Primocanes tied in on all plots (blocks 3 & 4) as per protocol and re-did blocks 1 & 2 again (help from BX).
29/07/08	Primocanes tied in on whole trial. Requested grass between plots to be cut.

13/08/08	Applied Timing 4 sprays to all plots as per protocol. Crop at end of fruiting. Assessment done for leaf spotting and cane spot.
26/01/09	Applied Timing 5 sprays to all plots as per protocol. Crop only just thinned and tied in by RW Walpole staff towards the end of last week and spraying then delayed by weather.
29/01/09	Trial assessed for purple blotch
27/5/09	Trial assessed for purple blotch and floricane growth vigour

Trial diary - Kent

Date	Action	Mean primocane length (cm)	Fruiting stage
03/03/09	Trial set up and marked out	-	
08//04/09	Spray 1 (Paraat drench) applied	47	In leaf
15/04/09	Spray 2 applied	93	Flower
29/04/09	Spray 3 applied	88	Flower
13/05/09	Spray 4 applied. Downy mildew present	98	Start of fruiting
26/05/09	Spray 5 applied. Full disease assessment	95	Fruiting
10/06/09	Spray 6 applied	106	50% fruit red
24/06/09	Spray 7 applied	113	5% fruit black
08/07/09	Spray 8 applied	161	Fruiting
21/07/09	Spray 9 applied	120	Fruiting
04/08/09	Spray 10 applied	140	Fruiting
19/08/09	Spray 11 applied	118	Fruiting
22/09/09	Spray 12 applied	133	End of fruit picking
15/10/09	Full disease assessment completed.	-	