www.efbs.admin.ch

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Eidgenössische Fachkommission für biologische Sicherheit EFBS
Commission fédérale d'experts pour la sécurité biologique CFSB
Commissione federale per la sicurezza biologica CFSB
Cumissiun federala per la segirezza biologica CFSB

Swiss Expert Committee for Biosafety SECB

Fire Blight Control: The Struggle Goes On

Comparison of different fire blight control methods in Switzerland in terms of biosafety, efficacy and durability

Short Version, May 2015

Michele Gusberti[1], Urs Klemm[2], Matthias S. Meier[2,3], Monika Maurhofer[1,2], Isabel Hunger-Glaser[2]

[1]Institute of Integrative Biology Zurich, Plant Pathology Group, Swiss Federal Institute of Technology, CH-8092 Zürich, Switzerland; [2]Swiss Expert Committee for Biosafety, CH-3003 Bern, Switzerland; [3]Research Institute of Organic Agriculture (FiBL), CH-5070 Frick, Switzerland.

Eidgenössische Fachkommission für biologische Sicherheit
c/o Bundesamt für Umwelt BAFU, 3003 Bern
Tel. +41 58 463 03 55, info@efbs.admin.ch
www.efbs.ch

Fire blight (FB), caused by *Erwinia amylovora*, is probably the most devastating and globally important bacterial disease in apple and pear orchards. In Switzerland, the first observation of *E. amylovora* was in 1989 on *Cotoneaster sp.*, while the first outbreak in apple and pear orchards occurred in 1991. Due to the highly destructive nature of this pathogen, quarantine and eradication measures were adopted. Nevertheless, in the following years the disease spread throughout most of the northern and central Swiss regions, reaching a peak in 2007. As a consequence, a thorough eradication of infected trees was performed. Moreover, to limit the spread of the disease, in 2008 the Federal Office for Agriculture (FOAG) authorized the use of streptomycin in apple and pear orchards. In addition to streptomycin other control measures (biocontrol agents, chemical products and tolerant cultivars) have also been used against FB.

This report aims to compare different FB control methods/products in routine use (except for genetically modified products) in Swiss apple orchards:

- BlossomProtect
- Copper-containing products
- Myco-Sin
- LMA
- Streptomycin sulphate-containing products
- Use of fire blight-resistant/tolerant cultivars obtained through conventional breeding
- Use of fire blight-resistant/tolerant cultivars obtained through genetic engineering.

The study focused on the following protection goals, with an emphasis on biosafety aspects:

- FB-free orchards and environment
- human health
- animal health
- protection of the environment
- economic interest
- agricultural diversity.

Information on each fire blight control measure in terms of the specified protection goals was obtained through a literature search and from interviews with experts. The results of the study are addressed to all potentially interested stakeholders including farmers, the Swiss Farmers Association, the Swiss Fruit Association, pear and apple producers, breeders, the crop protection industry, the media, consumers, federal offices, and politicians.

BlossomProtect, a product containing the biological control agent *Aureobasidium pullulans*, reduces FB infection by 76–82%. A decrease in its efficacy is not expected. The impact of this substance on operators and consumers was judged to be negligible. In addition, BlossomProtect was not predicted to have significant effects on exposed animals, soil or water organisms. Consumer acceptance and marketability of apples treated with BlossomProtect is expected to be high even if some lesions (russeting) may be observed on the fruit, depending on the cultivar used and the number of applications performed. Furthermore, the high efficacy of this biological control agent should give adequate protection to most FB-susceptible apple cultivars, especially when combined with other products such as Myco-Sin. BlossomProtect therefore has a positive impact on the diversity of planted apple cultivars and increases the diversification of agricultural practices, since its use is permitted in organic and integrated apple production.

Copper hydroxide, copper oxychloride, copper sulphate, and copper oxide, the most frequently used copper compounds, show an efficacy against FB of approximately 88%, 50%, 35% and 25% respectively. No development of resistance and no human health problems following its application were predicted. However, these substances may pose an increased risk to exposed animals as well as to a few crop plants, and may also cause prob-

lems due to their accumulation in water and soil. A negative impact on soil biodiversity and fertility is therefore possible. The potential marketability of apples treated with these products is high, as copper application is generally accepted by consumers. Nevertheless these products may decrease fruit marketability overall because they can cause fruit russeting, depending on the application period. Copper-based products are permitted in organic production.

Myco-Sin, a product composed of aluminium sulphate and *Equisetum* extract, shows a highly variable efficacy (50 to 69%) against FB, and the durability of the product has been evaluated as high. The possibility of side effects to operators and other persons handling this product have been identified but the risk has been evaluated as negligible. Potential side effects on exposed animals (thiaminase deficiency), and on aquatic and terrestrial organisms (medium acidification), have also been suggested but have been estimated as low. Fruits treated with this product do not show decreased marketability. However, the low efficacy of Myco-Sin does not provide full protection to FB-susceptible apple cultivars across different agricultural practices. Myco-Sin is also permitted in organic production.

LMA, a new pesticide containing potassium aluminium sulphate, shows an average efficacy of 73% and its durability has been predicted to be high. No effects were anticipated on operators, consumers or exposed animals. However, if not properly handled the product may have side effects on aquatic organisms (through medium acidification). The high efficacy of LMA should give good protection to FB-susceptible apple cultivars in integrated production, but its use is not permitted in organic production.

Ag-Streptomycin, Strepto and Firewall 17, all products containing streptomycin sulphate, show the highest efficacy against FB (80-89%) of all the FB-control measures analysed in this study. As a consequence of the restricted use of streptomycin in agriculture in Switzerland (currently max. one application per year), the durability of these products should be high. No intolerable effects on operators or consumers are expected if streptomycin is used according to the manufacturer's instructions. Potential side effects *i. e.* selection of multi-antibiotic resistance were forecast for exposed animals but the risk was estimated as low. In terms of biodiversity, streptomycin has a low impact on the bacterial communities of soil and phyllosphere. Fruits treated with streptomycin show no decrease in marketability as most consumers seem unaware of the use of antibiotics in apple production. The high efficacy of streptomycin-containing products should preserve the current cultivar diversity in integrated apple production. Streptomycin-based products are not permitted in organic production or standard tree orchards.

Ladina, a **FB-tolerant classically bred** apple cultivar, is already available on the market. This cultivar shows about 75% fewer infected shoots than the FB-susceptible control 'Gala Galaxy', an FB tolerance that reduces the disease to an acceptable level. As yet, there are no classically bred cultivars bearing either a single major resistance gene or several pyramided resistance genes. It is therefore not possible to estimate the efficacy or durability of these resistances. No side effects on operators handling conventionally bred cultivars have been predicted. However, there has been some discussion of the risks of incorporating "wild" traits during the breeding process. Tests for allergens or toxic compounds are not mandatory for conventionally bred cultivars. The use of conventionally bred FB-tolerant apple cultivars poses no problems to the health of exposed animals, soil and water organisms or to overall biodiversity. The marketability potential of conventionally bred apple cultivars is high. One disadvantage, however, is that plant breeders must select cultivars that not come onto the market for another 12–15 years after breeding, and it is obviously impossible to know which fruit type consumers are likely to prefer so far in the future. Furthermore, although the production of classically bred apples may guarantee the diversification of agricultural practices, but it may also produce a decrease in cultivar diversity.

The use of **genetic engineering** to insert one or more resistance genes into an existing and accepted apple cultivar is feasible. The ***FB-MR5*-resistant 'Gala'** has been produced recently. This cultivar shows almost total immunity to fire blight. However, a single point mutation in

E. amylovora would be sufficient to remove the MR5 resistance; a Canadian strain that can overcome the resistance gene used is already known. As with the conventionally bred cultivars, no particular risk to operators dealing with genetically engineered cultivars could be identified. Unlike conventional breeding, there is no risk of introducing unwanted “wild” traits into the new genetically engineered apple. At the environmental level, potential hazards relating to the dissemination of GM material (gene flow) have been identified, but these would only affect compatible plants; no effect on exposed animals or soil and water environments have been predicted. At present, the GM moratorium imposed in Switzerland means that GM fruits may not enter the market, thereby limiting the marketability potential of the product. Moreover, if farmers were able to plant the genetically engineered *FB-MR5* ‘Gala’ the risk of decreasing cultivar diversity would be high. On the other hand, as with the classically bred FB-tolerant cultivars, it could also preserve standard tree cultivation, thereby enabling the cultivation of both dwarf and standard trees in the same region.

Conclusion. Based on our assessment it can be concluded that the FB control methods currently used in Switzerland are reasonably effective (although the most effective products are not compatible with organic production), and are largely safe for consumers, workers and the environment (Tables 1a and 1b). However, there are several important gaps in our knowledge of the environmental and human health impacts of the different FB control methods, which mean that there is considerable uncertainty in these assessments. These gaps will need to be addressed in the near future. We have identified several issues about biosafety that need further analysis. These include the effect of BlossomProtect on exposed animals (birds and arthropods), copper accumulation in the soil, and the effect of copper and aluminium compounds on exposed animals (mammals, earthworms and bees). Moreover, there are few residue analyses for copper, aluminium and for the *Equisetum* plant extract in apple cultivation, and these need to be performed. Although streptomycin application is regarded as safe for operators, the potential accumulation of antibiotic (multi) resistance in operators handling streptomycin cannot be completely excluded because of the relevant studies have not been carried. The safest FB control method for humans, animals and the environment would definitely be the use of resistant cultivars. However, cultivars carrying major FB resistance genes do not yet exist. Moreover, the use of FB-resistant cultivars obtained through classical breeding or genetic engineering (1-gene scenario) may increase the risk of developing virulent *Erwinia* strains. The use of two or more resistance genes would lower this risk as soon as multi-resistant cultivars exist. Therefore multiple gene-based resistance breeding should be encouraged; whether this is achieved through classical or molecular breeding remains largely a political rather a biosafety issue. The use of such multi-resistant cultivars would cause a significant decrease in the number of FB-susceptible cultivars currently planted in Swiss apple orchards, and thus would contribute to a decrease in cultivar diversity. In the long term, most of the FB control products currently used are not effective enough to ensure safe apple production, especially in organic production. FB may be inadequately controlled, particularly in years with heavy infections and if susceptible cultivars continue to be planted. Therefore there is an urgent need for resistant cultivars and for new products that are more effective, durable and compatible with organic production.

Table 1: Overview of the assessment of fire blight control methods: classification of identified uncertainties and problems.

a) Summary based on literature search and interviews with experts

Protection Goals	Fire Blight control measures								
	Biological control	Chemical control				Conventional breeding [a]		"GMO" [b]	
						1 gene	2 genes	1 gene	2 genes
commercial name	Blossom Protect	Copper	Myco-sin	LMA	Strepto, Firewall,...	Ladina			
composition	*A. pullulans*		Aluminium sulfate	potassium aluminium sulfate	Streptomycin sulfate	FB_F7 QTL	FB_F7 QTL + ???	'Gala' + *FB_MR5* [c]	'Gala' + *FB_MR5* + ???
FB-free agricultural crop and environment									
Feasibility	E [d]	E	E	E	E	E	possible	E	possible
Efficacy of method	76-80%	25-88%	51-69%	73%	80-89%	about 75%	? [e]	nearly 100%	?
durability	high	high	high	high	resistant strains?	virulent strains?	virulent strains?	virulent strains?	virulent strains?
Protection of consumer and workers									
	AT [f]	AT	AT	AT	AT+ resistance [g] ?	Allergy?		?	?
						no tests required!			
Protection of environment									
Impact on exposed animals	low	low	low	low	low	low	low	low	low
Impact on biodiversity	low	medium	medium	medium	low	low	low	low	low
Impact on soil and water	low	medium	medium	medium	medium	low	low	low	low
Economic interest (acceptance)									
quality accepted and desired by consumer	medium	medium	high	high	medium	high	high	low	low
way of production acceptable for consumer	high	high	high	high	medium	high	high	low	low
Maintain cultivar diversity and diversity of cultivation practices									
Impact of method on cv diversity	low	medium	medium	low	low	high	high	high	high
Impact of method on cultivation practices	low	medium	medium	medium	medium	low	low	low	low

Green: no or negligible problems identified;
Yellow: minor uncertainties and/or minor problems identified;
Orange: Uncertainties and/or problems identified, that urgently need to be addressed.

[a] Conventional breeding: apple cultivars carrying a one or two gene-based FB resistance obtained by conventional breeding.
[b] GMO: Genetically Modified Organism carrying a one or two gene-based FB resistance.
[c] 'Gala'+*FB_MR5*: estimations based on transgenic lines tested under greenhouse conditions with two *E. amylovora* strains.
[d] E: Product already exists.
[e] ?: Unknown.
[f] AT: Safety of product tested for registration. If used according to instructions no problems for workers and consumers.
[g] Acquisition of antibiotic (multi) resistant bacteria in operators not tested.

b) Summary of questionnaire answered by experts

Protection Goals	Fire blight control measures								
	Biological control	Chemical control				Conventional breeding [a]		"GMO" [b]	
						1 gene	2 genes	1 gene	2 genes
commercial name	Blossom Protect	Copper	Myco-sin	LMA	Strepto, Firewall,...	Ladina		'Gala' + *FB_MR5* [c]	
composition	*A. pullulans*		Aluminium sulfate	potassium aluminium sulfate	Streptomycin sulfate	FB_F7 QTL	FB_F7 QTL + ???		'Gala' + *FB_MR5* + ???
FB-free agricultural crop and environment									
Feasibility	E [d]	E	E	E	E	E	possible	E	possible
Efficacy of method	medium	medium	medium	medium	high	high	? [e]	high	?
Durability	high	high	high	high	low	medium-low	medium	medium-low	medium
Protection of workers	low	low	low	low	?	low	low	low	low
Protection of consumer	low	low	low	low	low	low	low	low	low
Protection of environment									
Impact on exposed animals	low	low	low	low	low	low	low	low	low
Impact on biodiversity	low	medium	medium	medium	high	low	low	low	low
Impact on soil and water	low	low	low	low	medium	low	low	low	low
Economic interest (acceptance)	high	high	high	high	medium	high	high	low	low
Quality accepted and desired by consumer									
Way of production acceptable for consumer									
Maintain cultivar diversity and diversity of cultivation practices									
Impact of method on cv diversity	medium	medium	medium	low	low	high	high	high	high
Impact of method on cultivation practices	?	?	?	?	high	low	low	medium	medium

Green: no or negligible problems identified (severity 1 and probability of damages 1-4 or severity 2 and probability of damages 1);
Yellow: minor uncertainties and/or minor problems identified (severity 2 and probability of damages 2-4 or severity 3 and probability of damages 1);
Orange: Uncertainties and/or problems identified (severity 3 and probability of damages 2-4 or severity 4 and probability of damages 1-4).

[a] Conventional breeding: apple cultivars carrying a one or two gene-based FB resistance obtained by conventional breeding.

[b] GMO: Genetically Modified Organism carrying a one or two gene-based FB resistance.

[c] 'Gala'+*FB_MR5:* 'Gala'+*FB_MR5*: estimations based on transgenic lines tested under greenhouse conditions with two *E. amylovora* strains.

[d] E: Product already exists.

[e] ?: Unknown.