Project title	Sensitivity of apple powdery mildew (*Podosphaera leucotricha*) populations to triazole, QoI and SDHI fungicides
Project number:	TF195
Project leader:	Dr Angela Berrie East Malling Research
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Project coordinator:	
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Key words:	Apple mildew, insensitivity, fungicides

DISCLAIMER

AUTHENTICATION

I declare that this work was done under my 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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Report authorised by:

Professor Jerry V Cross
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GROWER SUMMARY

Headline

- There are some indications that there is more variability in the mildew response to Systhane (myclobutanil, a triazole fungicide) among the orchards tested than to Luna Privilege (fluopyram, an SDHI fungicide) and Tucana (pyraclostrobin, a QoI fungicide).

Background and expected deliverables

Apple powdery mildew can reduce yield and fruit quality in apples. Levels as low as 8% of mildewed leaves, can reduce yield and quality on sensitive varieties such as Cox. On other varieties, high levels of powdery mildew have been recorded in many commercial orchards, but the effect on yield and quality is not as well understood as on Cox.

All growers and advisors who have been consulted agree that powdery mildew control is becoming difficult. Some badly affected farms in East Kent have orchards with an average of 50-100% mildew-infected shoots. There are many possible reasons for poor mildew control, including a limited range of effective fungicides, reduced efficacy of triazole or QoI (strobilurin) fungicides due to changes in the sensitivity of the mildew population, change in shoot growth pattern due to climate change, poor spray cover or insufficient monitoring of mildew development.

Good control of powdery mildew during the growing season is the top priority. Triazoles are the most effective fungicides against apple powdery mildew and are therefore used intensively in apple orchards as there are few alternative products. This leads to repeated use of fungicides from the same chemical group, resulting in a high risk of mildew isolates with reduced sensitivity being selected.

Alternative products for mildew control, including potassium bicarbonate, potassium phosphite, Milsana (knotweed extract) and a biocontrol agent *Ampelomyces quisqualis,* have been evaluated as part of a Defra funded project (HH2502STF). Most had limited efficacy. A new Horticulture LINK project on chemical control in horticultural crops (CP 77, SCEPTRE) started in 2011. One of its objectives is to find new fungicides and/or alternative products for controlling powdery mildew on apple. Information on whether triazole (myclobutanil, penconazole) or QoI (kresoxim-methyl, pyraclostrobin) fungicides are less effective due to reduced sensitivity of mildew populations in orchards is important, as it will help growers to select appropriate fungicides to achieve good control and minimise the risk of insensitivity development. SDHI fungicides have a different mode of action to triazoles and QoI fungicides. New fungicides likely to be approved for use in apples in the future are SDHI fungicides and therefore it is relevant to include this group in the study.

Expected deliverables and benefits

Information on the sensitivity of apple powdery mildew to triazole and QoI fungicides and its possible contribution to the current poor mildew control will benefit the industry in the following ways:

(1) The information generated will complement that generated in the Horticulture LINK project (CP 77, SCEPTRE), in which new fungicides and/or alternative products for controlling powdery mildew are being investigated.

(2) It should provide the industry with a clearer understanding of fungicide control of apple powdery mildew.

(3) It will enable growers to select appropriate products to improve control as well as to reduce the risk of development of fungal resistance/insensitivity to fungicides.

Summary of the project and main conclusions

Potted MM106 rootstocks and Malus cv. Bittenfelder seedlings were raised in a mildew-free glasshouse. They were then treated with a range of doses of the test fungicides – Systhane (myclobutanil) Tucana (pyraclostrobin) and Luna Privilege (fluopyram) and then placed in apple orchards at East Malling and various parts of Kent where control of powdery mildew was known to be a problem. Untreated controls were also included. The apple rootstocks / seedlings were exposed to mildew for 48 hours and then collected and returned to the glasshouse to allow any mildew infection to develop. After one week the plants were assessed for mildew. The experiment was repeated twice – in May and July.

Through the mildew exposure experiment, we have determined the dose-response curves of mildew to Luna Privilege, Systhane and Tucana at several orchard sites in Kent. The results indicated that:

(1) Of the three fungicides tested, there were large differences in mildew response to the dose of Systhane among the sites tested.

(2) There were also indications that differences among sites in the mildew responses to Systhane increased from May to July.

Therefore, in year 3 the research will focus on instigation of mildew responses to the three fungicides at several sites over time (from May to August) using both seedlings and rootstocks.

Financial benefits

Growers can benefit from the project results in the following ways:

1) The results will help growers to select the correct fungicide products in spray programmes to control mildew and thereby minimise the establishment and subsequent spread of mildew strains that are insensitive to fungicides.
2) The results will help to maintain a good range of effective fungicides against mildew to achieve effective control.

Action points for growers

- There are no action points for growers at present as the project is at an early stage.

SCIENCE SECTION

Introduction

Apple mildew is probably, after scab and canker, the most important disease of apples in the UK. The disease can reduce yield and fruit quality. Mildew levels as low as 8% infected leaves can reduce the yield and quality of sensitive varieties such as Cox. On other varieties high levels of mildew have been recorded in many commercial orchards but the effect on yield and quality is not as well understood as on Cox.

All growers and advisers we have spoken to agree that powdery mildew control is becoming difficult, with some badly affected farms in East Kent having on average orchards with 50-100% mildew-infected shoots. All apple varieties appear to be affected, but the worst are Cox, Bramley, Gala, Jonagold and Braeburn. There are many possible reasons for the poor mildew control including:

- Limited range of effective fungicides – sulphur, myclobutanil, penconazole, pyraclostrobin, bupirimate and potassium bicarbonate
- Reduced efficacy of triazole or QoI (strobilurin) fungicides due to a change in the sensitivity of the mildew population. A previous project at EMR indicated some reduced sensitivity to myclobutanil
- Change in the shoot growth pattern due to climate change – shoot growth continuing after harvest when spraying has stopped, leading to a high incidence of primary vegetative mildew the following season
- Milder winters leading to improved survival of overwintering mildew
- Very favourable spring and summer weather – warm wet weather promoting shoot growth and mildew development and spread
- Growers more concerned with scab control
- Poor spray cover or insufficient monitoring of mildew development

Previous HDC-funded research (TF 156) at EMR showed that application of some surfactant products during the winter may significantly reduce the level of overwintering mildew in the buds. However, the rate necessary for achieving this exceeds the maximum concentration permitted. Thus, good control of powdery mildew during the growing season is the top priority.

Triazoles are the most effective fungicides against apple powdery mildew and consequently are used intensively in apple orchards as there are few alternative products. This leads to repeated use of fungicides from the same chemical group, resulting in a high risk of mildew isolates being selected with reduced sensitivity.

Alternative products for mildew control, including potassium bicarbonate, potassium phosphite, Milsana (knotweed extract) and a biocontrol agent *Ampelomyces quisqualis,* were evaluated as part of a Defra project (HH2502STF). Most had limited efficacy. A new HortLINK project on chemical control in horticultural crops (CP 77, SCEPTRE) started in 2011; one of its objectives is to find new fungicides and/or alternative products for controlling powdery mildew on apple. Information on whether triazole (myclobutanil, penconazole) or QoI (kresoxim-methyl, pyraclostrobin) fungicides are less effective, due to reduced sensitivity of the mildew populations in orchards, is important for selecting appropriate fungicides to achieve good control and minimise the risk of insensitivity development. New fungicides likely to be approved for use in apples in the future are SDHI fungicides and therefore it is relevant to include this group in the study.

Chemical companies routinely monitor fungicide resistance for the major fungicide chemical groups and the major fungal pathogens, including apple scab, as part of FRAC (Fungicide resistance action committee). No monitoring of sensitivity of apple powdery mildew to triazoles has been conducted in recent years and there are no standard methods for monitoring apple powdery mildew sensitivity to fungicides published by FRAC. Reduced sensitivity of powdery mildews to triazoles, and more recently to QoIs, has been reported in other crops, including grape.

Project aim

To develop a sustainable, cost effective system for the control of apple powdery mildew (*Podosphaera leucotricha*)

Project objectives:

1. To develop a practical method for monitoring the sensitivity of populations of *P. leucotricha* to triazole, QoI and other fungicides
2. To use the method to monitor the sensitivity of mildew populations to triazoles, QoI and other fungicides in apple orchards

Materials and methods

In year 1, we established exact protocols for conducting experimental work for determining the sensitivity of apple powdery mildew to fungicides; these protocols were used in the year 2 testing.

Potted rootstocks of MM 106 plants and apple seedlings cv. *Malus bittenfelder* were raised in a mildew-free glasshouse. Whenever there were trace levels of mildew on these plants, they were treated immediately with fungicides other than Systhane - these treatments were applied at least 10 days before the experimental treatments (fungicides) were applied. They were then treated with a range of fungicide concentrations of Systhane (myclobutanil), Tucana (pyraclostrobin) and Luna Privilege (fluopyram). Four levels of concentration for each fungicide (Table 1) were used; these levels were determined on the assumption of 1,000 L per ha for spray volume.

Table 1. Rate of each fungicide to be used

Product	active (single active product)	Mode of action	Concentration (g or ml in 1 L water)			
			C1	C2	C3	C4
Systhane	myclobutanil (20%)	DMI	0.0045	0.045	0.225	0.45
Tucana	pyraclostrobin (23.6%)	QoI	0.0044	0.044	0.22	0.44
Luna Privilege	fluopyram (50%)	SDHI	0.003	0.030	0.15	0.30

Treated plants were then exposed to one of several sources of powdery mildew. These plants were physically placed next to trees/plants with mildew in orchards in Kent for 48 or 72 h before being moved back to a contained glasshouse compartment. These orchards were known to have had problems with the control of powdery mildew in the past. There were four or five plants for each combination of fungicide, concentration and location. In addition, for each location, there were also six plants that did not receive any fungicides and these served as a control treatment.

About one week after the exposure, the number of powdery mildew lesions was counted on the top four fully unrolled leaves on each shoot; usually there were three shoots per potted plant. For seedlings, only four youngest unrolled leaves were assessed for powdery mildew.

This exposure treatment was conducted twice, once in May 2012 and once in July 2012. Table 2 gives the details of each exposure treatment.

Results

In the May exposure experiment, the rootstocks were exposed to six sites and the seedlings to three sites. For the rootstocks, only at five of the six sites was the level of resulting mildew moderate to high. For the sixth site (the Upchurch site), most plants stopped growing because of wind damage to the shoot tips during the transportation.

Table 2. Sites used in 2012 for rootstocks and /or seedling exposure to mildew

Trial date 2012	Code / site dates	Site	Rootstocks	Seedlings
May 21-25	A 21-23	CW108, Cox, Home Farm EMR	Yes	Yes
	B 21-23	TL161,Gala, Rocks Farm East Malling	Yes	Yes
	C 21-23	Checkley, Braeburn, Broadwater Farm, West Malling	Yes	Yes
	D 22-24	Hinge, Ham Green 2 row Braeburn, Upchurch	Yes	No
	E 22-25	Everett, Cox, Moatlands Farm, Paddock Wood	Yes	No
	F 22-24	Murch, Organic Jonagold and Gala, Cartlodge Orchard, Blean	Yes	No
July 24-30	A 24-26	CW120/121, Cox, Home Farm, EMR	Yes	No
	B 24-26	WM132, Cox, Gala, Fiesta, Discovery, Home Farm, East Malling	Yes	No
	C 25-27	Checkley, 2 row Bramley (12 & 19), Broadwater Farm, West Malling	Yes (C)	Yes (D)
	D 26-30	Highwood, Sheerlands Farm, Jonagold, Pluckley	Yes (D)	Yes (E)
	E 27-30	Hinge, Ham Green 2 row Braeburn, Upchurch	Yes (E)	Yes (F)
	F 27-30	NFF, Pope, Cox, Chartham	Yes (F)	No

For Luna Privilege, there were small differences in the relationship of mildew severity and incidence on seedlings with the dose (Fig. 1). At the C2 concentration, Luna Privilege effectively controlled mildew. For Systhane, there were considerable differences between the three sites in the dose-responsive curves for mildew development, particularly when the incidence of mildewed leaves was considered (Fig. 1). For example, only at one site was mildew effectively controlled at the C3 concentration. For Tucana, the dose-response of mildew development was between those for Luna Privilege and Systhane.

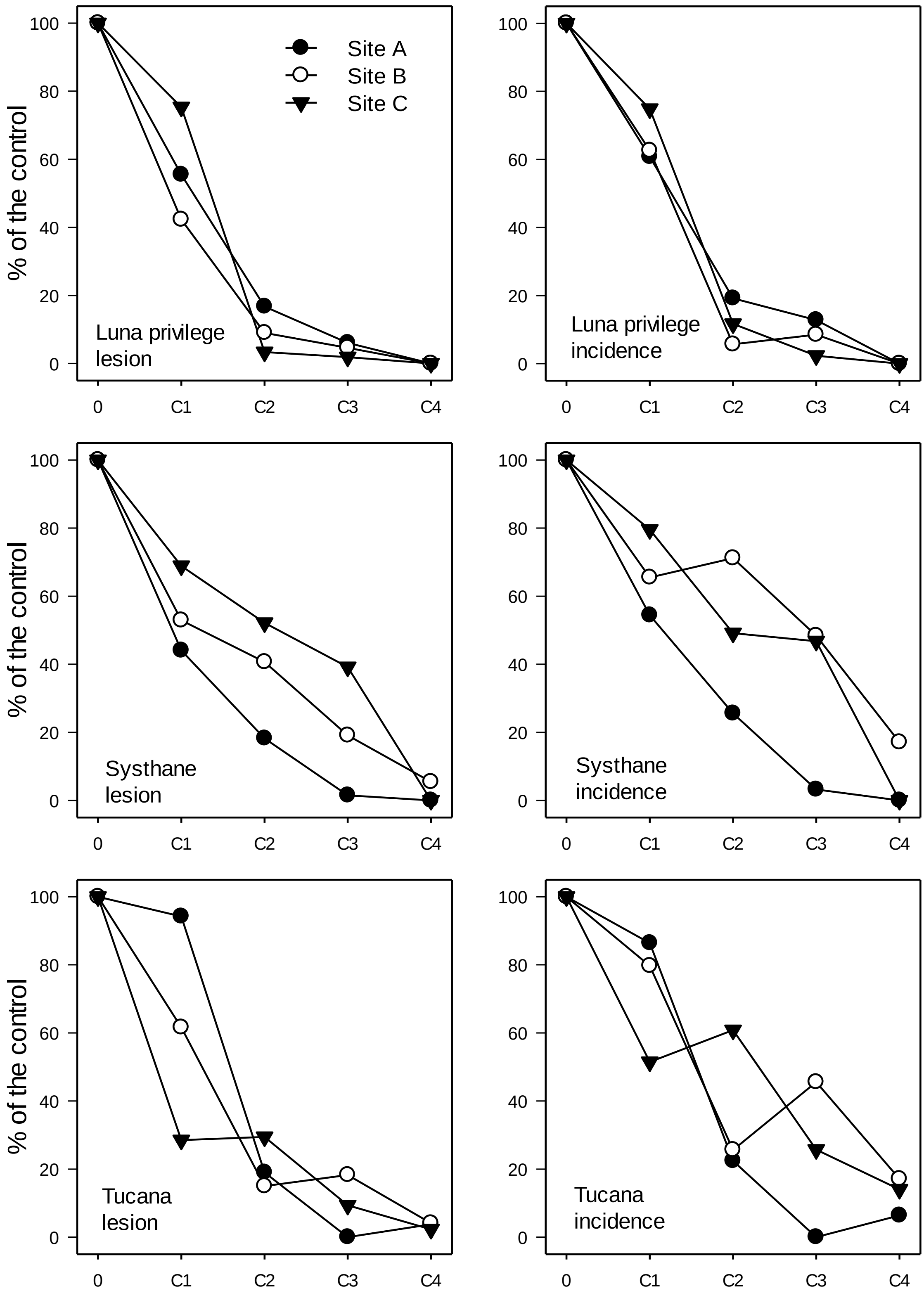

Figure 1. Average number of lesions per leaf and incidence of leaves with mildew on seedlings of cv. *Malus bittenfelder* to powdery mildew for 48-72 h at three sites in May 2012. The exact concentration for each fungicide and location were given in Table 1 and Table 2, respectively.

Similar results were obtained for the rootstock plants, except that differences in the dose-responses among the three fungicides were less than on seedlings (Fig. 2).

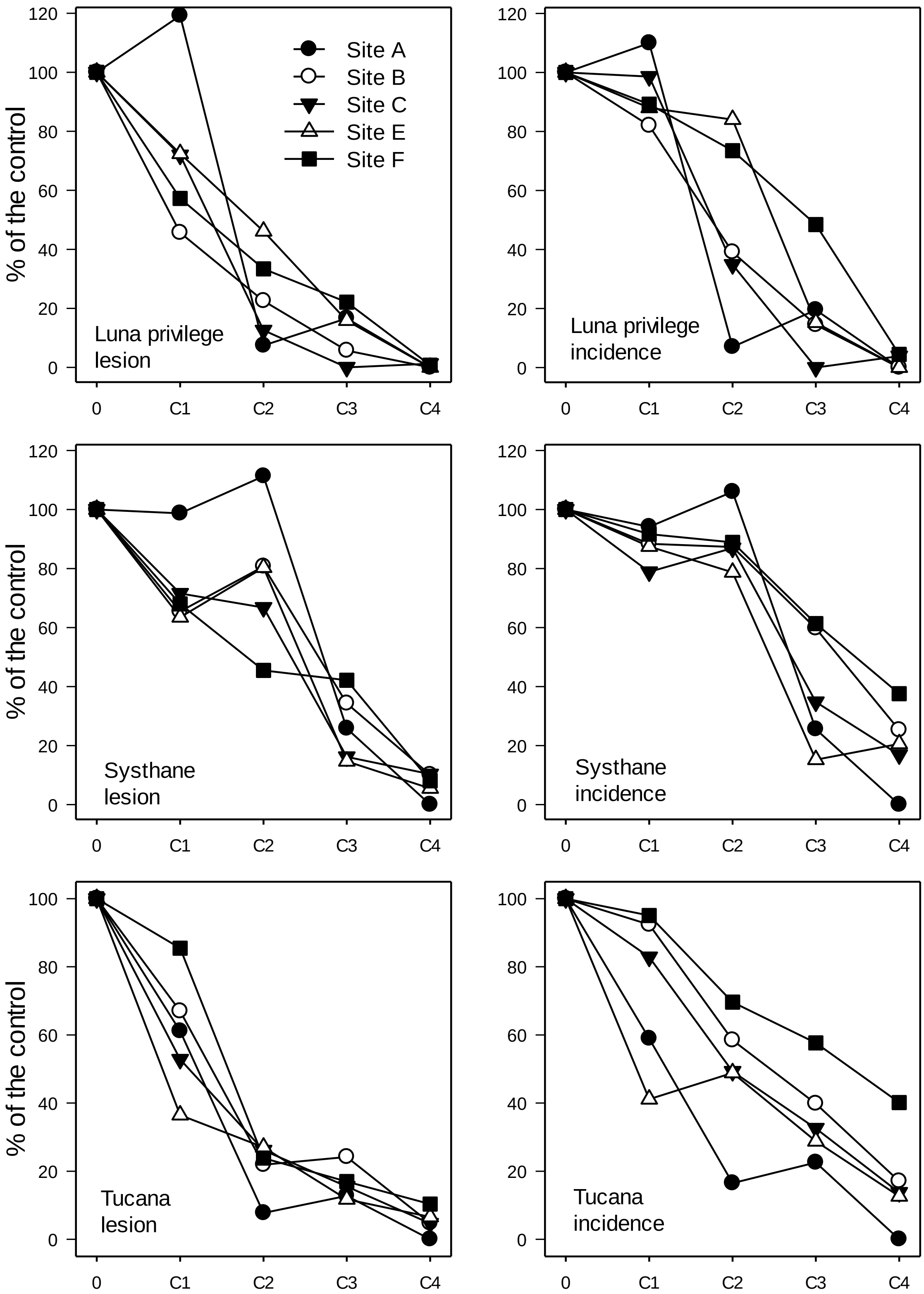

Figure 2. Average number of lesions per leaf and incidence of leaves with mildew on MM106 rootstock plants to powdery mildew for 48-72 h at six sites in May 2012. The exact concentration for each fungicide and location were given in Table 1 and Table 2, respectively. At one site, no mildew lesions were observed because most plants stopped growing due to wind damage to the shoots during the transportation.

For the July exposure experiment, there was only a trace level of mildew on rootstocks at all six sites; hence no useful data were generated on rootstocks. On the seedlings, the level of mildew was moderate on two sites whereas it was at the trace level at the third site. Again, similar to the seedling exposure in May, there was little difference in the dose-response curves between the two sites for Luna Privilege but large difference for Systhane (Fig. 3).

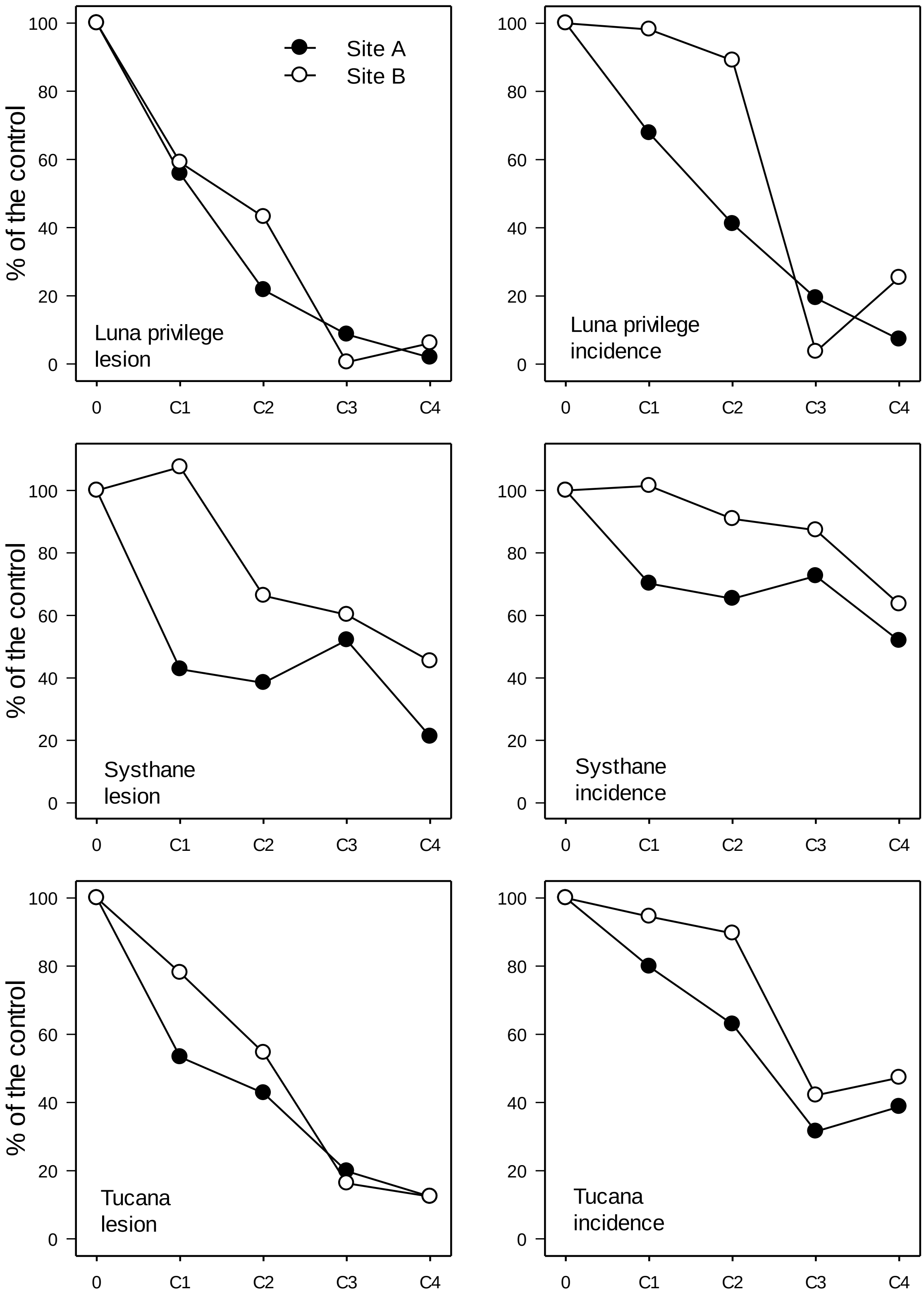

Figure 3. Average number of lesions per leaf and incidence of leaves with mildew on seedlings of cv. *Malus bittenfelder* to powdery mildew for 48-72 h at three sites in July 2012. The exact concentration for each fungicide and location were given in Table 1 and Table 2, respectively. At two sites, no mildew lesions were observed.

Discussion

Through the exposure experiment, we have determined the dose-response curves of mildew to Luna Privilege, Systhane and Tucana at several sites in Kent. The results indicated that of the three fungicides tested there were large differences in mildew response to the dose of Systhane among the sites tested. Furthermore, there were also indications that differences among sites in the mildew responses to Systhane increased from May to July.

Therefore, in year 3 we shall focus on an investigation of mildew responses to the three fungicides at six sites over time (from May to August) using both seedlings and rootstocks.

Conclusions

- We have established mildew response to a range of concentrations of three fungicides at several orchards
- Of the three fungicides, the differences in the dose-response of mildew among sites tested were greatest for Systhane

Technology transfer

- We discussed the project work with several consultants and briefly discussed this work during the HDC agronomy day at East Malling Research in 2012