



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

## Model farms and scenarios

Revised internal document

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Workpackage 2.1

**Description in project proposal (p. 23):** «Workpackage 2 will develop scenarios of 3 existing farming systems (conventional, integrated, and organic) and 3 potential farming systems that include GM plants. At least one representative of an annual crop rotation and one perennial crop will be selected as a baseline in each farming system. In order to make use of synergies with new research in NFP 59, model crop rotations will include maize and canola. Baseline scenarios with well-documented background information on societal benefits will be preferred...»

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

On 14 May 2008, the content of this document was outlined in workshop 2. The document was discussed in workshop 3 on 1 October 2008 (apple orchards) and 2 October 2008 (arable crops).

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## 1 Introduction

This document is prepared as a project-internal tool. It provides

- an overview of the crops/cropping systems which will be affected most strongly by the availability of GM crops;
- a short description of the current farming systems used for these crops, with emphasis on the Swiss Mittelland region;
- a short description of the trends in these farming systems expected within the next decade.

Because farming systems are always adapted to the properties of the crops grown, the fine-tuning of the farming systems is interdependent with the agronomic impact assessment. This document will therefore be refined in workshop 3

## 2 Farming systems

### 2.1 Definition of farming systems

#### 2.1.1 Conventional farming

There is no legal definition of conventional farming; it is best described as a farming system which does not fulfil the requirements of integrated or organic farming. In WS 2, the experts agreed that the importance of conventional farming is low in Switzerland, and will continue to decrease. It was therefore decided in workshop 2 that conventional farming does not need to be included in the scenarios. Later in the project, however, it became evident that the ÖLN production rules allow very little flexibility for designing novel crop rotations which would take advantage of the novel traits of GM crops. In order to explore the full range of possible impacts of GM crops, it was therefore decided to include also rotations which do not comply with the ÖLN production rules. These are called «conventional rotations».

#### 2.1.2 Integrated farming

In Switzerland, the term «integrierte Produktion» (IP) has two different meanings.

- IP is often used as a synonym for «ökologischer Leistungsnachweis» (ÖLN). If a farm fulfils ÖLN, it is entitled to receive ecological payments (Ökobeiträge). The production methods of ÖLN are defined by the «Direktzahlungsverordnung» (DZV; SR 910.13<sup>1</sup>). Ca 95 % of all Swiss farmers comply with ÖLN (note that organic farmers also comply with ÖLN by definition).
- IP may also be used as a synonym for IP Suisse. IP Suisse is a private association for integrated production<sup>2</sup>, which owns a marketing label. IP Suisse standards require production according to ÖLN, but also have some additional requirements. A little less than half of the ÖLN farmers are members of IP Suisse.

All socio-economic statistical data are based on ÖLN, while for IP Suisse, only few statistical data are available. Therefore, the «integrated farming» scenarios will be based on the production methods defined by ÖLN.

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<sup>1</sup> <http://www.admin.ch/ch/d/sr/9/910.13.de.pdf>

<sup>2</sup> <http://www.ipsuisse.ch>

### 2.1.3 Organic farming

In Switzerland, the organic farming ordinance (SR 910.18<sup>3</sup> and 910.181<sup>4</sup>) specifies the production methods allowed for organic farming. Ca 95 % of the organic farmers are members of Bio Suisse, and must therefore also comply with Bio Suisse standards<sup>5</sup>. In the organic scenario, both the organic farming ordinance and the Bio Suisse standards will be taken into account. Ca 11 % of all Swiss farmers are organic farmers according to this definition. In Swiss organic farming, all use of herbicides is strictly prohibited<sup>6</sup>.

### 2.1.4 Note on the combination of GMOs and integrated/organic farming

All standards and regulations for organic farming prohibit the use of GMOs at present. For the purpose of this project, we construct hypothetical scenarios where GM crops are used in organic farming. The aim is to analyze the potential risks and benefits of GM crops for these farming systems. It is explicitly not intended to anticipate any policy changes in organic farming regulations with respect to GMOs. Please note that the decision about the use or non-use of GMOs is not only based on advantages in production technique or favourable environmental profile, but also on the principles and traditions of organic production and on market profile.

The legal requirements for ÖLN (which will be used in this project; see section 2.1.2) allow the use of GMOs. In passing, it may be noted that the standards for «IP Suisse» and for «Suisse Garantie» do not allow the use of GM plants or animals, but these standards will not be considered in this project.

## 2.2 Future trends in agriculture

Because the study extends to GM crops available within the next decade, the description of farming systems should also consider the trends expected for this period. Overviews of the future trends are given in the studies «Scenar 2020» (Nowicki *et al.*, 2007) and «FFRAF report» (Anonymous, 2007). These studies give a good overview of the trends in European and global agriculture, and the following description of the major drivers of change is extracted from these two studies.

- **Global warming:** As a consequence of global warming, the cropping areas within Europe will generally shift further north. New land will become available for agriculture in Siberia, Scandinavia and Canada. Extreme weather events will become more frequent and more pronounced. The scarcity of irrigation water in southern Europe will aggravate the effects of droughts. As a consequence, the distribution pattern of crops, weeds, pests, diseases, pollinators and soil organisms across Europe will change.
- **Energy:** Energy prices will remain relatively high in the long term.
- **Liberalization:** The liberalisation process in agriculture continues. However, the outcome of future WTO negotiations is a major uncertainty in this area. In the EU, there is a shift from market price support to income support, which is increasingly coupled with public goods (environment, health). The willingness to protect the

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<sup>3</sup> <http://www.admin.ch/ch/d/sr/9/910.18.de.pdf>

<sup>4</sup> <http://www.admin.ch/ch/d/sr/9/910.181.de.pdf>

<sup>5</sup> <http://www.biosuisse.ch>

<sup>6</sup> <http://www.fibl.org/subdomain/hifu/hilfsstoffe/documents/positionspapier-fettsaeure-herbizide.pdf>

environment and especially biodiversity has increased, leading to new environmental regulations (birds, habitats, nitrates etc.).

- **Urbanization:** There is a tendency for depopulation of rural areas, which may lead to the abandonment of marginal land (e.g. alps).
- **Consumer preferences:** The consumption of cereals, meat (especially poultry) and dairy products has increased worldwide. In Europe, there is a shift towards fresh food, convenience food, functional food and diet products. Meat consumption shifts from beef towards poultry and pork. Finally, there is a higher demand for quality food (including labels, organic food and fair trade products) and resistance against GMOs. The future trends in European consumer demands are uncertain.
- **Biofuels:** Currently, policies favour the production of bio-fuels. In some foods, prices have risen because of competing demand by the bio-fuels industry. On longer terms, bio-fuels will probably be produced from non-food biomass. Although this excludes direct competition with the food market, there may still be competition with respect to land use. The future demand for bio-fuels is highly uncertain, because it depends on environmental, energy and food policies, and on developments in the petrol sector.

Statistical observations for European agriculture:

- **Production units:** Farm numbers decline steadily. There is a trend for concentration in larger farm units, which can better take advantage of technological developments and which can more easily integrate into the food chain (from production to distribution). This trend is facilitated by the liberalized European labour market and by the globalized food market. On the other hand, there is also a trend for small farms to combine food production with other food or non-food activities. These processes are interconnected with demographic changes, rural development and migration patterns within Europe.
- In Europe, production has been continuously intensified. This includes the large-scale use of fertilizers and pesticides, as well as rationalization, specialisation and mechanisation. Horticultural crops shift from open fields to glasshouses with highly controlled conditions.

### 2.3 Virtual model farms for Switzerland

To adapt to the future challenges of e.g. higher energy prices or trade liberalisation, from an economic point of view, Swiss farmers have at least two strategies at their disposal:

- 1) to improve farm productivity by reducing costs and / or increasing returns (higher yields or add value)
- 2) to diversify in on-farm or off-farm activities

To illustrate how Swiss farms implementing such strategies could look like in the future, we outline four virtual model farms below which also consider the international trends described under 2.2. Already today, there are some farms in Switzerland which resemble one of the four virtual model farms closely. We assume that such farms will become more frequent in the future.

### 2.3.1 The «intensive farm»

The strategy of the «intensive farm» is on the one hand to reduce costs through specialisation, low labour input and efficient farm structures (large field sizes), and on the other hand to improve yields by the use of state-of-the-art technology and external inputs (fertilizers, plant protection products). Such farms are typically situated in low elevation areas with favourable soil and climate. They are specialised either in arable production growing only a few crops, or in pig fattening, laying hens etc.

To reduce labour input, production is highly mechanized, with large and modern machinery. If feasible, low-till or no-till practices are adopted. Produce are sold to the bulk market. This farm type is more frequent among integrated farms than among organic farms. From an economic point of view, this farm type can be characterized as follows:

- High investments in machinery.
- High costs for fertilizers and plant protection products.
- High returns from high yields and good quality.
- Efficient management.
- Low costs for labour. A possible consequence is the «intensive part-time farm» (a combination of the the «intensive farm» described in 2.3.1 and the the «part-time farm» described in 2.3.4). However, this strategy is not considered separately.

### 2.3.2 The «low-input farm»

The «low-input farm» seeks to reduce costs also through specialisation, low labour input and efficient farm structures (large field sizes). Contrarily to the «intensive farm» however, the «low-input farm» minimises the use of inputs and integrates environmental measures in the farm organisation to maximize direct payments. Typically, such farms specialize on production which requires little labour, such as free-range cattle and fodder plants and thus usually focus on animal husbandry.. Such farms are typically situated outside the areas with best soil and climate. The farms are often large, and they always have large individual fields. These farms are often family farms without employees, so the available labour is limited. Cropping and animal husbandry systems are selected in such a way that the labour requirements are minimized. Whenever possible, hired state-of-the-art machinery is used instead of investing in own machinery. If feasible, low-till or no-till practices are adopted. While produce are sold to bulk markets, the farm is interested getting a low price premium for low-input production.

This farm type occurs both in integrated and organic farms. From an economic point of view, this farm type can be characterized as follows:

- Low production costs (including animal feed).
- Low investments in machinery and use of hired machinery.
- Low labour costs.
- Low costs for marketing.
- Low price premiums for low-input production.
- High transfers from agri-environmental measures by maximising direct payments.

### 2.3.3 The «direct sale farm»

The «direct sale farm» links the strategy of adding value to the products with the on-farm diversification strategy. Such farms produce a wide range of products for farm-gate sale and weekly markets. As a consequence, the product portfolio is primarily determined by consumer demand. The adoption of agri-environmental measure on the farm is used as a marketing instrument.

The «direct sale farm» is ideally situated in the neighbourhood of cities and is relatively small with small field sizes. To attract customers and to support marketing activities, it may be useful that the farm is located in a scenic area, or that the farmhouse is maintained tidy and in traditional style. The wide range of crops precludes the use of specialized machines. Apart from the core production activities, the farm integrates activities such as storage of crops, cleaning, packing and marketing (farm-gate sale, market stand, supply of local restaurants and specialty shops) in order to achieve a higher product price. Moreover, added value is created by food processing (e.g. bread, jam, sausages). Such farms employ relatively many farm workers. This farm type is particularly well suited for organic farms. From an economic point of view, this farm type can be characterized as follows:

- High investments in storage, packing and processing facilities, and in marketing activities.
- High labour costs.
- High returns because of premium prices.
- High returns from added value by processing.
- Medium / high transfers from agri-environmental measures (direct payments).

### 2.3.4 The «part-time farm»

The «part-time farm» diversifies its activities by an additional off-farm income. Thus, the importance of the farm income decreases. It is small and operated part-time by a family without employees. Non-farm activities have priority over farm activities. As a result, labour is not equally available at all times of the day, or all days of the week, or in all seasons of the year. This farm type is often situated in marginal regions which restricts the range of crops which can be grown by the climate (e.g. high elevations). Individual fields are often small. As the farm does not invest in machinery any more, production is further restricted by the old age of the machinery. However, the major restriction to production is labour availability. Often, these farms focus on animal husbandry due to an intrinsic motivation. The farm is interested in non-farm related income such as running a restaurant, renting horse stables or operating a camping ground. These activities may create synergies with the farming activities, and it may be useful that the farm is located in a scenic area, or that the farmhouse is maintained tidy and in traditional style. However, part-time farming can also be combined with pure off-farm activities. This farm type occurs both in integrated and organic farms. From an economic point of view, this farm type can be characterized as follows:

- Low income and low dependency on farming activities.
- Machinery and buildings are depreciated.
- Major income from non-farm activities.
- Production is intrinsically and not economically motivated.
- Labour is a scarce factor.

## 2.4 Virtual model farms used in the scenarios

All four virtual model farms described in section 2.3 are relevant for Switzerland. However, not all of them are equally relevant in the context of arable crops and fruit growing, for which we will study the impact of GMOs. In workshop 3, it was decided to underly the «intensive farm» strategy to the scenarios, because GM crops are most likely taken up by this model farm, and have the greatest impact on these farms. «Intensive farms» produce a large proportion of the arable and horticultural crops, and virtually all of the arable and horticultural crops sold through the major retailers.

## 3 Arable crops

### 3.1 Main production bottlenecks for arable crops

The main production bottlenecks for arable crops were discussed in workshop 2. The results are shown in table 1.

**Table 1:** Main potential bottlenecks for arable crops production. Abbreviations / colours: **NB:** usually no bottleneck; **PS:** partially solved (i.e. is sometimes a limiting factor); **LF:** limiting factor.

Crops & bottlenecks	significance for integrated farming	significance for organic farming
<b>potatoes</b>		
late blight ( <i>Phytophthora infestans</i> )	PS, control causes environmental problems	PS
<i>Rhizoctonia solani</i>	PS	LF
powdery scab ( <i>Spongospora subterranea</i> )	LF	LF
common scab ( <i>Streptomyces scabies</i> )	LF	LF
potato beetle ( <i>Leptinotarsa decemlineata</i> )	NB	NB
viral diseases	PS	PS
wireworms ( <i>Agriotes spp.</i> )	PS	PS
slugs	PS	PS
weeds	NB	NB
nutrient supply	NB	LF
<b>wheat</b>		
<i>Septoria nodorum</i>	NB	NB
rusts ( <i>Puccinia spp.</i> )	NB	NB
mildew ( <i>Erysiphe graminis</i> )	NB	NB
<i>Fusarium nivale</i>	PS	NB, but not durably solved
seed-borne diseases	NB	PS
weeds	NB	NB
nutrient supply	NB	PS
<b>soy</b>		
slugs	NB	PS, but causes high costs
hares	PS	PS
weeds	NB	LF
nutrient supply	NB	NB

**Table 1, continued.**

Crops & bottlenecks	significance for integrated farming	significance for organic farming
<b>maize</b>		
European corn borer ( <i>Ostrinia nubilalis</i> )	NB	NB
corn rootworm ( <i>Diabrotica spp.</i> )	NB	NB
corn smut ( <i>Ustilago maydis</i> )	NB	NB
<i>Helminthosporium</i>	PS with certain varieties	PS with certain varieties
<i>Fusarium</i>	PS with certain varieties	PS with certain varieties
crows	PS	LF
wild pigs	PS	PS
weeds	NB	PS
nutrient supply	NB	PS
<b>grass-clover meadow</b>		
weeds	NB	PS
<b>sugar beet</b>		
Rhizomania	NB	NB
<i>Cercospora / Ramularia</i>	NB, but causes high costs	PS with certain varieties
nematodes	PS, but causes environmental problems	PS
slugs & other soil pests	NB	LF
weeds	NB, but causes high costs	PS, causes very high costs / losses
nutrient supply	NB	NB, but causes high costs
<b>oilseed rape</b>		
pollen beetle ( <i>Meligethes aeneus</i> )	NB, but not durably	LF
stem-mining weevil ( <i>Ceutorhynchus napi</i> )	NB	LF
<i>Phoma</i>	NB	NB
<i>Sclerotinia</i>	NB	NB
slugs	NB	PS
weeds	NB	PS
nutrient supply	NB	LF

### 3.2 Selection of crop rotation(s)

The crop rotation(s) to be investigated were selected in an iterative process, illustrated in figure 1.

#### 3.2.1 Baseline

In workshop 2, it was decided to use information from the DOC-trial in Therwil (BL) for the baseline data. The DOC trial is based on a seven-year rotation which is identical for the integrated and the organic system. It is studied in great detail and well documented. However, the experts agreed that the rotation needs to be adapted for this project. The DOC rotation is shown in figure 1 (left hand side).

### 3.2.2 Adaptation of crop rotation

The DOC rotation is more complex than a modern rotation would normally be. On most integrated farms, there is a trend for concentration on fewer crops, with a higher proportion of cash crops. Two four-year rotations for integrated farming were developed, with either potatoes or oilseed rape in the second year (INT-potatoes; INT-rape). Two three-year rotations were also developed: one for mixed farms (INT-mixed) and one for stockless farms (INT-stockless).

On an organic farm, the rotation could also be simplified to contain fewer crops, but grass-clover would probably remain included. Stockless organic farms were not considered here, because they are rare. Two organic rotations were developed: a complex seven-year rotation (ORG-complex) and a simple three-year rotation (ORG-simple).

The adapted rotations (after workshop 2) are shown in figure 1 (center). Note that the rotations were modified in subsequent workshops. The most up-to-date version can be found in the document «Agronomic consequences of the use of GM crops. Part 1: arable crops».

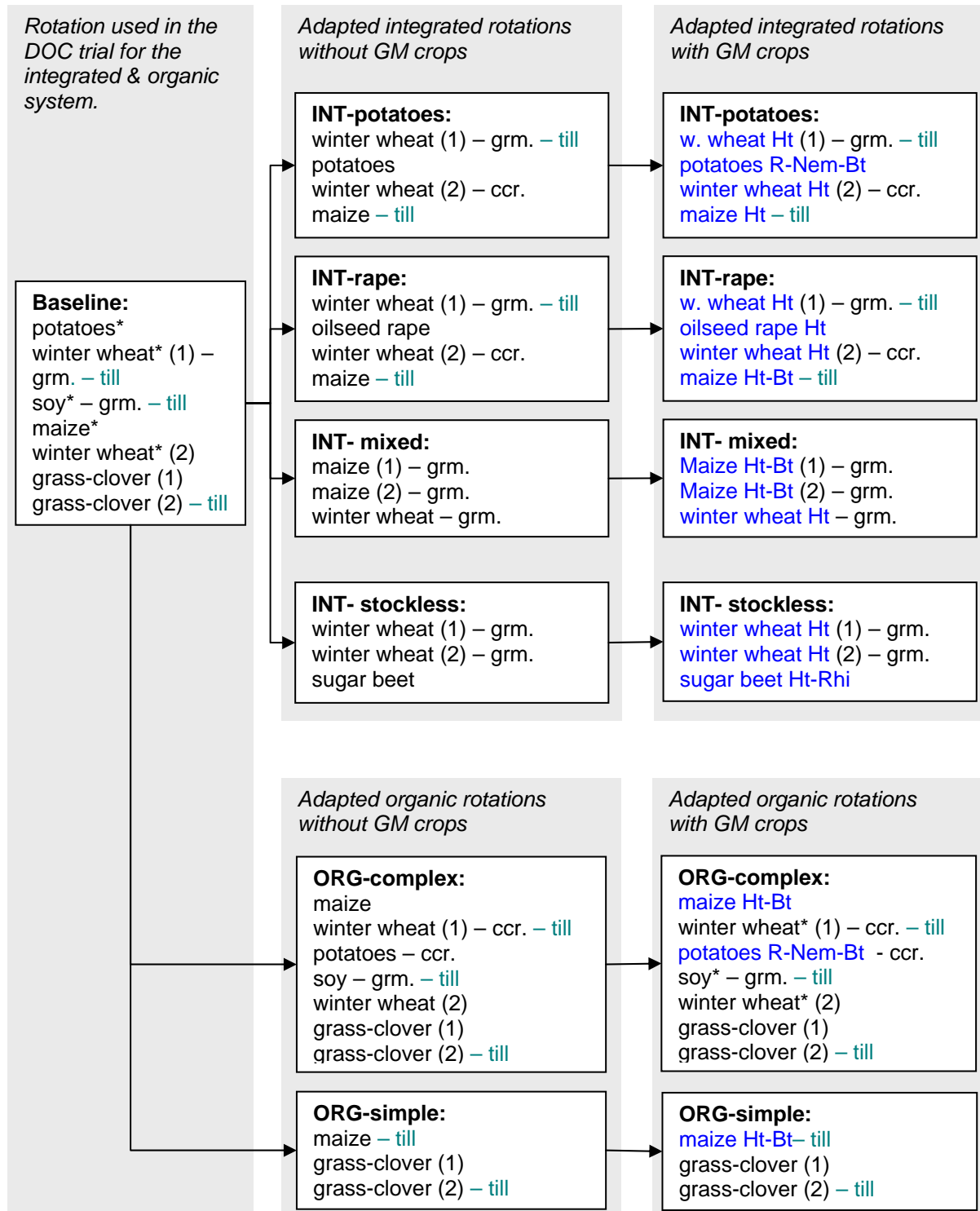
### 3.3 GM scenarios for arable crops

For the GM scenarios, non-GM crops are substituted by GM cultivars with the following properties (see also report of workshop no 1):

<b>GM crop</b>	<b>GM traits</b>	<b>abbreviation</b>
GM potatoes	resistance to late blight, nematodes and potato beetle	R-Nem-Bt
GM winter wheat	herbicide tolerance	Ht
GM soy	herbicide tolerance	Ht
GM maize	herbicide tolerance; resistance to European corn borer and corn rootworm.	Ht-Bt
GM sugar beet	herbicide tolerance, resistance to rhizomania	Ht-Rhi
GM oilseed rape	herbicide tolerance	Ht

Exception: In organic farming, herbicides may not be used. Therefore, GM crops with no other traits than herbicide tolerance are not included in the organic GM rotations. The adapted rotations with GM crops are shown in figure 1 (right hand side).

**Figure 1:** Variants of arable crop rotations, developed from the DOC rotation in workshops 2 and 3. Crops: grm. = green manure; ccr. = catch crop; w. wheat = winter wheat. Traits: Ht = herbicide tolerant; Bt = insect resistant through Bt genes; R = R-genes for resistance to *Phytophthora infestans*; Nem = nematode resistant; Rhi = resistance to rhizomania. All GM crops are shown in blue font. \* = although GM varieties are available, they are not included in the GM rotations. Note that the rotations were modified in subsequent workshops. The most up-to-date version can be found in the document «Agronomic consequences of the use of GM crops. Part 1: arable crops».



## 4 Perennial horticultural system

In workshop 2, it was decided to study a 10 ha orchard with deciduous fruit (several varieties of apples and pears, in typical production proportions).

### 4.1 Main production bottlenecks for apple and pear orchards

The main production bottlenecks for apple orchards were discussed in workshop 2 and 3. The results are shown in table 2.

**Table 2:** Main production bottlenecks for apple orchards. Abbreviations / colours: **NB:** usually no bottleneck; **PS:** partially solved (i.e. is sometimes a limiting factor); **LF:** limiting factor.

Bottlenecks	significance for integrated farming	significance for organic farming
<b>diseases</b>		
scab ( <i>Venturia inaequalis</i> )	<b>NB.</b> Increasing fungicide resistance reduces range of effective fungicides	<b>PS.</b> NB for resistant cv. like Topaz, or tolerant cv. like Boskoop); <b>LF</b> in humid years for Gala, Golden Delicious, Elstar, Braeburn, Pinova, Conference pear etc.
mildew ( <i>Podosphaera leucotricha</i> )	<b>NB</b>	<b>NB.</b> Fairly solved (depending on cultivar)
fire blight ( <i>Erwinia amylovora</i> )	<b>LF,</b> severe threat. Streptomycin applications authorized, but honey contamination might cause high costs	<b>LF,</b> severe threat. Available biocontrol agents provide only partial protection.
Sooty blotch ( <i>Gloeodes pomigena</i> ) and fly speck ( <i>Schizotoryum pomi</i> )	<b>NB</b>	<b>PS.</b> NB for some varieties; problematic in sensitive cv. like Gala, Idared, Pinova Topaz, Otava, Ariwa and Conference pear
storage diseases	<b>NB</b> for most varieties	<b>PS.</b> NB for many cv.; major problems with <i>Gloeosporium sp.</i> rot mainly in Pinova, Topaz, Gala, Otava, Ariwa
<b>pests</b>		
aphids	<b>NB</b>	<b>NB</b>
codling moth ( <i>Cydia pomonella</i> )	<b>NB</b>	<b>NB</b>
summer fruit tortrix ( <i>Adoxophyes orana</i> )	<b>NB</b>	<b>NB</b>
apple blossom weevil ( <i>Anthonomus pomorum</i> )	<b>NB</b>	<b>NB</b>
apple sawfly ( <i>Hoplocampa testudinea</i> )	<b>NB</b>	<b>NB</b>
Pear sucker ( <i>Cacopsylla pyrisuga</i> )	<b>PS</b> (only relevant for pears; Conference)	<b>PS</b> (only relevant for pears; Conference)

**Table 2**, continued.

<b>Bottlenecks</b>	<b>significance for integrated farming</b>	<b>significance for organic farming</b>
<b>other production bottlenecks</b>		
Skin russetting	<b>NB</b> for most varieties; occasionally problems with Golden Delicious and Conference	<b>PS.</b> NB for various cv.; PS for Golden Delicious, Pinova and pear cv.
Bi-annual bearing	<b>NB</b> for most varieties; less well solved for Conference	<b>LF.</b> Causes severe yeald losses with Gala, Elstar, Boskoop, Otava, Maigold, Ariwa and pear cv.
Bark and wood diseases, cankers	<b>NB</b> for most varieties; PS for Gala, Cox	<b>PS.</b> NB with different cv.; major problems with Gala and particularly Topaz
replant disease	<b>PS.</b> Problems increase, due to replant under hail nets	<b>PS.</b> Problems increase, due to replant under hail nets
long-term storage (ethylene control)	<b>NB</b> (CA storage and use of 1-MCP)	<b>PS.</b> minor problems with diff. cv., however no scab-resistant and long-term storable cv. available at the moment
adaptation to climate change	<b>PS</b>	<b>PS.</b> Not satisfyingly solved
Anchorage	<b>NB</b> , but causes some costs	<b>NB</b> , but causes some costs
<b>other bottlenecks</b>		
availability of varieties	<b>NB</b> for most varieties; restricted for Club cv. like Pink Lady or Jazz etc.	dito
acceptance of varieties on the market	<b>PS.</b> NB for most modern but scab sensitive varieties; decreasing acceptance for «older» cv. like Idared, Boskoop, Glockenapfel, Golden Delicious etc. Presently no acceptance for scab-resistant cultivars	<b>NB</b> for most currently produced apples, including resistant cv. thanks to taste-group-concept; decreasing acceptance for Golden Delicious

**Table 3:** Priorities for varietal traits in integrated and organic orchards.

<b>Trait</b>	<b>Integrated horticulture</b>		<b>Organic horticulture</b>	
	<b>Priority</b>	<b>Reason</b>	<b>Priority</b>	<b>Reason</b>
scab tolerance / resistance	low	easily controlled with fungicides	high	difficult to control
Bi-annual bearing	Low-medium	controlled with phyto-regulators	high	no effective control
fire blight resistance	medium	can be controlled with the antibiotic streptomycine	high	no effective control
marketable yield	high	great influence on profitability	high	Lower yields partially compensated by higher prices
cultivar properties must match the demand on the market	very high	market is inflexible («to sell or not to sell»)	high	market is more flexible (Switzerland)

## 4.2 Varietal choice and the apple market

In this study, the composition of the orchards under different scenarios is illustrated with apple varieties which are well-known today. From the marketing point of view, apples can be classified by distinct criteria (Weibel and Leder, 2007). The major characteristics are:

- **Flavour group:** «equilibrated to sweet»; «spicy to tart»; «predominantly tart».
- **Period of consumption:** early, autumn/winter, long storability

**Commercialization of cultivar:** All traditional Swiss apple varieties are so-called «free cultivars», which can be multiplied and produced by everybody without charges. By contrast, some modern apple varieties are commercialized as so-called «club varieties», which are registered and highly protected trademarks, and the grower of a club cultivar is obliged to pay licences. The competence team believes that GM apple cultivars can only be commercialized, if they can be marketed as «club varieties» (see document «List of GM plants and traits», section 3.7.1).

The priorities for varietal traits are different in integrated and organic orchards (table 3).

## 4.3 Baseline orchards

In workshop 2, it was decided to use the economic values given by the programme «Arbokost and Arbokost-Bio 2006» by ACW and FiBL as baseline data (new update since Sept. 2007 available). The size of the model orchard was assumed to be 10 ha. In the overall assessment, income security will be given priority over yield security.

The composition of the orchards reflects the different marketing groups among the apple varieties (see above). The groups are visualized with the names of varieties which are well-known at present. It is acknowledged that other varieties (currently less well-known) might represent some of the market groups. The assumed varietal composition of the baseline orchards is shown in figure 4.

### 4.3.1 Integrated baseline orchard

The integrated baseline orchard contains

- a predominant proportion of equilibrated to sweet apples,
- a certain proportion of spicy to tart apples cv., and
- a small proportion of pears.

Predominantly tart apples are a flavour group of minor importance on the market for integrated apples. The integrated orchard therefore does not contain this taste group. The distribution of taste groups and varieties is shown in figure 4.

Within the equilibrated to sweet apples, the orchard contains Gala, Golden Delicious or Maigold, and Pinova. Currently, the market demands a high proportion of Gala, a decreasing proportion of Golden Delicious (apples with a yellow skin are weakly demanded, because of the «negative reputation» of Golden Delicious in Switzerland).

Within the spicy to tart apples, the orchard contains Jazz and Braeburn. In Switzerland, presently Pink Lady and Jazz are the main so-called «club varieties». They are requested because of their appearance, firm texture, sugar and acid

content, and their good storage properties. Because of the good market demand, a high proportion of Braeburn is cultivated. Although Braeburn is not a club variety, there are many differently coloured clones of this variety available, which are protected.

#### 4.3.2 Organic baseline orchard

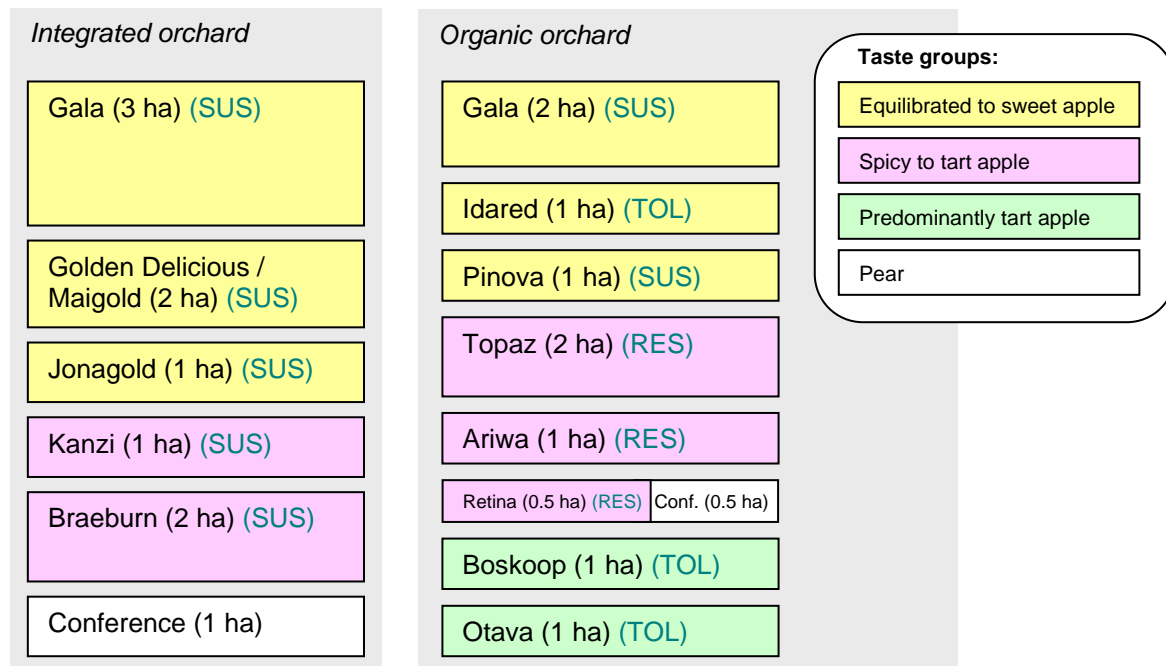
The organic orchard contains all flavour groups that are also present in the integrated orchard plus a proportion of predominantly tart apples (table 4, green).

Within the equilibrated to sweet apples, Gala has a high proportion because of the high market demand for such a sweet and long-term storable variety. Presently there is no scab-resistant alternative for Gala available. Idared is there, because it is a relatively reliable cv. in organic production in terms of disease tolerance and bi-annual bearing. Pinova (scab sensitive) is organically manageable in terms of scab and bi-annual bearing control. It is, however, highly susceptible to *Gloeosporium* disease, thus the fruit have to be hot water treated before storage.

Within the spicy to tart apples, Topaz (scab resistant) is the dominant cultivar because of its high acceptance by the consumers (and the retail, consequently). In the production, crown rot by *Phytophthora* causes major problems. Ariwa is resistant to scab and powdery mildew, but storability is limited. Retina is a resistant, very early ripening cv. for the very limited marked between mid-August and the first week of September.

Within the predominantly tart apples, Boskoop is still popular in organic fruit growing because of its generally good disease robustness, however it is very sensitive to bi-annual bearing and frost damages. Otava, scab-resistant, but rather susceptible against bi-annual bearing and powdery mildew is o.k. for organic growing but will be replaced as soon as better resistant cultivars will be available.

**Figure 4:** Share of different taste groups the market for integrated and organic apples, and composition of the baseline 10 ha orchard (without GM crops). Colours represent flavour groups (see legend). **TOL** = scab tolerant; **RES** = scab resistant; **SUS** = susceptible to scab. Surfaces are not drawn to scale.



#### 4.4 GM scenarios for orchards

In workshop 2, it was decided to develop two different GM scenarios:

1. GM apple varieties are only resistant against scab (*Venturia inaequalis*).
2. GM apple varieties are resistant against scab and fire blight (*Erwinia amylovora*).

The scenario «cis-genic apples» proposed in workshop 1 was not followed up. The experts believed that cis-genic and trans-genic apples would be received in a similar way by the Swiss consumers (i.e. no marketing advantage for cis-genic apples), and that it is therefore not justified to consider cis-genic apples separately.

Compared with arable crops, the integration of novel fruit tree varieties – including GMOs – is much slower. Replacement of old varieties before amortisation of the orchard is extremely cost intensive. Thus, growers will only replant a small proportion of their orchard. After planting, it will take several years before new varieties yield fully.

##### 4.4.1 Expected GM varieties

Some of the apple varieties which are grown in Switzerland are important varieties worldwide (e.g. Gala). The experts assume that these varieties will be transformed into GM varieties, soon. Other cultivars are of declining importance (e.g. Golden Delicious), or still niche varieties (e.g. Pinova, Jazz). The experts assume that these useful varieties will not be transformed into GM varieties, at least not within the time horizon covered in this project.

Concerning GM-rootstocks the situation is difficult to estimate. On one hand the market is less interesting for the breeder (royalties are excluded), on the other hand the fruit of a tree grafted on a disease resistant GMO-rootstock will probably not be considered as a GMO-fruit by the consumers. Interesting resistances for rootstocks are: fire blight, scab, woolly apple aphid, *Phytophthora*, *Nectria* and replant diseases. For the horizon of the project, the experts do not expect that GMO-rootstocks will be developed to a marketable stage.

#### 4.4.2 GM scenario 1 in the integrated orchard

In scenario 1, the GM apple varieties are scab resistant.

**Scab:** scab control causes some costs in integrated farming (fungicides, machinery and labour), but scab can be well controlled, and usually causes almost no losses in marketable yield. Thus, a scab-resistant GM variety will be grown, if it has a good market acceptance and if the club royalties are lower than the costs for fungicide treatment.

**Fire blight:** In case of need, fire blight can, so far, be controlled with streptomycine. Never the less, the problem is not solved in a satisfactory way, and fire blight remains one of the major threats to the orchard. Thus, the added value of «only» scab resistant but still fire blight susceptible cultivars is not striking for conventional growers.

**Market:** Integrated apple production is under strong pressure of the market. GM Gala will substitute conventional Gala and varieties not highly demanded by the market such as Golden Delicious or Maigold. However, a certain proportion of standard Pinova will need to remain in the orchard (GM Pinova is not expected to be available), in order to satisfy the market's demand for this variety. Similarly, a new market-dominating GM variety will reduce the proportion of the spicy to tart apples. Jazz and Braeburn are highly demanded, and either Jazz or Braeburn (or another variety of this market group) will remain in the orchard to some extent.

**Conclusions:** In scenario 1, the choice of varieties is primarily dictated by the demand of the market. The farmer has only a small potential to optimize the range of varieties. As a result, up to 80 % of the orchard is planted with scab resistant varieties, and the farmer still has to carry out fungicide treatments in a part of the orchard. On the other hand, the grower takes advantage of all opportunities within the market for integrated apples.

#### 4.4.3 GM scenario 2 in the integrated orchard

In scenario 2, the GM apple varieties are resistant to scab and fire blight.

**Scab:** As is scenario 1.

**Fire blight:** New fire blight resistant GM cultivars with a good market acceptance would enter into practical integrated (IP) growing much easier and quicker than «only» GMO-scab free cultivars. Mainly because such a cultivar guaranties a higher over-all yield security.

Thus, most IP growers will grow exclusively fire blight and scab resistant varieties. As a result, the orchard also contains only scab resistant varieties, so that scab treatments do not have to be carried out at all.

**Market:** The market demand of the two most important taste groups can be met with the fire blight resistant GM varieties (scenario 2). The demand for nice market cultivars such as Pinova, Jazz or Braeburn will probably be met by specialized orchards which are located in areas with low pressure of fire blight (not covered by scenario 2).

**Conclusions:** In scenario 2, the choice of varieties is determined mainly with a view to optimize yield security (trend for rationalization). The result is a very effective (low spray) and low-risk production of apples. The grower will be able to offer the apples at a comparably low price, but he will be unable to supply niche markets with varieties such as Pinova, for which he would likely obtain higher prices under this scenario. Also, the reduction of cultivars increases the risk for the farm income in case that – unexpectedly – other variety specific and yield affecting problems occur (insects, other diseases, post harvest problems etc.).

#### 4.4.4 GM scenario 1 in the organic orchard

In scenario 1, the GM apple varieties are scab resistant but still fire blight susceptible.

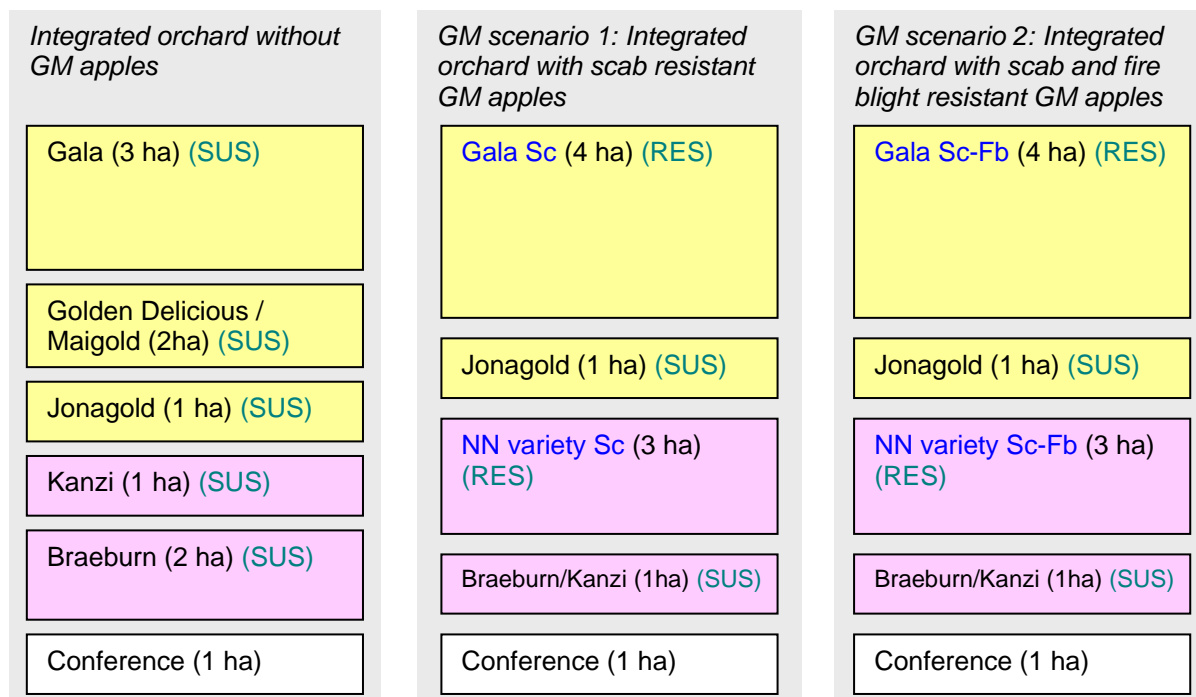
**Scab:** In organic farming, a certain proportion of scab resistant or tolerant, conventionally bred varieties are grown (e.g. Topaz). Topaz and Retina will remain in the orchard under scenario 1 because they are scab resistant. However today, the market is also demanding some scab susceptible varieties in organic quality (mainly Gala). As with these varieties scab can cause severe losses they will be replaced by scab resistant GM varieties. Given that the regulation and consumer acceptance is not a problem, and that the potential losses due to scab, are considerably higher than the requested club royalties.

**Fire blight:** Some control agents with partial efficacy against fire blight are authorized, but fire blight remains one of the major threats to the orchard.

**Market:** Today, the market for organic apples is more diverse than for integrated apples, and can absorb new varieties more easily (e.g. Topaz, Ariwa, Retina, Otava). Idared is not highly requested on the market, and can therefore easily be replaced by a GM Gala. Pinova is highly sought, but many growers will eliminate it from their orchards because it is more risky, expensive and difficult to produce than GM Gala. Ariwa is not highly sought on the market and bi-annually bearing. It will therefore be eliminated from the orchard. Predominantly tart apples are an important element of the organic apples market and will remain in the orchard to a certain extent. However, growers might concentrate on only one of two varieties of this flavour group.

**Conclusions:** In scenario 1, the choice of varieties is primarily dictated by the demand of the market. Scab susceptible varieties are eliminated from the orchard, but the range of varieties is kept sufficiently large to take advantage of most opportunities within the market for organic apples. The goal remains to supply all taste groups during all selling periods.

**Figure 5:** GM scenarios for integrated 10 ha orchard. Colours represent taste groups. TOL = scab tolerant; RES = scab resistant; SUS = susceptible to scab. Sc = Scab resistant GM cultivars (scenario 1); Sc-Fb = scab and fire blight resistant GM cultivars (scenario 2). Note that the exact varietal composition was modified in subsequent workshops. The most up-to-date version can be found in the document «Agronomic consequences of the use of GM crops. Part 2: apple orchards».



#### 4.4.5 GM scenario 2 in the organic orchard

In scenario 2, the GM apple varieties are resistant to scab and fire blight.

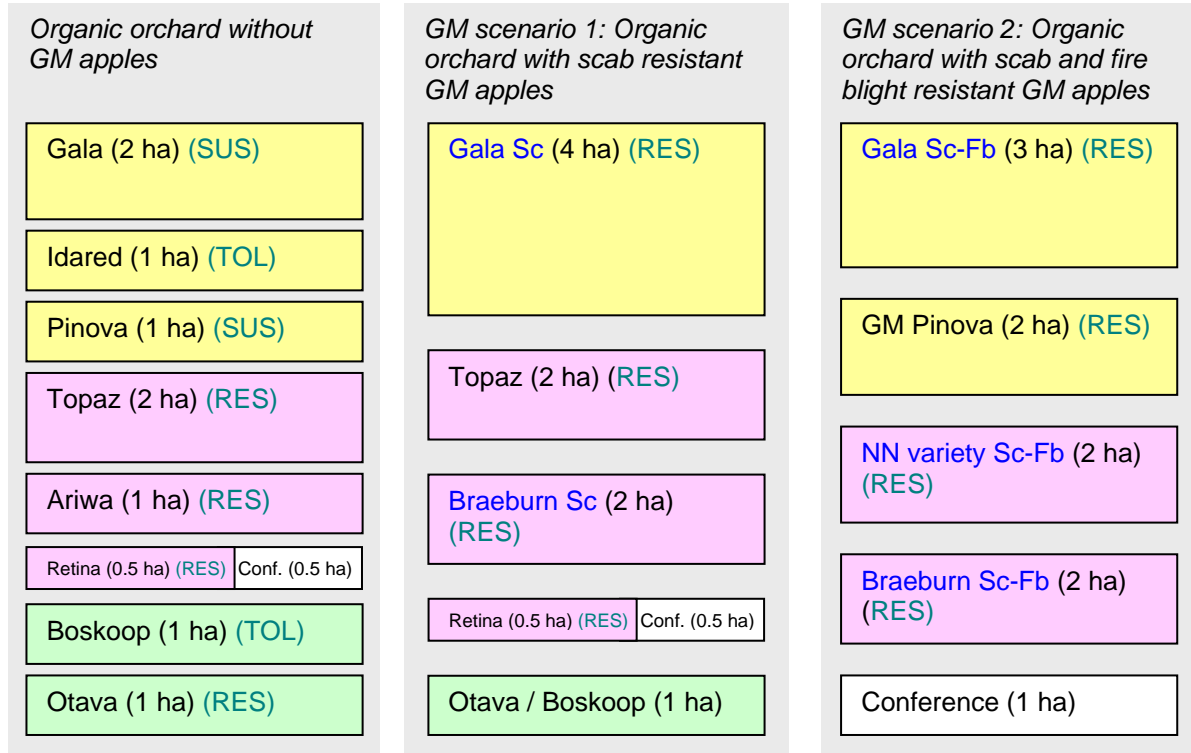
**Scab:** As is scenario 1.

**Fire blight:** Fire blight is not a threat with the resistant GM varieties anymore, but remains a threat with the susceptible, traditional varieties. Thus, most growers will replace the less yield-secure traditional cultivars with the new GM-fire blight resistant and scab resistant varieties.

**Market:** The market demand for the two major taste groups can be met with the fire blight resistant GM varieties (scenario 2). The demand for minor niche cultivars such as Topaz, Retina and the predominantly tart varieties like Boskoop or Otava) will probably be met by specialized orchards which are located in areas with low pressure of fire blight (not covered by scenario 2).

**Conclusions:** In scenario 2, the choice of varieties is determined mainly with a view to optimize yield security (trend for rationalization). The result is a more effective (low spray) and low-risk production of organic apples. The grower will be able to offer the apples at a comparably low price, but he will be unable to supply niche markets with varieties such as Topaz, for which he might obtain higher prices under this scenario. Interestingly, the organic orchard under scenario 2 is identical to the integrated orchard described above under scenario 2. The reason is the dominating threat of fire blight, which is similar for organic and for integrated orchards. As a result, the availability of fire blight and scab resistant GM varieties has a similar effect in both systems.

**Figure 6:** GM scenarios for organic 10 ha orchard. Colours represent taste groups. **TOL** = scab tolerant; **RES** = scab resistant; **SUS** = susceptible to scab. **Sc** = Scab resistant GM cultivars (scenario 1); **Sc-Fb** = scab and fire blight resistant GM cultivars (scenario 2). Note that the exact varietal composition was modified in subsequent workshops. The most up-to-date version can be found in the document «Agronomic consequences of the use of GM crops. Part 2: apple orchards».



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## 6 Acknowledgements

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