



Comparative sustainability assessment of the impact of GM plants in Swiss conventional, integrated and organic farming systems. A project funded by NRP 59.

Agronomic consequences of the use of GM crops. Part 2: apple orchards for project-internal use only

Internal document (final version)

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Workpackage 3

Description in project proposal (p. 23): «Workpackages 3-5 will assess the impact of the production system scenarios on (i) agronomy, (ii) biodiversity and agro-ecology and (iii) socio-economics at the farm and the regional level. Baseline and alternative scenarios will subsequently be submitted to a comparative technology impact assessment. The assessment will include changes in agronomic parameters, expected differences in yield, quality and input usage (e.g. land use, pesticide use etc.). The potential environmental benefits of GM plants will be assessed, with a special focus on pesticide use, crop yields, weed control, soil tillage and soil protection. The environmental risk assessment will take the impact on biodiversity and the soil ecosystem into account.

The central assessment tool in workpackages 3-5 will consist of semi-quantitative assessment matrices. The proposed comparative sustainability assessment matrix is a combination of the Swiss approach to assess sustainability of agriculture (BLW Agrarbericht 2005, ARE Nachhaltigkeitsbeurteilung) and the CSA-Matrix method proposed by ACRE (2006). The detailed criteria and parameters will be prepared during the project by the project leader and refined by the competence teams in workshop 3. The overall baseline for comparison is the state-of-the-art integrated production with good agricultural practice.»

Document history: This report was prepared by the competence team «farming systems».

The general agronomic consequences of the use of GM crops were outlined in workshop 3 on 1 – 2 October 2008. In workshop 4 on 30 April 2009, agronomic practices and consequences were discussed in detail for apple orchards. This document was discussed during workshop 4, and amended by E-Mail correspondence after the workshop. In workshop 7, the experts suggested several amendments and questioned the spraying schemes. A subsequent consultation of experts by E-Mail showed that some experts considered the spraying scheme rather intensive, others considered it rather extensive, and still other considered it adequate. It was therefore decided to keep the originally proposed spraying schemes. To improve the legibility of the report and its consistency with other reports, the co-ordinator made some editorial changes to the figures and tables, and in chapter 6. In the validation workshop on 31 August 2010, it was decided to clarify the term 'resistance' with respect to fire blight, and the sorting of apples in relation to disease pressure and varietal susceptibility to scab. After the validation workshop, the experts agreed to modify the assumptions regarding the use of Pinova under scenario 2.

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1 Introduction

This document is prepared as a project-internal tool. It assesses the agronomic consequences of the use of GM crops in selected Swiss agricultural systems (apple orchards). The agricultural systems and conditions are described in detail in the document «Model farms and scenarios», while the GM crops are described in detail in the document «List of GM plants and traits». The indicators to be used in the impact assessments have been described in a general way in the project-internal document «Criteria for sustainability assessment».

2 Agronomic assumptions

2.1 General agronomic assumptions

The agricultural systems and conditions, for which the impact of GM crops will be assessed, are described in detail in the project-internal document «Model farms and scenarios». They will not be repeated here. The following general assumptions are made for the model farm:

- The farm is assumed to be a family farm without employees.
- The farm is assumed to be a pure pome fruit growing farm, consisting mainly of the 10 ha of apples and pears.
- The 10 ha of fruit trees are arranged in four orchards.
- Unless explicitly specified otherwise, the values of the Excel-based programme «Arbokost Apfel» and «Arbokost Apfel Bio» will be used. The main features are described there under the headings «Systembeschreibung» and «Geometrische Daten».
- The orchard is assumed to be a high density orchard with fence around.
- The tree form is spindle.
- The turning area is assumed to be 10% of the orchards' surface.
- Ecological compensation area: For the integrated orchard, 3.5 % of ecological compensation area are assumed. However, this is often outside the orchard and is therefore not included in the model. For the organic orchard, 7 % of ecological compensation area are assumed. This is inside the orchard and therefore included in the model.
- The number of rows per hectare is 23 for the integrated orchard and 21 for the organic orchard.
- The tree distance is 1.1 m.
- Total orchard lifetime: 15 years (3 years of build-up; 12 years of full yield).
- Production of table apples; delivery to: retailers and co-operatives.
- The varietal composition of the orchards to be assessed is given in table 1 for the integrated farming system and in table 2 for the organic farming system.
- For the assessments, it is assumed that each variety is either 'susceptible' or 'resistant' to scab and to fire blight. It is acknowledged that in reality, some varieties may also have intermediate levels of resistance against these diseases.
- For new varieties, it is assumed that they will be immediately planted on 100 % of their final surface (100 % replacement of previous varieties).

2.2 Varietal composition of the model orchards under different scenarios

The varietal composition of the model orchards was determined by the experts during the workshops. In a first step, the composition of the orchards was determined for the baseline scenario, taking into account the requirements of the market in terms of taste groups, ripening times and well-known varieties. In a next step, the likely changes in composition under scenario 1 and 2 were discussed (see below).

Note 1: The varieties indicated are typical representatives of a given taste group-ripening time-susceptibility combination; they might be replaced by other varieties with the same properties.

Note 2: For the purpose of this project, it is assumed that the GMO status of apples is irrelevant for consumer choices (for details, see the report «Socio-economic impact of the use of GM crops. Part 2: apple orchards»). Today, this would clearly not be the case in Switzerland.

Note 3: Because of the high costs for registration and market introduction, it is assumed that GM varieties will only be produced for varieties of great economic importance. In the model orchards, GM varieties are assumed to be available for Gala and Braeburn, but not for the other varieties.

Note 4: All model orchards are assumed to contain 9 ha of apples and 1 ha of pears. For pears, GM varieties are assumed not to be available. Therefore, the socio-economic and the ecological impact analysis are restricted to the apple segment of the model orchards.

2.2.1 Varietal composition of the integrated model orchard

The assumptions for the integrated model orchard are given in table 1. The experts made the following assumptions:

Baseline

- The orchard contains equilibrated to sweet and spicy to tart apples. It does not contain predominantly tart apples, because these are of little importance on the market.
- Within each taste group, several varieties are grown for the following reasons: (i) the market demands several varieties with well-known names and slightly different properties (acid content, consistency of the flesh); (ii) varied ripening times reduce labour peaks during harvest; (iii) varietal diversity reduces risks for the grower.
- Because fungicides allow good scab control, varieties are not selected according to their scab resistance and the baseline orchard contains no resistant varieties.

Scenario 1 (integrated orchard)

- Scab-resistant GM-Gala replaces non-GM-Gala, and scab-resistant GM-Braeburn will replace non-GM-Braeburn.
- With these replacements, a large proportion of the orchard is subject to a reduced scab spraying programme. With this trend, the grower is assumed to give up Golden Delicious/Maigold, and to enlarge the surface of GM Gala and GM Braeburn.

- Despite this trend, Jonagold and Kanzi remain in the model orchard, because they are demanded by the market. Jonagold is more acid and has a firmer flesh than Gala, and Kanzi is a club variety with a market on its own.

Scenario 2 (integrated orchard)

- Scab- and fire blight-resistant¹ cultivars of Gala and Braeburn will replace the previous cultivars.
- Jonagold and Kanzi remain in the model orchard, because they are demanded by the market (see above).
- The pear variety Conférence is replaced by the less known variety Elliot, which is resistant against fire blight.

2.2.2 Varietal composition of the organic model orchard

The assumptions for the organic model orchard are given in table 2. The experts made the following assumptions:

Baseline

- The orchard contains equilibrated to sweet, spicy to tart apples and predominantly tart apples (on the organic market, the latter are also demanded).
- Because fungicides allow only moderate scab and fire blight control, farmers grow as much scab resistant and/or fire blight-resistant varieties as possible. However, market demand forces them to supply a certain proportion of susceptible varieties, because they have well-known names.

Scenario 1 (organic orchard)

- Scab-resistant GM-Gala replaces non-GM-Gala.
- The scab-resistant GM Braeburn will replace Retina and Ariwa, because the market demand is higher for Braeburn.
- Together with the resistant non-GM varieties already present in the baseline scenario, these replacements create a trend towards a reduced scab spraying programme in the orchard. As a consequence, the grower is assumed to give up the susceptible variety Idared, and the intermediately resistant variety Boskoop (Boskoop is also at risk of biannual bearing, sensitive to frost, and less demanded by the market than Otava).
- Despite these trends, Pinova, Topaz and Otava remain in the model orchard. Pinova is classified here as resistant against fire blight, and it has more acidity than Gala. Topaz has a more intense taste than Braeburn, and matures earlier. Otava remains in the assortment as the only predominantly tart apple.

Scenario 2 (organic orchard)

- Scab- and fire blight-resistant cultivars of Gala and Braeburn will replace the previous cultivars.
- The pesticides allowed in organic farming provide only partial control, and fire blight is a serious threat to the organic model orchard. Thus, the organic grower will give more weight to the safety of his orchard and to the management flexibility

¹ in this report, we use the term «fire blight-resistant» for all varieties with full or with partial resistance against fire blight, see section 3.3.2.

obtained by not having to spray against fire blight than to the demand of the market for additional, minor varieties. The only minor variety retained is Pinova, which is fire blight resistant.

- The pear variety Conférence is replaced by the less known variety Elliot, which is resistant against fire blight.

Table 1: Assumptions for the integrated model orchard under the different scenarios (9 ha apple segment only; A: varietal composition, B: partitioning of resistance traits in apples). Traits: s=susceptible; r=resistant (first letter: scab; second letter: fire blight). GM1=GM apple which is resistant against scab; GM2=GM apple which is resistant against scab and fire blight. For details of fire blight susceptibility, see section 3.4. Elliot is a pear cultivar which is fairly robust against fire blight, but not yet well-known on the market.

A) Composition by varieties

Baseline Variety	ha	Scenario 1 Variety	ha	Scenario 2 Variety	ha
Gala (ss)	3	Gala GM1 (rs)	4	Gala GM2 (rr)	4
Golden Delic. / Maigold (ss)	2	Jonagold (ss)	1	Jonagold (ss)	1
Jonagold (ss)	1	Braeburn GM1 (rs)	3	Braeburn GM2 (rr)	3
Braeburn (ss)	2	Kanzi (ss)	1	Kanzi (ss)	1
Kanzi (ss)	1				

B) Composition by traits

Baseline Trait combination	ha	Scenario 1	ha	Scenario 2	ha
ss: Scab-susceptible + fire bl.-susceptible	9 ha (100%)		2 ha (22 %)		2 ha (22 %)
rs: Scab-resistant + fire blight-susceptible	-		7 ha (78 %)		-
sr: Scab-susceptible + fire blight-resistant	-		-		-
rr: Scab-resistant + fire blight-resistant	-		-		7 ha (78 %)

Table 2: Assumptions for the organic model orchard under the different scenarios. For details, see table 1.

A) Composition by varieties

Baseline Variety	ha	Scenario 1 Variety	ha	Scenario 2 Variety	ha
Gala (ss)	2	Gala GM1 (rs)	3	Gala GM2 (rr)	4
Pinova (sr)	1	Pinova (sr)	1	Pinova (sr)	1
Idared (ss)	1	Topaz (rs)	2	Braeburn GM2 (rr)	4
Topaz (rs)	2	Braeburn GM1 (rs)	2		
Retina (rs)	0.5	Otava (rs)	1		
Ariwa (rr)	0.5				
Otava (rs)	1				
Boskoop (rr)	1				

B) Composition by traits

Baseline Trait	ha	Scenario 1 Trait	ha	Scenario 2 Trait	ha
ss: Scab-susceptible + fire bl.-susceptible	3 ha (33 %)		-		-
rs: Scab-resistant + fire bl.-susceptible	3.5 ha (39 %)		8 ha (89 %)		-
sr: Scab-susceptible + fire blight-resistant	1 ha (11 %)		1 ha (11 %)		1 ha (11 %)
rr: Scab-resistant + fire blight-resistant	1.5 ha (17 %)		-		8 ha (89 %)

3 Agronomic considerations regarding apple diseases

3.1 Complex of fungal diseases

Although scab is the most important fungal disease of apples, there are a number of «secondary diseases» which are normally controlled by the fungicide treatments against scab. In the case of scab resistant apples, secondary diseases may lead to yield losses and/or fungicides need to be applied for their control. The most important secondary diseases are:

- Mildew (*Podosphaera leucotricha*)
- Sooty blotch (*Gloeodes pomigena*)
- Fly speck (*Schizotyrium pomi*)
- «Frog eyes» (*Alternaria*)
- *Gloeosporium* (storage disease)
- *Botrytis cinerea*, *B. fuckeliana*

3.2 Apple scab (*Venturia inaequalis*)

3.2.1 Incidence and impact of scab

The experts present in workshops 3 and 4 estimated the frequency and impact of scab as shown in figure 1. 80 % of all years are estimated to be «good scab years» with a low disease pressure, while 20 % of all years are «bad scab years» with a high disease pressure. In case of scab infection, a certain proportion of apples may not be sold as first quality. However, in all years some apples do not reach the first quality for various reasons not related to scab.

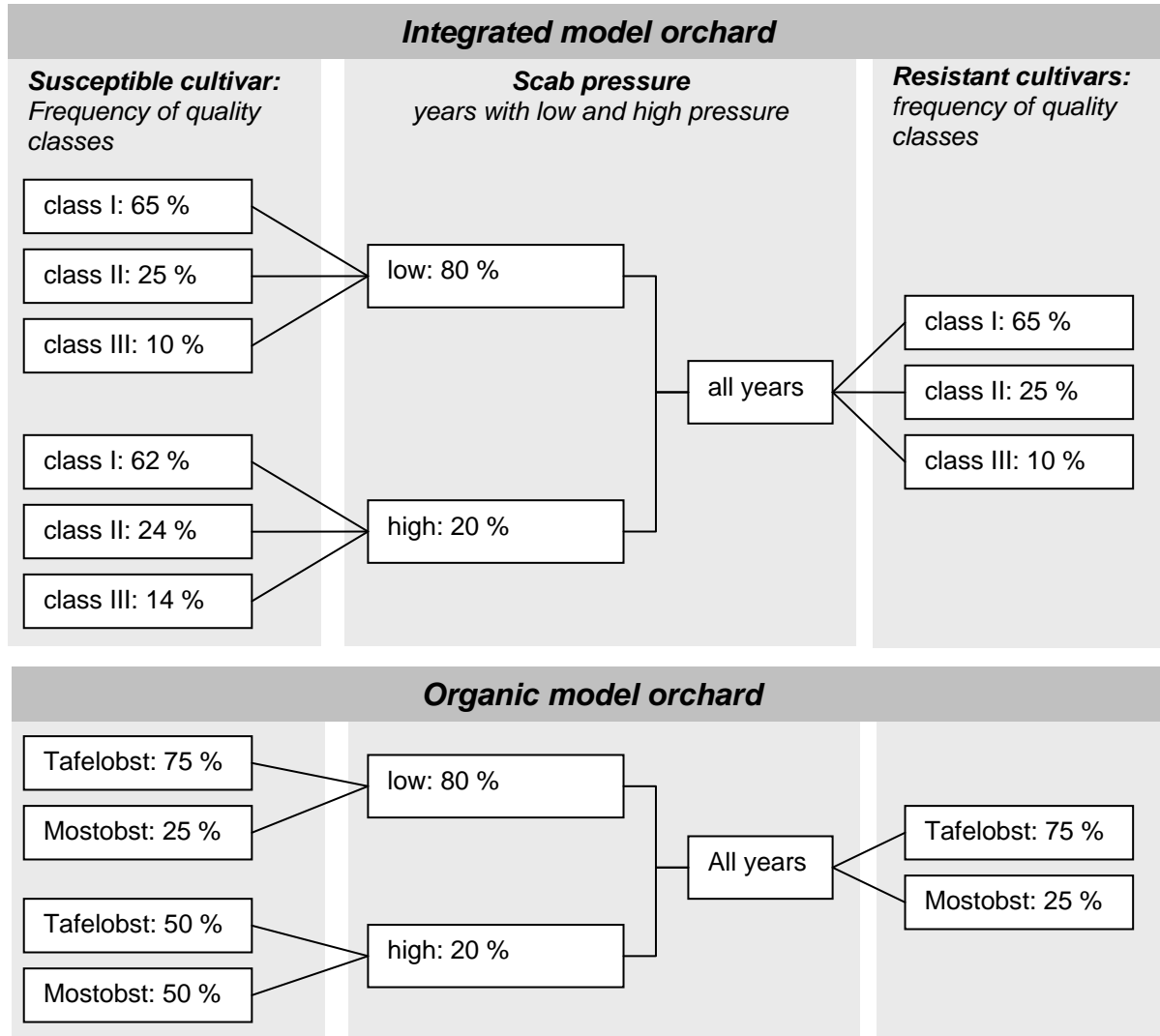
Integrated farming: in *susceptible* varieties in good scab years, 65 % of all apples can be marketed as class I, while 35 % of all apples do not reach the quality of class I for various reasons not related to scab. In bad scab years, ca 3 % of the apples show scab infections and therefore have to be marketed in class II or III. This reduces the proportion of apples in class I from 65 % to 62 %. In *resistant* varieties, there will be no losses due to scab. Thus, 65 % of all apples are in class I in good and in bad years. For details, see figure 1.

Organic farming: in *susceptible* varieties, 75 % of all apples can be marketed as 'Tafelobst' in good scab years, and 50 % in bad years. 75 % of all apples can be marketed as 'Tafelobst' in good and bad scab years. For details, see figure 1.

3.2.2 Durability of scab resistance

Unless proven otherwise, all scab resistance currently used is based on Vf genes. Durability of scab resistance is inversely proportional to the surface of scab resistant varieties grown. The experts concluded that during the lifetime of the model orchard, scab resistance can be maintained, if the recommended sanitary measures are carefully carried out. As part of the resistance management, resistant and susceptible varieties should be grown in separate orchards. These statements are true for GM and non-GM scab resistant varieties.

Figure 1: Proportion of apples in different quality classes, depending on resistance of cultivar, scab pressure and farming system (source: estimates during project workshops). For scab resistant apples, no scab infection is assumed, but some apples are only in class II or III for other reasons. For quality class 'Tafelobst' for organic apples corresponds to the classes I and II, while 'Mostobst' corresponds to class III.



3.3 Fire blight (*Erwinia amylovora*)

3.3.1 Incidence and impact of fire blight

The experts present in workshops 3 and 4 estimated the frequency and impact of fire blight as shown in Figure 2.

Incidence: Fire blight is a new disease in Switzerland, therefore its incidence and severity have to be estimated in this study. In recent years, temperatures at flowering have increased continuously. This trend will likely aggravate the risk of fire blight infections. As a rough estimate, 80 % of all years are estimated to be «good fire blight years» with a low disease pressure, and 20 % of all years are estimated to be «bad fire blight years» with a high disease pressure. For details see figure 2.

Avoidance: Infections can be avoided by netting of the orchards (to prevent access by honey bees; pollination by bumblebees living inside the net).

Direct control: in *integrated farming*, 2 treatments with streptomycine and 1 treatment with Regalis are foreseen in the model spraying scheme. The effectivity of these treatments is judged to be 60 – 80 % (note: it is unclear whether streptomycine will still be authorized in ten years time, and if not, whether an equally effective substitute will be available). Application technology and prognosis can be improved. In *organic farming*, streptomycine is not allowed. Instead, microbial biocontrol agents like BlossomProtect can be used. Their effectivity is judged to be 30 – 70 %. It is unclear whether more effective substitutes will be available in ten years time. Effectivity of all products is likely to rise because of improvements in application technology and prognosis.

Impact: fire blight has several kinds of impact:

- **Visual controls** of the entire orchard are needed to detect infections. Independently from disease pressure (i.e. in good and bad years), 4 visual controls are needed per season. Each control requires 1 h/ha.
- In the case of infections, robust varieties can often be saved by **sanitation pruning**. This causes high labour costs, and may also lead to reduced yields. For integrated farming, the labour for sanitation pruning is estimated at 100 h/ha in a bad year. In organic farming, fire blight infections are likely to be more severe than in integrated farming. As a consequence, the labour for sanitation pruning is much higher (150 – 400 h/ha). Besides the labour costs, this may cause labour bottlenecks on the farm.
- Sensitive varieties usually cannot be saved by sanitation pruning, and have to be **cleared**. This causes material costs (new trees), labour costs (replanting) and yield losses. In the scenarios, we assume that 80 % of robust varieties can be saved with sanitation pruning, while 20 % have to be cleared. For sensitive varieties, we assume that 20 % could be saved with sanitation pruning, while 80 % have to be cleared.

The sensitivity of different apple varieties is described in (Anonymous, 2008). For varieties not mentioned in this technical note, the categorization is based on expert judgement (F. Weibel and/or P. Triloff, pers. Comm.). For the varieties used in the model orchards (Table 1 & 2), the following sensitivity is assumed:

Robust: Ariwa; Boskoop; Pinova.

Sensitive: Braeburn; Conférence; Gala; Idared; Jonagold; Otava; Topaz, Golden Delicious; Kanzi; Maigold; Retina (uncertain assumption made in the absence of reliable data; F. Weibel, pers. Comm.).

3.3.2 Level and durability of fire blight resistance

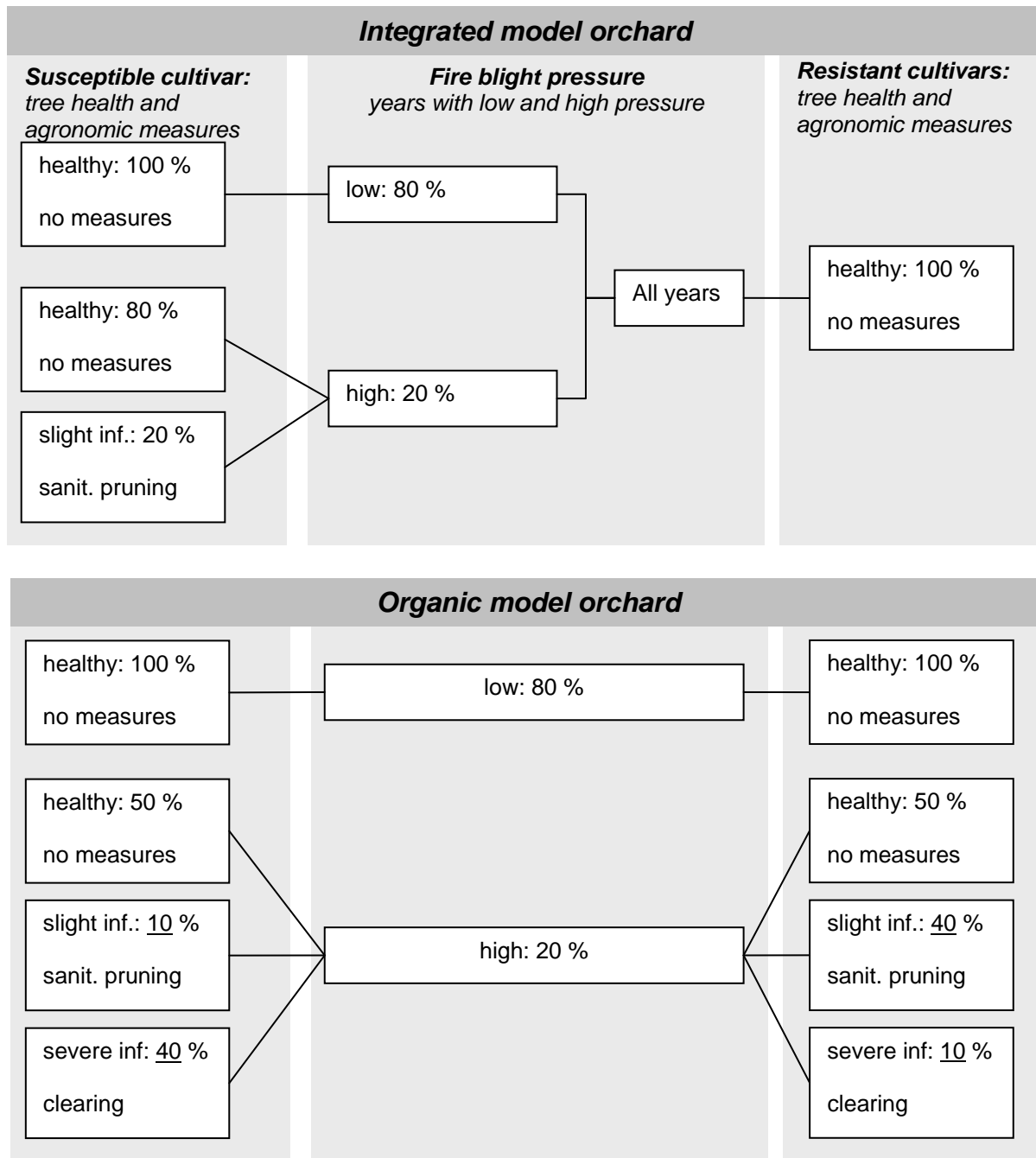
In this report, we use the term «fire blight-resistant» for all varieties with full or with partial resistance against fire blight: non-GM Pinova and Boskoop have a partial resistance against fire blight, while GM-Gala and GM-Braeburn under the scenario 2 are assumed to have full resistance. It is estimated that resistance can be maintained for the lifetime of the orchard with the standard practices of resistance management and sanitation recommended today.

3.3.3 Fire blight resistant rootstocks

Some non-GM fire blight resistant rootstocks have been developed, but are not yet commercialized on a large scale (e.g. Geneva 11). If fire blight resistant varieties are used, or if pesticides are sprayed against fire blight, there will be no inoculum, and

therefore resistant rootstocks are not necessary. However, if there are other sources of inoculum near the orchard (e.g. standard trees [Hochstämme]), resistant rootstocks are necessary. The experts assume that resistant rootstocks are unlikely to be used in integrated orchards, but likely for organic orchards.

Figure 2: Proportion of healthy apple trees, depending on resistance of cultivar, fire blight pressure and farming system (source: estimates during project workshops). In healthy trees, no measures are taken. In case of slight fire blight infection, the tree is sanitation pruned; in case of severe infection, the tree is cleared.



4 Plant protection measures in the different scenarios

Note: For the purpose of this project, it is assumed that the GM varieties vary only in their resistance to scab and/or fire blight, but not in other agronomic traits. Therefore, control of insect pests and other agronomic treatments such as fertilization and also yield are assumed to be constant in all scenarios.

4.1 Plant protection on cultivars with different resistance levels

4.1.1 Treatments against scab

Scab-susceptible cultivars are regularly treated with fungicides against scab. As a side-effect, mildew and sooty blotch are also controlled.

Scab-resistant cultivars are treated only few times against scab, to manage resistance of the scab pathogen. In addition, they receive several fungicide treatments to control other diseases such as mildew and sooty blotch.

4.1.2 Treatments against fire blight

Fire blight-susceptible cultivars are treated three times against fire blight, while fire blight-resistant cultivars are not treated at all.

4.2 Plant protection schemes for the model orchards

All apple cultivars in the model orchards have one out of four combinations of traits: scab-susceptible/resistant and fire blight-susceptible/resistant. Accordingly, they are subject to one of four plant protection schemes: high or low frequency of fungicides and with/without treatments against fire blight. The relationship between trait combinations, cultivars and surfaces is given in table 1 and 2.

Both in the integrated and in the organic model orchard, all of the trait combinations occur. However, the frequency of trait combinations varies, and completely different substances are used in the integrated and in the organic orchard.

The plant protection scheme for the integrated orchard is shown in Table 5, the scheme for the organic orchard is shown in Table 6.

4.3 Plant protection and management flexibility

Scab resistance: In scab susceptible varieties, a large number of fungicide applications are currently made. Often, the timing for these applications is very critical, which gives little management flexibility to apple growers. As a consequence, orchards are often sprayed when the soil is wet, which leads to soil compaction. For the control of secondary diseases, the timing of applications is much less critical.

Fire blight resistance: As for scab control, the timing of applications against fire blight is very critical. As a consequence, orchards are often sprayed against fire blight when the soil is wet, which leads to soil compaction.

Table 5: Plant protection scheme in the integrated apple orchard (timing, targets & pesticides) for cultivars with different trait combinations. For frequency of trait combinations in the model orchards, see table 1. Dates are examples based on the year 2008. Each line represents a separate application (e.g. the treatments on May 3 against rust mites and against fire blight are not mixable). All products are applied at the recommended rates. **Green:** Targets and/or applications which differ between scab susceptible and resistant cultivars; **Blue:** Targets and/or applications which differ between fire blight susceptible and resistant cultivars. For explanation and frequency of traits see Table 1 & 2.

Integrated model orchards				Combination of traits			
Date, stage, BBCH code		Primary target	Target on scab resistant cultivars	Scab-sus + FB-sus	Scab-res + FB-sus	Scab-sus + FB-res	Scab-res + FB-res
Apr 1		Apple blossom weevil	--	Al	Al	Al	Al
Apr 4	C3 54	Scab	No scab treatment	De	--	De	--
Apr 8		Apple blossom weevil	--	Al	Al	Al	Al
Apr 13	D 56	Scab	Scab (resistance man.)	De	De	De	De
Apr 18	E	Scab & Mildew	No fungicide treatment	De	--	De	--
Apr 22	E2 29	Scab & Mildew	Scab (resistance management) & Mildew	De	De	De	De
Apr 23		Rosy apple aphid	--	Py	Py	Py	Py
Apr 24	F	61 Scab & Mildew	Scab (resistance man.) & Mildew	Sli+Ca	Sli+Ca	Sli+Ca	Sli+Ca
Apr 25		Weeds	--	Ro	Ro	Ro	Ro
Apr 29		Scab, Mildew & Thinning	Scab (resistance man.), Mildew & Thinning	Sli+Ca+Et	Sli+Ca+Et	Sli+Ca+Et	Sli+Ca+Et
Apr 29		Fire blight	--	Str	Str	--	--
May 3	G	Rust mites	--	Ki	Ki	Ki	Ki
May 3		Fire blight	--	Str	Str	--	--
May 8	H	Aphids	--	Py	Py	Py	Py
May 8		Fire blight	--	Reg	Reg	--	--
May 13		69 Codling moth	--	Al	Al	Al	Al
May 15		Weeds	--	Ba	Ba	Ba	Ba
May 19		Scab & Mildew & Thinning	No fungicide treatment, Thinning	Ca+Rh	Rh	Ca+Rh	Rh
May 27		Scab & Mildew	Mildew	Ca	Ca	Ca	Ca
June 2	I	71 Scab & Mildew	No fungicide treatment	Ca	--	Ca	--
June 12		Scab & Mildew	Mildew	Ca	Ca	Ca	Ca
June 21	J	74 Codling moth	--	Ma	Ma	Ma	Ma
June 29		Scab & Mildew & Sooty blotch & Codling moth	Mildew & Sooty blotch & Codling moth	Fli+Ma	Fli+Ma	Fli+Ma	Fli+Ma
July 14		Scab & Mildew & Sooty blotch & Codling moth	Mildew & Sooty blotch & Codling moth	Fli+Ma	Fli+Ma	Fli+Ma	Fli+Ma
July 31		Codling moth	--	Ma	Ma	Ma	Ma
Aug 8		Scab & Mildew & Sooty blotch & Codling moth	Mildew & Sooty blotch & Codling moth	Fli+Ma	Fli+Ma	Fli+Ma	Fli+Ma
Sept 6		Codling moth	--	Ma	Ma	Ma	Ma
Sept 25		81 Scab & Mildew & Sooty blotch	Mildew & Sooty blotch	Fli+Ca	Fli+Ca	Fli+Ca	Fli+Ca
Number of spray passages				28	25	25	22

Abbreviations:

Fungicides & bactericides

 Ca=Captan 80 (captane)
 De=Delan WG (dithianone)
 Fli=Flint (trifloxystrobin)
 Sli=Slick (difenoconazole)
 Reg=Regalis (prohexadione-calcium)
 Str=streptomycine

Insecticides

 Al=Alanto (thiacloprid)
 Ki=Kiron (fenpyroximate)
 Py=Pyrinex (clorpyrifos)

Micro-organisms

Ma=Madex 3 (granulosis virus)

Herbicides

 Ba=Basta (glufosinate)
 Ro=Roundup (glyphosate)

Growth regulators

 Et=Ethephon (ethephone)
 Rh=Rhodofix (2-(1-naphthyl) acetic acid)

Table 6: Plant protection scheme in the organic apple orchard (timing, targets & pesticides) for cultivars with different trait combinations. For frequency of trait combinations in the model orchards, see table 2. For details see Table 5. Notes: (1) Bio Suisse limits copper fungicides to 1.5 kg/ha of pure copper (Speiser *et al.*, 2010), corresponding to 3x 500 g/ha. (2) Sulfur is applied at 0.2 % in combination with Armicarb, otherwise at >0.4 %. (3) On scab-resistant cultivars, the omission of sulphur late in the season necessitates an additional application of Armicarb on June 12 for the control of sooty blotch. (3) On Sept 25, the sulfur treatment is omitted to avoid visible spraying residues on apples.

Organic model orchards				Combination of traits				
Date, stage, BBCH code			Primary target	Target on scab resistant cultivars	Scab-sus + FB-sus	Scab-res + FB-sus	Scab-sus + FB-res	Scab-res + FB-res
Apr 3	C3	54	Scab	No fungicide treatment	Ko	--	Ko	--
Apr 8			Scab	No fungicide treatment	Ko	--	Ko	--
Apr 13	D	56	Scab	No fungicide treatment	Ko	--	Ko	--
Apr 18	E	59	Scab & Mildew	Scab (resistance man.) & Mildew	S+My	S+My	S+My	S+My
Apr 22	E2	59	Scab & Mildew	No fungicide treatment	S+My	--	S+My	--
Apr 23			Rosy apple aphid	--	NA	NA	NA	NA
Apr 24	F	61	Scab & Mildew	Scab (resistance man.) & Mildew	S+My	S+My	S+My	S+My
Apr 29		63	Codling moth	--	Iso*	Iso*	Iso*	Iso*
Apr 29			Scab & Mildew	Scab (resistance man.) & Mildew	S+My	S+My	S+My	S+My
Apr 29			Fire blight	--	BP	BP	--	--
May 3	G	67	Scab & Mildew	No fungicide treatment	S+My	--	S+My	--
May 3			Fire blight	--	BP	BP	--	--
May 8	H	69	Scab & Mildew	Scab (resistance man.) & Mildew	S+My	S+My	S+My	S+My
May 8			Fire blight	--	BP	BP	--	--
May 13		69	Scab, Mildew & Sawfly	Scab (resistance man.), Mildew & Sawfly	S+My+Qu	S+My+Qu	S+My+Qu	S+My+Qu
May 19			Scab & Mildew	No fungicide treatment	S+My	--	S+My	--
May 27			Scab & Mildew	No fungicide treatment	S+My	--	S+My	--
June 2	I	71	Scab & Mildew & Codling moth	No fungicide treatment, Codling moth	S+Ma	Ma	S+Ma	Ma
June 12		73	Scab & Mildew	Mildew & Sooty blotch	S	Ar	S	Ar
June 21	J	74	Scab & Mildew	No fungicide treatment	S	--	S	--
June 29			Scab & Mildew & Sooty blotch	Mildew & Sooty blotch	S+Ar	Ar	S+Ar	Ar
July 8			Scab & Mildew	No fungicide treatment	S	--	S	--
July 14			Scab & Mildew & Sooty blotch	Mildew & Sooty blotch	S+Ar	Ar	S+Ar	Ar
July 22			Scab & Mildew	No fungicide treatment	S	--	S	--
July 31			Scab & Mildew & Sooty blotch	Mildew & Sooty blotch	S+Ar	Ar	S+Ar	Ar
Aug 8			Scab & Mildew	No fungicide treatment	S	--	S	--
Aug 24			Scab & Mildew & Sooty blotch	Mildew & Sooty blotch	S+Ar	Ar	S+Ar	Ar
Sept 6			Scab & Mildew	No fungicide treatment	S	--	S	--
Sept 25		81	Scab & Mildew & Sooty blotch	Mildew & Sooty blotch	Ar	Ar	Ar	Ar
Number of spray passages					28	16	25	13
*Application of pheromone dispensers					1	1	1	1

Abbreviations:

Fungicides

Ko=Kocide Opti (copper hydroxide)
 S=Schwefel Stulln (sulphur)
 My=Myso-Sin (acidified clay)
 Ar=Armcarb (potassium bicarbonate)

Micro-organisms

BP=BlossomProtect (*Aureobasidium pullulans*)
 Ma=Madex 3 (granulosis virus)

Insecticides

NA=NeemAzaI-T/S (azadirachtine)
 Qu=Quassan (quassia extract)

Pheromone dispensers

Iso=Isomate-C Plus (pheromone)

Herbicides

None

Growth regulators

none

5 Licenses, royalties and other fees

Currently, apple growers in Switzerland have to pay **licenses** (on a per-tree basis) for most apple varieties. A license of ca 1 – 2 CHF is charged from the tree nursery when the tree is sold to the farmer.

In the case of so-called «**club varieties**», the owners of the club variety make considerable marketing efforts, for which they charge additional money from the growers. If a farmer wants to grow and sell apples under the club's brand name, he has to join the club. The **accession fees** for the clubs are highly variable, with a maximum up to several 10'000 CHF. In addition, the growers have to pay **royalties** (on a yield basis) of ca 0.1 – 0.3 CHF/kg.

5.1 Licenses and royalties for scab resistance

The experts assume that no additional licenses or royalties will be charged for scab resistant GM crops. Thus, a GM Gala will cost a similar license as a conventional Gala, and a GM club variety will cost a similar license as a conventional club variety.

5.2 Licenses and royalties for scab and fire blight resistance

The experts assume that no additional licenses or royalties will be charged for scab and fire blight resistant GM crops. Again, a GM Gala will cost a similar license as a conventional Gala, and a GM club variety will cost a similar license as a conventional club variety.

For fire blight resistant rootstocks, a license of CHF 1 – 2 is assumed (for non-GM rootstocks such as Geneva 11, as well as for GM rootstocks, which are not assumed to be available in this study).

6 Comparison with GM arable crops

In this project, GM apples are studied as a complement to GM arable crops. A separate report is dedicated to arable crops. Some of the aspects which are discussed for arable crops were judged by experts not to be relevant for GM apples. These are briefly mentioned here:

- The experts do not foresee relevant changes in **crop development, planting or harvest time** associated with the genetic modification to be studied.
- The experts have no information on **stress tolerance (e.g. heat, draught)** or need for irrigation. They are therefore assumed to be unchanged by the genetic modification to be studied.
- The experts do not foresee relevant changes in **fertilization** associated with the genetic modification to be studied.
- The experts assume that **crop management practices** will remain unchanged by the genetic modification to be studied, except for those practices related to monitoring or control of scab and fire blight.
- The genetic modifications to be studied are not relevant for **herbicide** use (in contrast to the arable crops studied).

7 References

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