



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

List of GM plants and traits

Internal document (final version)

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Workpackage 1.4

Description in project proposal (p. 22): «A primary inventory of GM crops and traits will be compiled for use in workpackage 2. [...] GM plants with interesting properties (already marketed world-wide or to be expected in the next decade) will be identified as a preliminary step for workshop 2»

Scope (p. 17): «The proposed study will concentrate on the potential impact of varietal traits which are relevant for agricultural production techniques»

Document history: This report was prepared by the competence team «GM plants».

On 12 March 2008, the first draft of this document was elaborated in workshop 1. The document was subsequently amended by E-Mail correspondence, and discussed in workshop 2 on 14 May 2008. This draft version was posted on the project website for public commenting. In workshop 3, it was decided to modify section 3.7.1 (GM apples). In workshop 6 (September 2009), the section on oilseed rape (3.3.1) was amended. In the validation workshop on 31 August 2010, it was decided to modify the aspect of commercialisation of GM apples in section 3.7.1.

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1 Introduction

This document is prepared as a project-internal tool. It should provide an overview of GM-crops and traits which are technically feasible within the next decade and therefore have a probability to be available for Swiss agriculture. It is based on expert judgement by the competence team (CT) «GM crops». The scope of crops is limited to crops for agricultural food production, with emphasis on the Swiss Mittelland region. Therefore, the following crops are excluded from the list: (1) crops which do not grow in the Swiss Mittelland (a few crops were included as exceptions, if it was considered likely that after modification they could be grown in Switzerland; exceptions can be made case-by-case for crops which are studied in other NRP 59 projects); (2) fiber crops; (3) energy crops; (4) plants for recreational/urban use; (5) crops for production of pharmaceutical or industrial substances; (6) ornamentals; (7) herbs and spices. (8) The list is restricted to GM traits which are relevant at the farming stage of the production chain (for example, prolonged shelf life is excluded). (9) Only information from 1998 or later was used (based on the assumption that all cultivars with promising traits would have been commercialized between 1998 and 2008).

The list is primarily based on official information (authorizations, notifications and deliberate releases) for Switzerland and the EU. This was complemented by information from the USA and by input from experts.

This study determines which GM traits are technically feasible within the next decade, but it is not possible to predict exactly what GM cultivars will be available in ten years time, and which traits each of them will have. Therefore, the CT has decided to describe for each crop an «**ideotype GM plant**», which possesses all the GM traits judged to be likely available.

2 Generic comments on GM traits

2.1 Herbicide tolerance

At present, herbicide tolerance is one of the major traits of GM crops. Several systems are available:

2.1.1 Tolerance to glyphosate

Glyphosate is the active ingredient of the herbicide Roundup® (Monsanto). Four genes are known to give tolerance:

The gene **cp4 epsps**: This gene was isolated from the cp4 strain of *Agrobacterium tumefaciens*. It codes for a version of 5-enolpyruvoyl-shikimate-3-phosphate synthetase (EPSPS) which is less sensitive to glyphosate inhibition than the normal enzyme. The cp4 epsps gene has been transferred into a number of crops. Such crops are often commercialized under the name «Roundup ready». Current Roundup Ready crops include soy, maize, sorghum, canola, alfalfa, and cotton, with wheat still under development.

The gene **mepsps** is a mutated maize *epsps* gene which gives high tolerance to glyphosate. Example: maize variety GA21.

The gene **gox** (example: oilseed rape GT73): This gene was isolated from the soil bacterium *Ochrobactrum anthropi*. *Gox* codes for the enzyme glyphosate oxidase, which accelerates the normal breakdown of glyphosate.

The gene **gat4621** (example: Maize 98140): This gene was derived from the soil bacterium *Bacillus licheniformis*. The *gat 4621* protein codes for the gene glyphosate-N-acetyltransferase and thus confers tolerance to glyphosate.

2.1.2 Tolerance to glufosinate

Glufosinate is the active ingredient of Basta® (BASF) and other herbicides. Two genes are used to induce tolerance to glufosinate:

The gene **pat**. This gene was isolated from the Tü494 strain of the bacterium *Streptomyces viridochromogenes*. The *pat* gene codes for the enzyme Phosphinothricin-Acetyltransferase (PAT) and leads to increased tolerance to glufosinate. The *pat* gene has been transferred into a number of crops: e.g. maize BT11 and T25, oilseed rape T45, soy A2704-12.

The gene **bar**. This gene was isolated from the bacterium *Streptomyces hygroscopicus* and also codes for PAT. Examples: oilseed rape variety Liberator, experimental varieties of wheat and triticale.

2.1.3 Tolerance to other herbicides

Tolerance to **sulfonylureas** is conferred by the gene **zm-hra** (example: Maize 98140) that codes for a modified maize acetolactate synthase. This confers tolerance to a range of ALS-inhibiting herbicides such as sulfonylureas.

Tolerance to herbicides of the oxynil family is conferred by the gene **oxy**. This gene was isolated from the bacterium *Klebsiella pneumoniae* ssp. *ozeanae* and encodes for the enzyme nitrilase, which converts bromoxynil and ioxynil into non-toxic compounds (Halford, 2004). Example: oilseed rape variety Navigator.

There are crop varieties which are **tolerant to imidazolinone** (oilseed rape, maize, wheat, sunflower, rice). These crops contain a variant of the enzyme acetohydroxy-acid synthase (AHAS) which is insensitive to imidazolinone. These varieties have been obtained with conventional breeding techniques and are therefore **no GMOs** (Halford, 2004). These crops have been commercialized since 1992 under the trade name «Clearfield».

2.1.4 Comments on herbicide tolerance

(1) Herbicide tolerance is used as a marker for selection and is at the same time a trait with agronomic relevance.

(2) The technology for producing herbicide tolerant GM crops is patented. At the moment, it is unlikely that a GM cultivar will be tolerant against more than one herbicide. With company mergers, however, this could change in the future.

(3) The herbicides against which GM crops are tolerant are currently registered in Switzerland for use *before* the growing season, but not for use *on the crop*. After authorization of a herbicide tolerant GM crop, the manufacturer of the herbicide will have to apply for use of the herbicide on the crop. New aspects of the toxicity of the

active substance and its metabolites will have to be evaluated, pre-harvest intervals will have to be determined and maximum residue levels (MRLs) might have to be revised. As a consequence for this project, there will be a delay between the authorization of a herbicide tolerant GM crop and the authorization of herbicide use on that crop. If herbicides are to be used on these crops, carry-over effects on the next season have to be taken into consideration.

(4) It has been observed that herbicide tolerant crops often suffer from micronutrient deficiencies (Eker *et al.*, 2006; Ozturk *et al.*, 2008), and for some herbicide tolerant GM crops, it is recommended to apply micronutrient fertilizers as a remediation (Huber, 2007b). There is also evidence for potassium deficiency in conventional maize grown after roundup-ready soybeans (Dick and Lorenz, 2006), and for changes in soil microbial populations related to roundup-ready soybeans (Kremer and Means, 2006). Micronutrients, potassium and soil microbial populations may all interact with plant diseases. For example, manganese deficiency may increase the susceptibility of crops to various diseases (Huber, 2006; Huber, 2007a).

(5) In a number of crops, the trait of herbicide tolerance facilitates low till/no till production systems. This has advantages with respect to soil erosion, but it can also lead to increased disease pressure by *Fusarium* spp. in wheat (Bateman *et al.*, 2007) and barley (Fernandez *et al.*, 2007), and/or to higher incidence of corn borer (Sass *et al.*, 2007), or soil pests such as slugs.

2.2 Bt-derived insect resistance

Resistance to insect pests derived from *Bacillus thuringiensis* (Bt) is the second major trait of GM-crops. Bt is a Gram-positive, soil dwelling bacterium. Upon sporulation, it forms sporangia, which contain spores and crystals of a protein called δ -endotoxin. Many subspecies of Bt have been described. They have different endotoxins, which are poisonous either to Lepidoptera (caterpillars), certain Coleoptera (beetle larvae) or to Diptera (larvae of flies and mosquitoes). Bt was first described in the early 1900s, and is now the most widely used microbial biocontrol agent. It is used for the control of pest insects in agriculture (mainly in organic farming) and forestry, and for the management of mosquitoes and flies. Bt is very host specific, has no effect on birds or mammals, does not affect most non-target insects and degrades fast. Bt based insecticides are therefore regarded as environmentally friendly. Bt based insecticides are applied to crops as liquid sprays. They must be ingested to be effective. Under the alkaline conditions of the insect's gut, the crystals dissolve. Specific gut proteases transform the endotoxin into the active toxin, which binds to specific receptors in the gut and punctuates the membranes of gut cells. Poisoned (pest) insects stop feeding, become dehydrated and die. Different strains of Bt are specific to different receptors in the insect gut wall.

Bt derived insect resistance based on the genes coding for the endotoxin crystals (**cry** genes). As early as 1985, insect-resistant tobacco plants were produced by the Belgian company Plant Genetic Systems.

As with any pesticide, the problem of resistance is unavoidable. Resistance against the Bt spray is known from several investigations (Diamondback moth; *Plutella xylostella*). With Bt crops, the risk of resistance development is higher than with Bt sprays, because the toxin is continuously available throughout the cropping season. Resistance management includes the planting of 20 to 50 % of «refuges» (susceptible varieties) next to Bt crops. This practice is mandatory in the USA and the

EU. However, the cotton bollworm (*Helicoverpa zea*) has evolved resistance to Bt-plants according to a new research report. Bt-resistant populations of bollworm were found in more than a dozen crop fields in Mississippi and Arkansas between 2003 and 2006 (Tabashnik *et al.*, 2008).

2.2.1 Resistance to Lepidoptera

Resistance to caterpillars of Lepidoptera is conferred by a number of genes obtained from Bt *ssp. kurstaki* and *ssp. aizawai* (e.g. *cry1A*; *cry1Ab*; *cry1A105*; *cry1F*; *cry2Ab2*). These genes have been introduced into a variety of crops.

2.2.2 Resistance to Coleoptera

Resistance to the larvae of Coleoptera is conferred by a number of genes obtained from Bt *tenebrionis* or *ssp. kumamotoensis* (e.g. *cry3A*; *cry3Bb1*; *cry34Ab1*; *cry35Ab1*). These genes have been introduced into a number of crops.

2.2.3 Other mechanisms of insect resistance

Alternative strategies to confer insect resistance are far less advanced. In a review, (Engel *et al.*, 2002) list lectines, proteinase inhibitors, alpha-amylase inhibitors and cholesterol oxidase. At the time when that review was written, none of these approaches were available on the market.

2.3 Disease resistance

2.3.1 Virus resistance

Resistance to viruses is obtained in two ways: (1) by incorporation the coat protein gene of a **mild strain** of the virus into the crop, which inhibits virus reproduction. This approach has been successful in papaya grown in Hawaii. (2) by the use of **antisense or co-suppression** techniques, where a RNA fragment coded by the introduced gene induced post transcriptional silencing. Among others, this approach has been used to render potatoes resistant against the leaf roll virus (Halford, 2004).

2.3.2 Resistance to fungi

Resistance to fungi can be conferred by GM-induced biosynthesis of phytoalexins, by the expression of cell wall-hydrolyzing enzymes (chitinases, beta-glucanases) or expression of ribosomal inhibition proteins (Engel *et al.*, 2002) and by host resistance genes recognizing specific genotypes of the pathogen.

2.3.3 Resistance to bacteria

Strategies ranging from antibacterial enzymes to engineered detoxification proteins and pathogen derived resistance elicitors with pathogen-inducible promoters have been described (Engel *et al.*, 2002).

3 Comments on GM crops

3.1 Cereals

3.1.1 Maize

Maize (*Zea mays*) is one of the crops where GM varieties have progressed far. The major GM traits in maize are herbicide tolerance (various herbicides) and insect resistance (Lepidoptera and/or Coleoptera). Among the Lepidoptera, the major target is the European corn borer (*Ostrinia nubilalis*); other lepidopteran targets are the pink borer (*Sesamia* spp.), fall armyworm (*Spodoptera frugiperda*), black cutworm (*Agrotis ipsilon*) and southwestern corn borer (*Diatraea grandiosella*).

The major coleopteran targets are corn rootworms (*Diabrotica* spp.), e.g. the western corn rootworm (*Diabrotica virgifera*), northern corn rootworm (*D. barberi*), and mexican corn rootworm (*D. virgifera zea*). Secondary GM traits include protogyny (= synchrony between male and female to improve success of pollination), draught resistance, increased micronutrient uptake (to compensate for side-effects of glyphosate (Huber, 2007b), *Fusarium* resistance (to compensate for side-effects of minimum tillage) and improved photosynthesis. However those last traits are not yet available in commercialized cultivars.

In Switzerland, maize is mostly grown as green maize for animal feed and silage (ca 38'000 ha). Grain maize for feed is cropped on 17'000 ha, of which 290 ha are organic fields. Local varieties of food maize are grown in Ticino (Polenta) and St. Galler Rheintal (Ribelmais).

So far, no GM maize is grown in Switzerland. Weeds are the main phytosanitary problem of the maize crop in Switzerland. Weeds are controlled with pre-emergence herbicides in conventional and integrated farming, and with cultural and mechanical methods in organic farming. The European corn borer is the major maize pest in Switzerland, but it is only a problem in few areas and only, when grain maize is cropped. As in France, in the south west of Switzerland, more than one generation on Corn Borer may occur. Swiss famers are not allowed to use insecticid to control the corn borer. The only registered control method is biocontrol with *Trichogramma brassicae* wasps.

The rootworm has recently migrated into the southernmost areas of Switzerland. However, it is not a problem in most of Switzerland, because the crop rotations prevent its establishment.

Ideotype GM maize: For the purposes of this project, the CT «GM crops» recommends to consider an «ideotype GM maize» in the scenarios with the following traits:

1. tolerance to one herbicide (glyphosate, glufosinate or another herbicide, but not several herbicides at the same time¹);
2. resistance to the European corn borer;
3. resistance to the corn rootworm.
4. quality assumed to be similar to the non-GM varieties

The CT estimates that other GM traits are unlikely to be available for Swiss agriculture within the next ten years.

¹ Recently, GM crops with stacked tolerance against several herbicides have been developed. In the model rotations, however, only tolerance against one herbicide will be utilized at a time.

3.1.2 Other cereals

In wheat (*Triticum aestivum*), triticale (x triticosecale), rye (*Secale cereale*), oats (*Avena sativa*) and barley (*Hordeum vulgare*), Swiss farmers use a range of local varieties with very limited distribution. For Wheat, more than 80% of the cultivars are swiss varieties, for triticale about 45% are swiss. Rye is also grown as Hybrids.

Main problems in cultivation are Septoria diseases, leaf rusts (*Puccinia* sp), various leaf spots, fusarium, eyespot disease (*Pseudocercospora*) and mildew. The CT judges herbicide tolerance not to be agronomically useful in these cereals, because they regularly outcross with grass weeds (a few % of total offspring (Guadagnuolo et al., 2001)).

Wheat: Worldwide, there is no GM wheat authorized for cultivation at present. Wheat breeders in the USA have decided not to use Herbicide resistance techniques, and Monsanto withdrew its application for Roundup Ready wheat, because acceptability of GM wheat in the European and Asian market was judged to be low². Nevertheless, R&D work is continuing.

Glyphosate tolerant wheat (epsps gene) is under development, and likely to be technically feasible within the next decade.

From 2008 on, a number of GM wheat varieties, which have been genetically modified for improved fungal resistance will be field-tested in Switzerland. Some lines carry specific resistance against mildew (*Blumeria graminis*, ex *Erysiphe graminis*) based on wheat resistance genes (**Pm3b**), while the other lines have broader putative fungal resistance derived from two barley genes coding for the enzymes glucanase and chitinase. These materials are model plants for fundamental research in biosafety, but are unfit for practical agronomic use³.

Ideotype GM wheat: the CT estimates that GM wheat is technically feasible and therefore might be available for Swiss agriculture within the next ten years, and recommends to include an «ideotype GM wheat» in the scenarios. This should be herbicide tolerant⁴, but not disease resistant (although the latter trait is subject to current research in Switzerland, it is unlikely to be available for agricultural use within the time frame of ten years).

3.2 Root crops

3.2.1 Potatoes

GM breeding of potatoes (*Solanum tuberosum*) aims at a number of traits. (1) In the UK, great efforts are made to achieve resistance to nematodes (*Globodera* spp.). (2) Resistance against the Colorado potato beetle (*Leptinotarsa decemlineata*) based on genes from Bt is technically possible and a cultivar (new leaf) was shortly marketed. However, processors in the USA object to the use of GM potatoes, because they fear bad acceptance by consumers. (3) Resistance against the potato leaf roll virus (PLRV) is technically possible, but its introduction into practice is considered unlikely

² <http://www.transgen.de/pflanzenforschung/anbaueigenschaften/192.doku.html>, accessed on 29 May 2008

³ www.konsortiumweizen.ch

⁴ See footnote for ideotype GM maize

for commercial reasons (low interest by breeders, availability of non-GM resistance). (4) Resistance against late blight (*Phytophthora infestans*) has been achieved by transferring a number of R-genes from *Solanum bulbocastanum* (Haltermann, 2008) (similar results have been achieved prior by classical breeding). From conventional resistance breeding, it is well known that late blight resistance based on R-genes alone is not durable, and breeders have switched to more durable approaches. (5) Other traits include water balance, starch, amylose and amylopectin content. These latter traits are either not relevant for Swiss potato production (starch potatoes), or they are out of the scope of the project (biofuels).

Ideotype GM potato: The CT «GM crops» recommends to consider a «model GM potato» which

1. is resistant to the nematode *Globodera*, and to Colorado beetle
2. carries R genes against late blight.

Other GM traits are unlikely to be available for Swiss agriculture within the next ten years, or they are considered not to be durable.

3.2.2 Sugar beet

GM breeding of sugar beet (*Beta vulgaris*) aims at traits. (1) Resistance against rhizomania, which is caused by the beet necrotic yellow vein virus (BNYVV). However, full resistance against rhizomania has been achieved by conventional breeding. (2) Tolerance against herbicides (see 2.1.4).

Ideotype GM sugar beet: The CT «GM crops» recommends considering an «ideotype GM sugar beet» which is resistant to rhizomania and tolerant to one herbicide⁵. Other GM traits are unlikely to be available for Swiss agriculture within the next ten years, or not durable. The considered cultivar should substantially be similar (sugar content, growth characteristics) to the most popular cultivar.

3.3 Oil seed

3.3.1 Oilseed rape

Oilseed rape (*Brassica napus*) is the crop which is most frequently transformed by GM techniques. The term «canola» was introduced in the 1980ies by Canadian farmers for edible oilseed rape oil (low in erucic acid and glucosinolates), but is now used as a synonym for oilseed rape. Because oilseed rape is very sensitive to weed competition, herbicide tolerance has great importance in this crop. As a general rule in breeding of oilseed rape, higher oil content of the seeds is correlated with lower yield. Breeding aims are: (1) Tolerance against herbicides (see 2.1.4); (2) increased oil content and improved oil composition. For example, the contents of lauric acid is elevated. Lauric acid is a detergent traditionally obtained from coconut or palm oil (Halford, 2004). This goal is out of scope of the present project. Summer rape (canola) is not considered as it is not used in Switzerland. For some time, oilseed rape with Bt genes (which was supposedly resistant against the pollen beetle, *Meligethes aeneus*), has been tested. However, this line of research was discontinued, therefore the ideotype does not contain Bt genes.

⁵ See footnote for ideotype GM maize

Ideotype GM oilseed rape: The CT «GM crops» recommends considering an «ideotype GM oilseed rape» which is tolerant to one herbicide⁶. Other GM traits are unlikely to be available for Swiss agriculture within the next ten years, or not durable.

Note: In WS 6 on 23 September 2009, the experts on agro-ecology noted that for GM rape the risk of outcrossing with non-GM rape, as well as with other cultivated and wild *Brassica* species is high. They concluded that GM rape is unlikely to be authorized in Europe. Nevertheless, it is kept in the scenarios.

3.3.2 Soybean

Due to international trade agreements, soybean (*Glycine max*) is cultivated very little in Europe at the moment. In 1992, The European Union was forced to limit its surfaces to 5.13 million ha oilseeds (WTO, Uruguay Round, Blair House agreements). However, the CT expects a pronounced increase of soybean production in Eastern Europe in the mid-term. In Switzerland, soybean is grown commercially on a very limited area (a little more than 1000 ha in 2006 and 2007) mainly in the milder parts of Switzerland. Soybean could become more important in farms without livestock for its value in the crop rotation providing the price remains competitive with rape. Outside Europe, herbicide tolerant GM cultivars make up a significant proportion of Soy crops (64 % of the total acreage in 2006).

Conclusion: It is unlikely that soybean will be an important crop in Switzerland within the next ten years. The CT therefore does not recommend their inclusion in the scenarios.

3.3.3 Other oilseed crops

In sunflowers (*Helianthus annuus*), GM transformation is still in the experimental phase. Sunflower is a native crop in North America, is highly cross-breeding and wild sunflower is classified as a weed. That could be a reason why there are no GM sunflower in the US (Cantamutto and Poverene, 2007). In Switzerland, cultivation of GM sunflowers is unlikely because of the great risk of outcrossing (Snow, 2002).

Conclusion: The CT does not recommend the inclusion of other GM oilseed crops in the scenarios.

3.4 Other arable crops, including fodder crops

Tobacco (*Nicotiana tabacum*) is grown in very limited areas in Switzerland, and is of very low importance for Swiss agriculture. Fodder beets (*Beta vulgaris* var. *crassae*) are grown very little in Switzerland, because they are difficult to harvest mechanically. If their harvesting properties could be improved, fodder beets might gain more importance, because they are good feed for cattle. In field beans (*Vicia faba*) and fodder peas (*Pisum sativum*), there are only limited activities for GM transformation (?). Green manures are important in Swiss agriculture, and comprise several Brassicaceae. However, the CT is not aware of any GM green manure crops. In alfalfa (*Medicago sativa*), white clover (*Trifolium repens*), ryegrass (*Lolium perenne*) and creeping bentgrass (*Agrostis stolonifera*), there are some activities for GM

⁶ See footnote for ideotype GM maize

transformation. Some GM grasses are authorized in the USA, but in the EU, there are no field releases and no applications for authorization.

Sorghum and Millets (*Sorghum bicolor* & related genera) Sorghum is currently grown only experimentally in Switzerland, but could be grown as feed, if cold-tolerant varieties become available. Lupins (*Lupinus* spp.) have little importance in Swiss agriculture.

Conclusion: The CT does not recommend the inclusion of other GM arable crops or fodder crops in the scenarios.

3.5 Field vegetables

Brassica rapa has been modified for herbicide tolerance. Whether this applies to cultivars currently grown in Switzerland (e.g. Chinese cabbage), is unknown to the CT. Chicory (*Cichorium intybus*) has been modified for herbicide tolerance. Lettuce (*Lactuca sativa*), carrot (*Daucus carota*), pea (*Pisum sativum*) and beans (*Phaseolus* sp., *Vicia* sp., *Vigna* sp.) have been modified for various traits, but are still in the experimental phase. Squash (*Cucurbita pepo*) has been modified for resistance against cucumber mosaic virus (CMV), zucchini yellow mosaic virus (ZYMV) and watermelon mosaic virus (WMV). GM squash varieties are authorized in the USA, but there are no field releases in the EU, and no applications for authorization.

Conclusion: In those crops frequently grown as field vegetables in Switzerland, GM transformation has not progressed very far until now. Therefore, the CT does not recommend the inclusion of GM field vegetables in the scenarios.

3.6 Glasshouse vegetables

GM breeding of tomatoes (*Lycopersicon esculentum*) aims at a number of traits (resistance to caterpillars, whiteflies, nematodes, cucumber mosaic virus, tomato spotted wilt virus, bacteria and fungi; herbicide tolerance). Of these traits, only resistance against tomato spotted wilt virus and *Phytophthora infestans* are agronomically relevant in Switzerland. Tomatoes are frequently modified for traits such as shelf life and processing quality, which are outside the scope of this project.

Cucumber (*Cucumis sativa*), pepper (*Capsicum annuum*) and eggplant (*Solanum melongena*) have been modified for a number of traits, but this work has not progressed very far until now.

All seeds for glasshouse vegetables are imported in Switzerland. Therefore, the pattern of available cultivars strongly depends on international developments.

Conclusion: The CT does not recommend the inclusion of GM glasshouse vegetables in the scenarios.

3.7 Fruit trees

Fruit trees are long-lived, high-value crops which are multiplied vegetative. Once sold, they last for several decades and can be multiplied by the farmer, however some newly bred cultivars such as Pink lady are only planted and commercialized under exclusive contracts allowing therefore a protection of the cultivar. This makes it economically unattractive for breeders to commercialize GM fruit trees. However,

there are GM apples with interesting traits, which might be commercialized with the aid of public funding.

3.7.1 Apple

GM breeding of apples (*Malus x domestica*) aims at various traits: (1) resistance to codling moth (*Cydia pomonella*) conferred by Bt genes; (2) resistance to fire blight (*Erwinia amylovora*) achieved with exotic genes or with pathogen derived resistance elicitors genes; (3) resistance against scab (*Venturia inaequalis*) conferred by the **Vf** gene; (4) improved rooting properties of rootstock by incorporation of the **ROL**-genes; (5) resistance to mildew (*Podosphaera leucotricha*); (6) selfing; (7) modifications in ripening and in polyphenol content). Some of these traits are in an early stage of development or speculative, while resistance to scab is judged to be technically feasible within the next decade (Gessler and Patochi, 2007). Resistance to fire blight might not be available within the next decade, but it should be included in this study because it is currently of high public interest.

The European apple GM R&D is moving into the direction of «selection gene-free GM-apple» as only possibility to pyramidize various traits, as the selection system has to be reused with the additional benefit of eliminating exotic and questionable genes such as antibiotic resistance (**nptII**).

Commercialization of apple cultivars: The commercialization mechanisms in apples are very different from arable crops. 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. The grower of a club cultivar is obliged to pay licences on a per tree basis, plus yearly royalties depending on the yield. Currently, Jazz, Rubinstep and Pink Lady are club varieties produced in Switzerland.

Almost all research and development on GM-apples is done by non-profit public research institutions such as universities (except in Holland, where a private-public consortium is developing scab resistant cultivars. The competence team assumes that the ideotype GM apple will be commercialized as a free cultivar. However, the experts have some doubts whether non-profit research institutions have the financial capacities to carry the costs for dossier preparation necessary before a GM cultivar can be commercialized. The experts also noted that the 10 years duration of registration for GMOs is very short in comparison to the time necessary for multiplication of apple trees to full yield of an orchard, and constitutes a great risk for the applicant, the tree nurseries and the apple growers.

The competence team further believes that consumers will not discriminate between «cis-genic» and transgenic apples, so that cis-genic apples need not be studied separately. Finally, the control of codling moths might meet opposition by consumers, because the toxins must be expressed in the edible crop parts.

Ideotype GM apple: The CT recommends including an «ideotype GM apple» in the scenarios which has the following properties: the original cultivar to be substituted should be highly popular (Gala, Braeburn). It should have the following properties:

1. resistance against scab, and
2. resistance to fire blight*.

*Resistance to fire blight might not be available within the next decade, but it should be included in this study because it is currently of high public interest. However, fire blight resistance should be studied separately from scab resistance. Note: resistance to fire blight may be partial only.

3.7.2 Plum

GM plums (*Prunus domestica*) resistant to the plum pox virus (PPV; also called sharka virus) have been field-tested in Denmark. Plums are a crop of little agronomic importance in Switzerland.

Ideotype GM plum: The CT recommends including an ideotype GM plum in the scenarios which is resistant to the plum pox virus.

3.7.3 Other fruit trees

Other fruit trees are modified for various traits: (1) apricot (*Prunus armeniaca*) for resistance to the plum pox virus; (2) pear (*Pyrus* sp.) for resistance to diseases (fire blight); (3) sweet cherry (*Prunus avium*) and sour cherry (*Prunus cerasus* ??); (4) chestnut (*Castanea sativa*) and walnut (*Juglans regia*) for resistance against various pests and diseases. This work is still in an early stage of development or even speculative, and all of these crops are of little agronomic importance in Switzerland.

Conclusion: The CT does not recommend the inclusion of other GM fruit trees in the scenarios.

3.8 Soft fruit

The most advanced GM soft fruit are the strawberries (*Fragaria* sp.) transformed to contain rooting enhancing genes (**Rol-C**), with the benefit of earlier flowering and higher production. These properties are demonstrated to be valuable in hors-sol (high bed) production of strawberry.

Other GM soft fruit are in an early stage of progress: raspberry (*Rubus idaeus*), blackberry (*Rubus* sp.), and blueberry (*Vaccinium myrtillus* and spp.) (Prodorutti et al 2007).

Conclusion: The CT recommends the inclusion of GM strawberry in the scenarios. The CT estimates that substitution of the most popular cultivar used in high bed cultivation with the Rol-gene transformed GM cultivar will shorten growing time by ca 10 % and increase total fruit output by ca 10 %.

3.9 Vines

3.9.1 Grapevine

GM breeding of grapevine (*Vitis vinifera*) aims at various traits: (1) resistance to grapevine fanleaf virus (GFLV); (2) resistance to downy mildew (*Plasmopara viticola*); (3) resistance to powdery mildew (*Erysiphe necator*); (4) resistance to grey mould (*Botrytis cinerea*). None of this work is in an advanced stage. INRA Colmar has abandoned all GM breeding of grapevine, because of low public acceptance of vine from GM grapes.

Conclusion: The CT does not recommend the inclusion of GM grapevine in the scenarios.

3.9.2 Other vines

There are some activities for GM breeding of kiwifruit (*Actinidia* sp.) and hop (*Humulus lupulus*), but none of this work is in an advanced stage.

Conclusion: The CT does not recommend the inclusion of other GM vines in the scenarios.

4 Online sources of information

Most information in this document is taken from:

- the public register of GMO commercialization⁷ and the public register of deliberate GMO releases⁸ in Switzerland,
- the data base of notifications for the EU⁹ and the data base of deliberate releases within the EU¹⁰,
- the data base GMO Compass¹¹,
- the data base Agbios¹²,
- the data base Transgen¹³,
- the data base of deliberate releases and marketing of GMO in the USA¹⁴,
- product pipelines described on the company websites of Monsanto, BayerCropScience, Syngenta and KWS,
- application files and evaluation reports accessible through the above data bases (particularly through GMO Compass).

⁷ <http://www.bafu.admin.ch/biotechnologie/01760/01761/index.html?lang=de>

⁸ <http://www.bafu.admin.ch/biotechnologie/01756/01757/index.html?lang=de>

⁹ http://gmoinfo.jrc.it/gmc_browse.aspx?DossClass=0

¹⁰ http://gmoinfo.jrc.it/gmp_browse.aspx

¹¹ <http://www.gmo-compass.org/>

¹² <http://www.agbios.com/dbase.php>

¹³ <http://www.transgen.de/home/>

¹⁴ <http://www.aphis.usda.gov/biotechnology/index.shtml>

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