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Key staff:	Professor Xiangming Xu Joyce Robinson
Location of project:	East Malling Research New Road East Malling, Kent ME19 6BJ
Project coordinator:	Nigel Kitney
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The results and conclusions in this report are based on an investigation 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.

Professor Xiangming Xu

East Malling Research

Signature ..... Date .....

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GROWER SUMMARY

Headline

- It would be advisable not to continuously use myclobutanil or fenbuconazole and dithianon together over many seasons for scab control.

Background and expected deliverables

One consequence of overusing fungicides is the selection of fungal strains less sensitive to the fungicides. Disease management strategies have been developed in order to reduce the risk of emergence and spread of these insensitive fungal strains. Overusing demethylation inhibitor (DMI) fungicides has led to emergence of scab strains less sensitive to DMI fungicides in the USA and Canada. In the long-term, this may lead to loss of disease control. There is some anecdotal evidence that isolates from DMI-sprayed orchards in the UK appear to have an overall reduced sensitivity to myclobutanil (Systhane), which is commonly observed in other regions. However, failure in scab control is often due to poor spray timing.

A few recent studies showed that cross-resistance of the scab fungus to fungicides may or may not exist, depending on particular fungal populations concerned. If reduced sensitivity to one fungicide exists, then care is needed to select alternative products without jeopardising disease control and resistance management. However, the necessary knowledge on cross-resistance that is required to make such rational selection decisions is not yet available.

Recent Canadian research points to independent resistance mechanisms to myclobutanil and kresoxim-methyl (Stroby) but a positive correlation in resistance to myclobutanil and flusilazole. This result does not agree with results obtained in New York State. More recent research on other pathogens also suggests that the presence and the extent of cross-resistance depend on the particular fungal populations and fungicides concerned. It is, therefore, necessary to carry out research for each particular fungal population to understand the potential of cross-resistance to particular fungicides. In any anti-resistance strategy, information on cross-resistance is critical to devising control strategies in cases where reduced sensitivities to one fungicide have been observed. There has been no published information on the baseline sensitivity and the current status of sensitivity to common scab fungicides in the UK scab population.

Recently, HDC funded East Malling Research (Project TF 190) to conduct a preliminary investigation on the cross-resistance of apple scab (with a limited number of isolates) to all

scab fungicides registered in the UK. Most of the observed cross-resistance to fungicides is expected on the basis of the chemistry. However, the strong correlation in the sensitivity to dithianon (a multi-site action fungicide) with DMI fungicides (e.g. myclobutanil and fenbuconazole) was unexpected, and is also worrying since dithianon and DMI fungicides are often used in the same spray programmes.

Understanding scab population structure with particular reference to its virulence (race) is critically important for a breeding programme and effective deployment of current cultivars with different resistance genes. Recently, the nomenclature of scab races and the corresponding resistance genes has undergone extensive revisions, culminating in the proposition of a new nomenclature system in 2011. Consequently, a new set of indicator genotypes is proposed to differentiate scab races.

Scientists at EMR propose to establish a plot with all 16 proposed indicator genotypes for future monitoring of scab race structure, joining a world-wide monitoring programme. This monitoring will generate valuable information not only for growers in terms of cultivar deployment, but also for breeders in terms of breeding for resistance and for pathologists in terms of predicting the spread of new virulence.

- This project will generate information to confirm whether there is significant correlation in the scab response (sensitivity) to dithianon and myclobutanil.
- This correlation, if confirmed, will have a significant impact on our current scab control programmes.

Summary of the project and main conclusions

EMR has obtained grafting wood of all indicator genotypes for differentiating scab races from a Swiss researcher and successfully grafted them to rootstocks and maintained them as potted plants. These will be planted out in an orchard at East Malling Research in 2014.

Thirty single spore isolates were collected from several orchards where scab control was problematic in recent years, and initiated *in vitro* testing for their sensitivities to myclobutanil, fenbuconazole and dithianon. The following conclusions were drawn:

- Dithianon is more effective against apple scab as a protectant then as a curative fungicide.

- Using QoI (quinone outside inhibitors) fungicides alone to control scab is not advisable.
- There is a weak (though overall significant) correlation between the sensitivity to dithianon and DMIs (fenbuconazole and myclobutanil) in reducing germ tube elongation, suggesting that it might be better not to continuously use these three fungicides together over many seasons.

Financial benefits

New information on the sensitivity of scab isolates to different fungicides can inform growers and advisors in drawing up fungicide spray programmes. Improving spray programmes to maintain good control of apple scab will reduce the level of crop losses to this disease.

Action points for growers

- Use correct products as alternatives to control scab and minimise the establishment and subsequent spread of scab strains that are insensitive to fungicides.
- Maintain a good range of effective fungicides against scab to achieve effective control.
- Plant apple cultivars with an appropriate resistance background, selected partially on the basis of scab monitoring results on the indicator genotypes in the future.
- Dithianon is a good protectant fungicide against scab. It would be advisable not to continuously use myclobutanil or fenbuconazole and dithianon together over many seasons.

SCIENCE SECTION

Introduction

Apple scab, caused by *Venturia inaequalis* (Cke.) Wint., is an economically important disease of apples worldwide. The disease attacks leaves, flowers, fruits, shoots and bud scales. Scab control is usually achieved by the use of fungicide sprays applied routinely from bud burst at 7-10 d intervals until the risk of scab ceases. Demethylation inhibitor (DMI) fungicides are probably the most important group of fungicides for scab control in the UK because of their curative action against scab and their control of powdery mildew, which in the UK is one of the other most important disease of apples. Overuse of DMI fungicides in some countries has led to selection and subsequent establishment of *V. inaequalis* strains that are less sensitive to DMI fungicides (Stanis & Jones, 1985; Thind *et al*., 1986; Hildbrand *et al*., 1989; Braun & McRae, 1992; Köller *et al*., 1997; Jobin & Carisse, 2007). Resistance to DMI fungicides is believed to be quantitative (Georgopoulos & Skylakakis, 1986; Köller & Scheinpflug, 1987; Smith *et al*., 1991); consequently, the loss of sensitivity by the pathogen tends to be gradual.

Information on cross-resistance is critical for devising control strategies where reduced sensitivity to one fungicide is observed. For *V. inaequalis*, there appears to be a lack of cross-resistance among dodine, the benzimidazoles and the DMIs. The efficacy of scab control achieved with benzimidazoles in orchards with fungal strains resistant to dodine was high (Jones, 1981), and DMI fungicides controlled scab effectively in orchards located within a region known for widespread dodine and benzimidazole resistance (Wilcox *et al*., 1992). Recent research indicated, however, that the mechanisms of resistance to DMIs and dodine fungicides might not be entirely independent (Köller & Wilcox, 1999; Köller & Wilcox, 2000). Isolates of *V. inaequalis* selected for phenotypic traits of resistance to dodine or benomyl remained as sensitive to other classes of fungicides; but isolates that were already resistant to dodine were prone to accelerated adaptations to other fungicides.

In the UK, most apple growers apply spray programmes, made up of combinations of fungicides which differ in mode of action, to achieve better control and minimise the risk of fungicide resistance. The use of DMI fungicides in the programme has increased in recent years, mainly because of the lack of alternative products to control powdery mildew. Two common DMI fungicides used in the UK to control scab are Systhane (a.s. myclobutanil) and Indar (a.s. fenbuconazole); the former is more widely used because of its efficacy against powdery mildew. There is some evidence for reduced sensitivities to myclobutanil in the UK (Roberts & Crute, 1994; Gao *et al*., 2009); nevertheless, poor scab control in sprayed

orchards can usually be attributed to poor spray timing and/or extended spray intervals due to unfavourable weather (Berrie, pers comm.). Due to the lack of alternatives in controlling scab and powdery mildew, growers sometimes continue to use DMI fungicides, even in orchards with reduced sensitivity to them.

Recently, HDC funded EMR (TF 190) to conduct a preliminary investigation on the cross-resistance of apple scab (with a limited number of isolates) to all scab fungicides registered in the UK (TF190). Most of the observed cross-resistance to fungicides is expected on the basis of the chemistry. However, the strong correlation in the sensitivity to dithianon (a multi-site action fungicide) with DMI fungicides (e.g. myclobutanil and fenbuconazole) was unexpected and is also worrying since dithianon and DMI fungicides are often used in the same spray programmes.

Understanding scab population structure with particular reference to its virulence (race) is critically important for effective deployment of current cultivars with different resistance genes. Recently, the nomenclature of scab races and the corresponding resistance genes has undergone extensive revisions, culminating in the proposition of a new nomenclature system in 2011. Consequently, a new set of indicator genotypes is proposed to differentiate scab races.

Defra is funding EMR for a project on scab epidemiology and genetics. In the Defra project, we shall collect many isolates from different orchards for molecular characterisation. These isolates can also be used for testing insensitivities to fungicides, thus saving cost.

We propose to establish a plot at EMR with 16 proposed indicator genotypes for future monitoring of scab race structure, joining a world-wide monitoring programme. This monitoring will generate valuable information not only for growers in terms of cultivar deployment.

Materials and methods

Establishing a plot with scab race indicator genotypes

Graft bud wood of all indicator genotypes was obtained from Switzerland, grafted onto MM106, potted up and maintained in a sand-bed.

Collection of samples

Samples of leaves or fruit with actively sporulating lesions of apple scab were obtained from various orchards in the summers of 2009 and 2010 via several consultants; these orchards all experienced problems in controlling scab. Once delivered to the lab at EMR, actively sporulating lesions were cut out from the leaves or fruit using a cork borer. The lesions were then laid out on paper towels and allowed to air dry for 48 h. The scab lesions were individually placed into a micro-centrifuge tube, and stored at -18°C until required.

Obtaining single-spore isolates

In order to produce reliable test results, we made single spore isolates from sampled leaf discs. We aimed to obtain 10-15 single spore isolates for each sampling site. PDA agar (WA, 15 g/L), amended with rifamycin (50 mg/L) (Sigma-Aldrich, Poole, UK) after autoclaving, was used to obtain single-spore isolates. An infected leaf disc (stored at -18°C) was added to deionised water and agitated thoroughly to release conidia. Conidial suspensions were adjusted to $8x10^3$ per ml and 40 µl of suspension pipetted onto the rifamycin-amended WA plates and spread evenly. After incubation at 15°C for 24 h, individual germinated spores were excised using a needle under a microscope in a laminar flow cabinet, and placed on potato dextrose agar (PDA) plates. Plates were incubated at 15°C and, when large enough, each colony was transferred to a fresh PDA plate.

In vitro testing for fungicide sensitivity

Fungal isolates were tested for sensitivity to three fungicides (Table 1). For those fungicides with two active substances, we have obtained formulated products with each active substance (a.s.) for ease of data interpretation. The concentrations for testing were determined from the previous HDC-funded project (TF190); for each fungicide, five concentrations were used. A stock solution for each fungicide was prepared and an appropriate amount of the stock solution was used to amend PDA to produce agar plates with required concentrations of each fungicide. Rifamycin was also added to the agar (0.05 µg/ml) to reduce bacterial contamination.

Table 1. List of fungicides and their a.s. and testing concentrations (ppm, mg/L) used for testing scab isolates

Product	a.s.	Mode of action	FRAC code	Concentration					
				C1	C2	C3	C4	C5	C6
Systhane	Myclobutanil	Curative (DMI)	G1(3)	0	0.01	0.1	0.5	2	5
Indar	Fenbuconazole	Curative (DMI)	G1(3)	0	0.01	0.05	0.25	0.5	1
Dithianon	Dithianon	Both (MSC)	M9	0	0.01	0.1	0.5	2	5

Curative effect

Mycelial plugs of 6 mm size were cut from each isolate and placed on to the agar plates with each concentration of specific fungicide (Table 1). For each combination of concentration, isolate and fungicide, there were two replicate plates. On each plate there were three mycelial plugs that were 5 cm from each other. The plates were incubated at 20°C on the bench in the lab. The length and width of each colony was measured 4-5 weeks after incubation. For each isolate/fungicide/dose combination, there were two plates, each with three plugs. For the control treatment (no fungicides), 4-5 plates were used.

Because of heavy contamination of many isolates during the plug test, we have used the germination tube elongation test to assess fungal sensitivity to fungicides. A suspension of *V. inaequalis* conidia of a test sample (leaf disc) was prepared and adjusted to approximately 5000 conidia per ml using a haemocytometer. A 20 µl drop of each spore suspension was then placed in the centre of an agar plate and evenly spread over the agar surface using a sterile rod. The plates were then incubated at 20°C on the bench for 48 hours. After incubation, the growth of fungal hyphae was assessed. Where a conidium developed multiple germ tubes, only the longest hypha was recorded. Assessment of a single sample at all concentrations was completed within 60 min. Hyphal length was measured using a graticule eyepiece placed in the eyepiece of a microscope (eyepiece magnification X10, objective magnification X10); 200 intersections on the graticule eyepiece are equal to 10 mm. A germinated spore was then randomly selected from the view field and hyphal length was estimated. For each isolate/fungicide/dose combination, there were two plates and within each plate 50 spores were randomly assessed for germination and, if germinated, germ tube length.

Data analysis

In several cases, where the fungal growth/development was much greater in fungicide-amended plates than in untreated plates, we substituted the fungal development without fungicides with the larger development value. ED_{50} values were estimated by fitting an exponential or a linear by linear quotient model to the fungal growth data (adjusted for initial plug size). It is not possible to fit a single model type to all the data sets; thus, the better of the two models (on the basis of the percentage of variance accounted for) was chosen for each sample to estimate the ED_{50} value. For a few data sets, both models failed to fit the data but the fungal development was clearly reduced by more than 50%; we used the simple linear interpolation to estimate the ED_{50} value. In several other cases, it was not possible to estimate the ED_{50} value and fungal growth was only reduced slightly within the fungicide concentration tested; for these cases, we simply indicate that the ED_{50} value was greater at the largest concentration tested. Both normal and Spearman correlation coefficients were calculated between ED_{50} values for each pair of fungicides. Genstat (Payne, 2006) was used in all analyses.

Analysis from BASF

We also supplied BASF with 18 single spore isolates for testing against other fungicides: dithianon (spore germination test), boscalid (spore germination test), difenconazole (detached leaf test - Epilogic, Freising, Germany), pyrimethanil (spore germination test, detached leaf test), and quinone outside inhibitor or QoI (pyrosequencing of cytochrome b, spore germination test).

Results and discussion

Establishing a plot for monitoring scab race structure

We have obtained graft wood of all 16 indicator genotypes (Table 2) for testing scab races from a Swiss researcher Dr Andrea Patocchi (Agroscope Changins-Wädenswil Research Station ACW, Schloss, P.O. Box 8820, Wädenswil, Switzerland) and have successfully grafted them to rootstocks. There are about four-five plants per indicator genotype. They have been re-potted and maintained in a sand-bed. Because of the extreme wet weather in early 2014, we plan to plant them out later in 2014, together with the new apple genetic banks. These plants will be regularly monitored to assess the race profile of the scab fungus and contribute to global research on understanding the scab race structure over time.

Table 2. A set of 16 *Malus* indicator genotypes to differentiate scab races

Host	Phenotype	Resistance	Virulence	Race
Durello di Forlì	stellate necrosis	Vd (Rvi13)	AvrRvi13	13 (EU-NL05)
Dülmener Rosen	chlorosis	Vdr1 (Rvi14)	AvrRvi14	14
Hansen's baccata #2	chlorosis	Vb (Rvi11)	*AvrRvi11*	11
TSR34T15	stellate necrosis	Vh2=Vr-A (Rvi2)	AvrRvi2	2
Gala	susceptibility			0
J34 (F1 of Dolgo)	stellate necrosis	Vdolgo (Rvi9)	AvrRvi9	9
Priscilla	chlorosis	Vf (Rvi6)	AvrRvi6	6 (EU-D42)
9-AR2T196	hypersensitive response	Vm (Rvi5)	AvrRvi5	5
TSR33T239	hypersensitive response	Vh4 = Vx = Vr1 (Rvi4)	AvrRvi4	4
F1 of *M.* x *floribunda* 821	hypersensitive response	Vfh (rvi7)	AvrRvi7	7
A723-6	hypersensitive response	Va (Rvi10)	AvrRvi10	10
Golden Delicious	necrosis	Vg (Rvi1)	AvrRvi1	1
GMAL2473	hypersensitive response	Vr2 (Rvi15)	AvrRvi15	15
Q71 (Geneva x Braeburn)		Vh3.1 (Rvi3)	AvrRvi3	3
B45 (Pacific Beauty x *M. sieversii* GMAL 4302-X8)		Vh8 (Rvi8)	AvrRvi8	8
M. baccata jackii		Vbj (Rvi12)	AvrRvi12	12

Isolate collection and testing

We have collected 30 single spore isolates from several orchards where scab control was problematic in recent years - in 2009 and 2010. Unexpectedly, we encountered severe contamination problems because we cannot sterilise fungicides before we add them to the agar media. It took us at least a month to find a way to reduce (though not eliminate) the contamination problem. Thus, we had to use the germ tube length test method for assessing curative effects, which was much more labour intensive. In all we have tested 18 isolates for their sensitivities to three fungicides: nine were tested with the plug method and the other with the germ tube elongation method. Including the 22 isolates tested in the previous project (TF 190), we have 40 isolates with sensitivities to fenbuconazole, myclobutanil and dithianon determined (22 with the plug method and 18 with the germ tube method).

ED_{50} values

Table 1 presents the estimated ED_{50} values for three fungicides. As pointed out previously, the project focus is on the correlation among the estimated ED_{50} values rather than their actual magnitudes. For the most samples from problematic orchards (isolates starting with 07, 09 or 10 in Table 1), the level of insensitivity to myclobutanil has increased at least 10 times compared to previously reported baseline values and to the baseline value estimated from the isolates in unsprayed orchards (isolates starting with 05 and 06 10 in Table 3).

Figure 1 shows the scatterplot of ED_{50} values against two fungicides. There is significant ($P < 0.01$) correlation between all three pairwise ED_{50} values: $r = 0.483$ (dithianon – fenbuconazole), 0.559 (dithianon – myclobutanil) and 0.524 (myclobutanil –fenbuconazole). However, the correlation is far from perfect (Fig. 1). For example, there is nearly 68% of variability in the fenbuconazole ED_{50} values that cannot be explained by the myclobutanil ED_{50} values.

Interestingly, the ED_{50} values based on the plug test were significantly higher than those from the germ tube test for all three fungicides, especially for dithianon (Fig. 2). The median ED_{50} value was 4.0, 0.9 and 3.7 ppm for dithianon, fenbuconazole and myclobutanil, respectively, based on the plug test. The corresponding values for the germ tube test were 0.21, 0.36 and 0.20 ppm. This could be due the fact that fungal mycelium mass may be more tolerant to fungicides than individual germ tubes. The results may also suggest that dithianon is not as good as myclobutanil and fenbuconazole when applied as a curative treatment (of course, assuming no reduced sensitivities to all three fungicides).

As expected, dithianon had much better efficacy as a protectant – reducing the number of spores that germinated – than both myclobutanil and fenbuconazole (Fig. 3), which are known to control apple scab as curative fungicides. For dithianon, the ED50 values for reducing germination were significantly lower than for reducing germ tube elongation of the same isolates; it ranged from 0.01 to 0.57 ppm (median = 0.12 ppm) in germination reduction, compared to 0.08 to 1.40 ppm (median = 0.21 ppm) for reducing germ tube elongation.

Table 3: Summary of fungicide testing results (ED_{50} values – ppm) with apple scab; those isolates tested in 2012 were from the previous project TF190

Type	Test year	Isolate	Dithianon	Fenbuconazole	Myclobutanil
Plug	2012	07/064Short1	N.A.	0.822	2.955
Plug	2012	07_064inter5	3.012	0.143	2.623
Plug	2012	07_064Long5	4.0	1.007	7.50
Plug	2012	07_064short8	7.50	1.25	7.50
Plug	2012	07_065Inter6	7.656	1.25	7.494
Plug	2012	07_065long_4	3.887	0.909	5.079
Plug	2012	07_065long10	8.082	0.661	4.93
Plug	2012	07_065long4	0.406	N.A.	0.01
Plug	2012	07_065short1	0.004	0.006	0.006
Plug	2012	09_003	3.4	1	0.015
Plug	2012	09_006	1.149	0.9	0.166
Plug	2012	09_031(6)	3.894	2.02	4.722
Plug	2012	09_034(2)	5.168	0.987	4.841
Plug	2014	09_0151-1	0.053	0.171	N.A.
Plug	2014	09_020-7	> 5[a]	1.25	4.372
Plug	2014	09_026-11	> 5	0.524	4.964
Plug	2014	09_028-1	> 5	0.073	1.401
Plug	2014	09_030-1	> 5	1.25	3.543
Plug	2014	09_032-1	0.855	0.055	4.847
Plug	2014	09_034-1	> 5	0.676	3.382
Plug	2014	09_037-1	1.376	0.694	3.712
Plug	2014	09_039-1	> 5	1.25	3.4
Spore	2012	05_320	0.008	0.014	0.003
Spore	2012	05_340	0.003	0.022	0.021
Spore	2012	05_354	0.689	0.825	2.50
Spore	2012	06_003	0.05	N.A.	0.001
Spore	2012	06_034	2.5	N.A.	0.028
Spore	2012	06_053	1.719	0.25	0.041
Spore	2012	06_112	0.522	0.003	0.01
Spore	2012	09_001	0.286	N.A.	0.707
Spore	2012	09_31_4	0.018	0.105	0.1
Spore	2014	09_027	0.2408	0.368	0.081
Spore	2014	09_028	0.209	0.236	3.282
Spore	2014	09_032	0.082	0.747	2.659
Spore	2014	09_033	0.098	0.364	5.0
Spore	2014	09_035	0.210	0.361	0.1
Spore	2014	09_036	1.143	0.050	3.683
Spore	2014	09_037	0.078	1.25	2.036
Spore	2014	09_040	1.404	0.477	0.306
Spore	2014	10_001	0.086	0.926	3.926

[a]: In statistical analysis (correlation and ANOVA), ED_{50} was given a value of 7.5 ppm

Type	Test year	Isolate	Dithianon	Fenbuconazole	Myclobutanil

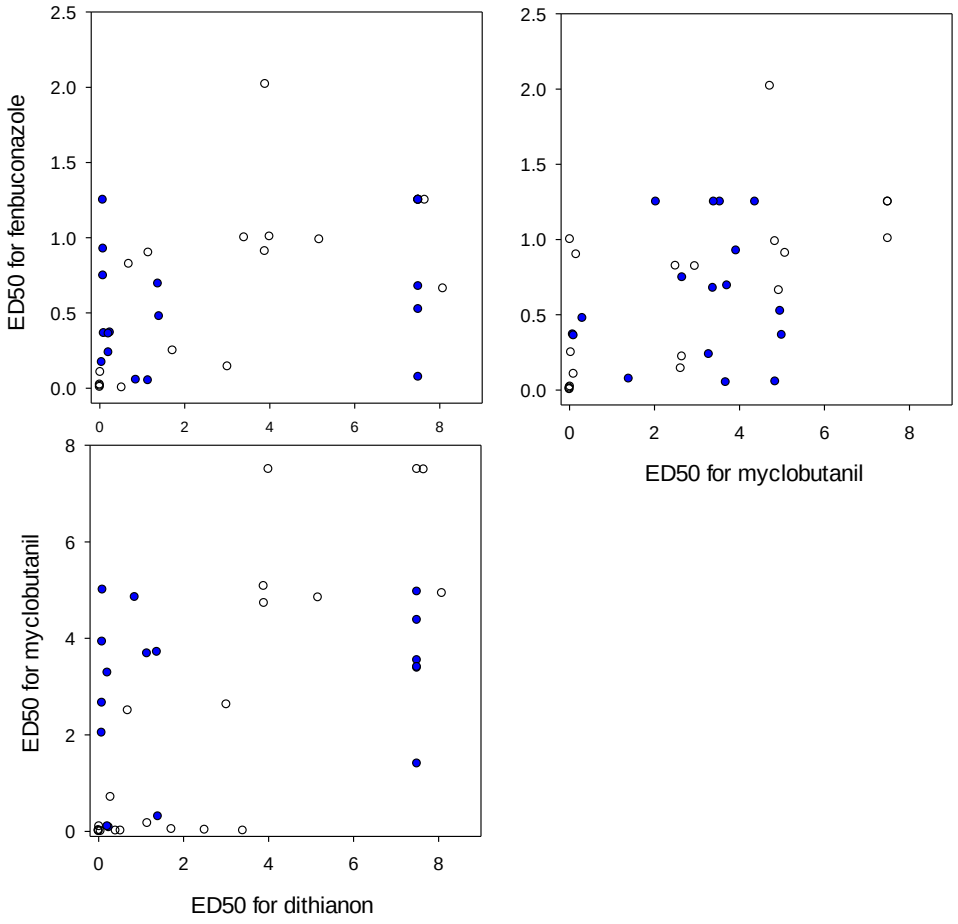

Figure 1. Plot of pairwise estimated ED_{50} values (ppm) among the three fungicides: dithianon, fenbuconazole and myclobutanil. In all cases, ED_{50} values > 5 ppm were assigned with a value of 7.5 ppm (Table 1). Filled circles are for isolates tested in TF 202 and the open circles for those isolates tested in TF 190.

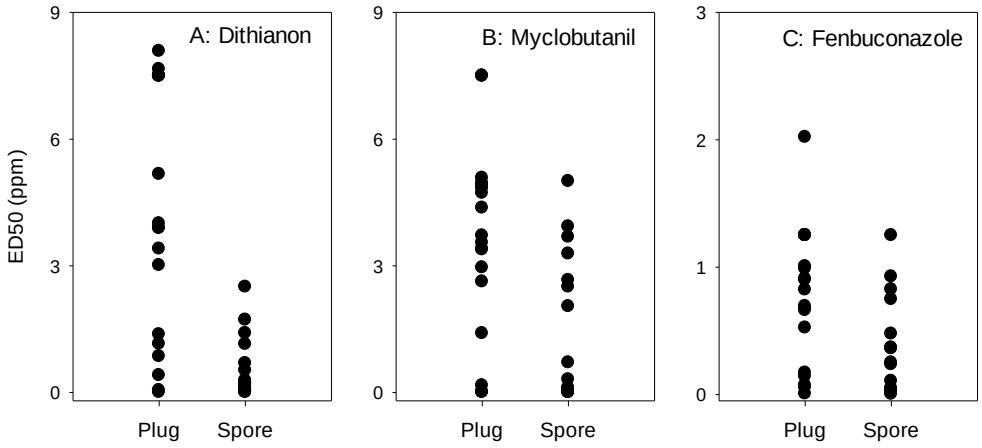

Figure 2. Estimated ED_{50} values (ppm) using the mycelium plug and germ tube elongation (spore) methods for the three fungicides: dithianon, fenbuconazole and myclobutanil. In all cases, ED_{50} values > 5 ppm were assigned with a value of 7.5 ppm (Table 1).

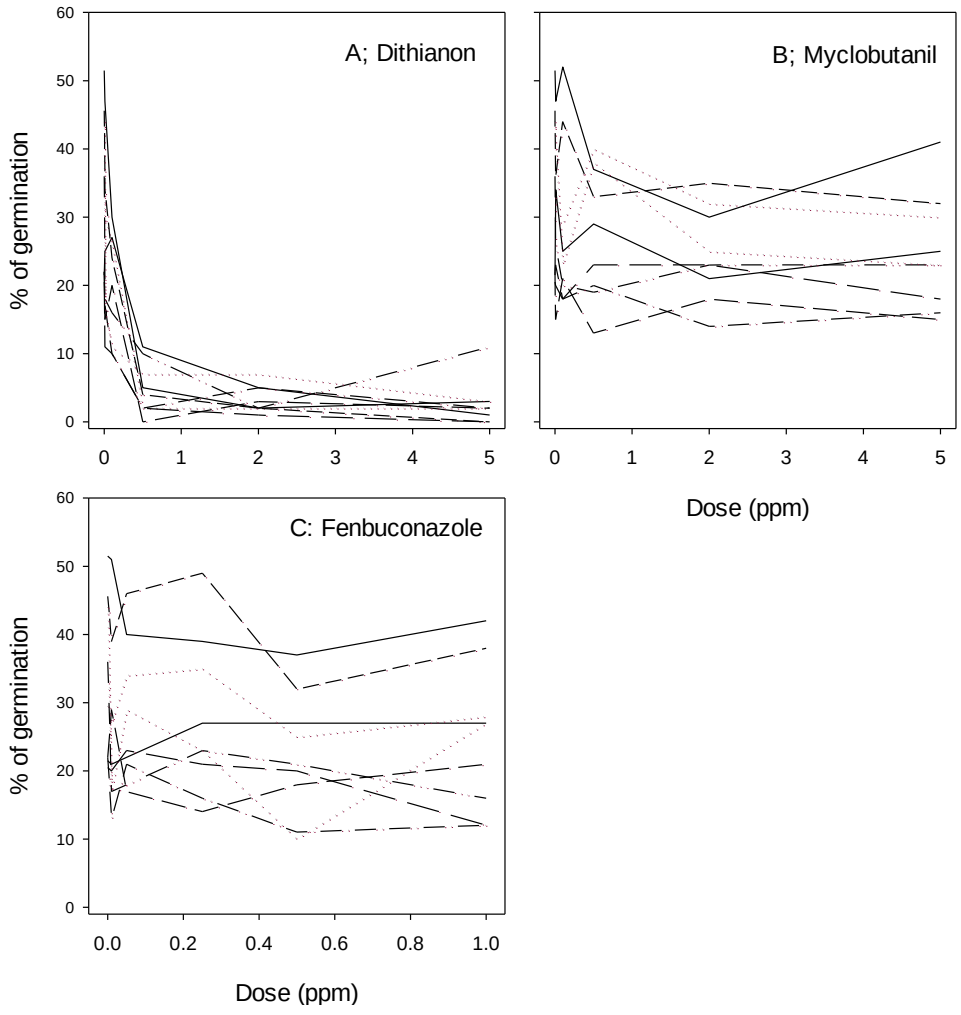

Figure 3. Percentage of germination in relation to dose for all the three fungicides: dithianon, fenbuconazole and myclobutanil

BASF test results

Table 4 presents the summary of BASF test results. Tests for difenoconazole and pyrimethanil are still continuing. We can draw two tentative conclusions from these tests: (1) boscalid and dithianon are still effective fungicides, and (2) use of QoI fungicides alone is not recommended. We have four (out of 18 isolates) isolates that have mutations at the position that confers resistance to QoI fungicides. Three of these four isolates were from the same farm.

Table 4. Summary of tests of 18 apple scab isolates against several fungicides (BASF)

Isolate	MIC* Dithianon	MIC Boscalid	MIC Pyri-methanil	EC_{50} + Difeno-conazole	MIC Pyri-methanil	QoI (G143A)
09/001-9	3	1	100			No
09/001-10	3	1	100			No
09/001-15	1	0,3	100			No
09/015-4	3	1	100			No
09/020-5	1	1	100			No
09/024-1	3	1	100			No
09/026-1	3	3	100			No
09/026-6	No growth	No growth	No growth	No growth	No growth	No
09/028-1	3	1	100			No
09/030-1	3	1	100			Yes
09/034-2	3	1	100			No
09/035-2	No growth	No growth	No growth	No growth	No growth	No
09/035-4	1	1	100			No
09/037-1	1	3	100			Yes
09/037-13	1	3	100			Yes
09/037-17	1	3	100			Yes
09/039-1	3	1	100			No
Sensitive reference isolates	1-3 (11 trials in 2012/13)	0,3-3 (11 trials in 2012/13)	100 (3 trials in 2013)			No

*: Minimum inhibition concentration; +: Still to be completed.

Conclusions

- Sufficient numbers of isolates were obtained from orchards experiencing difficulties in controlling scab
- Dithianon is more effective as a protectant fungicide than as a curative fungicide
- Using QoI fungicides alone to control scab is not advisable
- There was a weak (though significant) correlation between the sensitivity to dithianon and DMI fungicides (fenbuconazole and myclobutanil), suggesting that it might be better not to continuously use these three fungicides together over many seasons
- Indicator genotypes were successfully grafted to the rootstocks and will be planted out in 2014 at EMR

Technology transfer

Because of the sensitivity of this work, we purposely did not actively involve ourselves with technology transfer activities with growers until we have obtained clearer results.

- In March-April 2013, we held in-depth discussions of the work with BASF researchers and agreed to exchange isolates for testing sensitivities to fungicides
- In Feb 2014, we briefly reported the project progress in the HDC Agronomist Day

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