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Editorial

Dear reader

We all want to eat good and healthy food. A prerequisite for this is highly advanced and responsible plant breeding – because almost everything we put on our plates every day comes from plant varieties which have been previously crossed and selected in some way, in other words have been bred. Hardly anyone is aware of just who is involved in plant breeding, of what the necessary conditions for successful plant breeding are, of what contribution it makes to a successful agri-food industry and how it is important for meeting future challenges. I am thinking here particularly of population growth worldwide, but also in Switzerland. An ever-decreasing area of land has to ensure varied and affordable food production without overloading our ecosystems.

Plant breeding has been carried out for thousands of years, using methods which are constantly being developed. Whereas at the beginning it was a matter of selecting the best plants in the field purely by eye for the next season's sowing, today it is possible to combine and utilize the desired and known properties of a plant for a specific purpose. Timescales for plant breeding are long. It generally takes at least 10-15 years to develop a new variety to the point where it meets the ever-higher demands of the market and consumers. We must therefore anticipate the needs of tomorrow today. Successful varieties must guarantee good crop yields every year and must produce high quality and perfectly healthy products. However, with an eye on changing conditions, properties such as heat and drought tolerance, pest resistance and efficient use of water and nutrients come to the fore. Meeting all these demands is highly complex. Apart from creativity and the ‚breeder's eye', it means establishing successful links with the market and research. Thanks to modern technologies and forward-looking, innovative players, potential can be developed to the full and continually increased.

Switzerland offers the best conditions for nationally and internationally recognized plant breeding. I am thinking especially of our skill in research and development and our outstanding training facilities as well as our strength in putting theoretical findings into practice. In this context, this strategy is of very special importance. It helps us to use current know-how even better, to develop it further and thereby to make an even greater contribution to the competitiveness of our agri-food sector. This strategy has been drawn up over the last 3 years by a team of experts and has been put out to wide consultation. I would like to thank everyone who has been involved for their deep knowledge and commitment. The seed has been sown. We now have to cultivate and harvest it!

Johann N. Schneider-Ammann
President of the Swiss Confederation

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Management Summary

The Swiss Strategy for Plant Breeding 2050 sets forth for the first time standards for publicly financed plant breeding in Switzerland. It is based on a vision of plant breeding that recognizes the importance of plant breeding for decades to come and is geared to a sustainable and multifunctional agriculture:

“Swiss plant breeding with its outstanding varieties and competence is a pillar of a sustainable and innovative agriculture and food sector.”

The strategy was developed in conjunction with diverse stakeholders. It creates transparency regarding priorities to be set by the federal government in the breeding of new plant varieties. It provides for decision makers the foundations for the allocation of public resources. To practitioners in the field it serves as orientation for determining their own strategies. It defines the framework for greater cooperation with the breeder community in Switzerland and thus creates the prerequisite for a more efficient investment of public monies.

The strategy was prepared by the FOAG with a project team under the guidance of project senior management. The project team was composed of experts from public and private sector breeding, research, seed trade as well as the farmers union. At two stakeholder events and through a broad consultative process in the summer of 2015, other circles concerned with plant breeding were able to bring their interests and expectations to bear on the strategy.

The present strategy document is composed of six sections. The first marks out the **framework of the strategy**. A **situation analysis** then covers the current activities in plant breeding in Switzerland and gives an overview of the plant breeding world, which besides aspects of plant cultivation also takes into account developments relevant to breeding.

At present in Switzerland, ten independent practitioners are active in the breeding of new plant varieties, the research institution Agroscope being the sole public-sector practitioner. In all, about 50 plant species are subject to breeding work, of which about 20 are being developed by Agroscope. The nine privately organized breeders are working on a total of 36 plant species. Today already there is cooperation between Agroscope and the private sector. On average the development costs of a new variety run to 345,000 Swiss francs. About 1.5 full-time jobs are available per plant species. By comparison internationally the majority of Swiss plant breeding programs can be classed as small.

In Switzerland annual investment in plant breeding totals about 10 million Swiss francs. The public portion comes to 40%, the private 60%. International comparison shows investment in plant breeding in Switzerland to be rather low. Germany, for example, sees annual investment in plant breeding of about 200 million euros, 20 times the level in Switzerland. Comparing total investment in plant breeding in Switzerland with the value of plant production (> 4 billion Swiss francs), one arrives at an investment of just 0.25%.

Among the most important challenges facing plant cultivation are the increase in population and the growing scarcity of natural resources. These developments are intensified by the anticipated impacts of climate change. Plant breeding is seen as having great potential for meeting these challenges. For the mostly small breeding programs in Switzerland it will be critical to be able to keep pace with technological progress. This will impact breeding success in future even more strongly than it does today. Equally important is straightforward access to plant genetic resources as a foundation for plant breeding methods.

In the third section, based on the situation analysis, the **current and future need for action** in plant breeding is derived for seven thematically delimited areas.

- The fourth section presents the **vision and systematic objectives** describing the expected services and contributions of publicly financed plant breeding to a sustainable food and agriculture sector. The systemic objectives fall into three target areas.
- The first target area focuses on the direct products and services of plant breeding and postulates high-value varieties that are very well adapted to the diverse conditions of

Switzerland, are successful in seed and seedling markets and contribute to a varied spectrum of cultivated species and varieties.

- The second target area covers the expected contribution of plant breeding to a sustainable food and agriculture sector. Further development and innovation in breeding should advance resource-efficient production systems and strengthen the competitiveness of this sector as a whole.
- The third target area comprises the necessary contribution of plant breeding to satisfying such far-reaching societal demands as food security for the population and preservation of the natural foundations for life, in Switzerland and beyond its borders.

The fifth section defines the **strategic thrusts** needed for achieving the objectives envisaged. The strategic thrusts comprise seven fields of action:

- Further development of the portfolio of breeding programs based on objective criteria and involving the stakeholders concerned.
- Efficient introduction of new varieties into the market so that advances in breeding are rapidly turned to account in agricultural practice.
- Increased cooperation among practitioners for easier access to new breeding methods and efficient use of resources.
- Creation of favorable conditions for plant breeding in Switzerland and internationally in the realm of legislation, norms and standards.
- Informing the public and raising public awareness as to the importance and the benefits of plant breeding for a sustainable agricultural and food industry.
- Securing financial resources for successful development of plant breeding. Efficient investment through synergies and greater cooperation.

The concluding section 6 briefly sketches the **further course of action** once the strategy has been adopted by the management of the FOAG. On the basis of this strategy the FOAG will work out a plan of measures to concretize and prioritize the action points indicated in the strategy. The plan should be worked out together with interested parties and be completed at the latest 18 months after the strategy has been adopted.

1 Design and framework of the strategy

1.1 Preparation and design of the strategy

The present strategy was developed step by step from 2013 to 2015 based on the principles of public management and under the direction of project senior management (for a list of contributors see Imprint). A project team of practitioners in public and private breeding, research, seed trade and from the farmers union has closely followed the preparatory studies and provided the requisite expert inputs for them. Two specific stakeholder meetings and a final consultation enabled a wider circle of those directly affected by plant breeding to put forward their interests and expectations.

The strategy is structured in five parts (see Figure 1). Its foundation is a comprehensive situation analysis, which involves first taking stock of the diverse activities of plant breeding in Switzerland (actual-state analysis) and critically analyzing the context of plant breeding (environment analysis, ETH 2014). The present document gives only the most important facts relevant to understanding the strategy. These are supplemented with reference to relevant breeding developments to be expected in the coming years (development appraisal). Based on this analysis, in the second part the current and future needs for action in plant breeding are derived.

The third part defines the strategic vision and objectives that in future should govern publicly financed plant breeding in Switzerland and optimally should be shared by those broadly active in the agricultural sector. Vision and objectives imply a fundamental commitment to plant breeding in Switzerland. They define the services henceforth expected from breeding and its contribution to a sustainable agricultural and food sector. The results of a target-performance comparison based on objectives and situation analysis was used iteratively for re-examining and complementing the need for action from the actual-state and environment analyses.

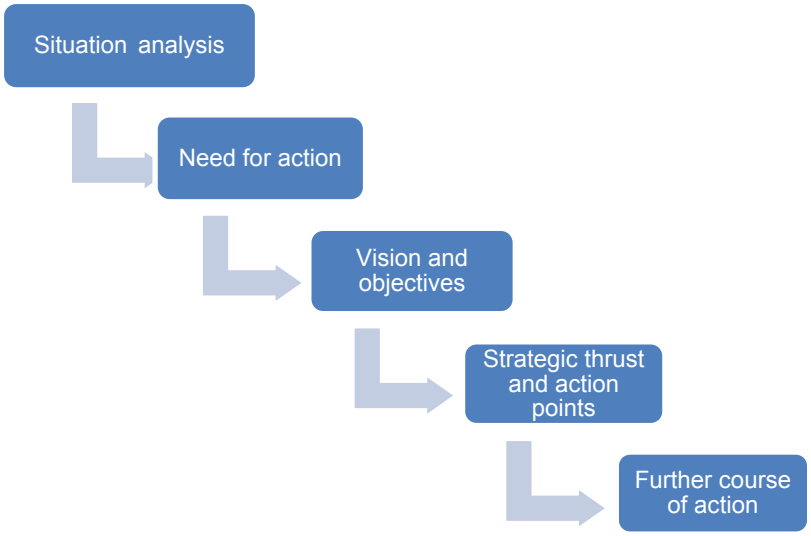

Figure 1: Steps/Design of the Plant Breeding Strategy for Switzerland

Finally, the strategy sketches the ways and means by which the defined objectives can be achieved. Viewed as a whole, the performance record of Swiss plant breeding will in future also depend on very different factors. These include regulation of breeding programs, collaboration among practitioners, access to genetic resources and provision of financial means. The strategy therefore takes a holistic approach and identifies a series of “strategic thrusts” with corresponding “action points” in seven leading “fields of action” for the public sector. This palette clearly shows that progress in terms of set objectives in plant breeding now demand different approaches carried out simultaneously and that future successes greatly depend on optimal combination of the different structural elements in a “comprehensive system of plant breeding”.

Among the fields of action the strategy consciously devotes special attention to the further development of the portfolio of breeding programs called for. Following intensive advance clarifications, expert discussions and a first validation test run, the strategy defines, in an excursus to

“Strategic thrust and action points”, the criteria to be applied in future for the further regulation and management of the portfolio of programs.

The strategy is followed by a brief look at implementation. The action points identified in the strategy have to be concretized in a plan of measures to be taken according to appropriate priorities. The participatory approach taken in elaborating the strategy should also be fostered in the planning and implementation of practical measures with the collaboration of interested parties from plant breeding, research and agriculture.

1.2 Framework for the Swiss Strategy of Plant Breeding 2050

1.2.1 Subject matter, interfaces and demarcations

The strategy is geared to the model of a sustainable and multifunctional agriculture as stipulated under Article 104 of the Federal Constitution[1] and to the expectations of the Swiss people with regard to agriculture as set forth in Food and Agriculture 2025 (FOAG, 2010). It is embedded in the objectives set for food security and for other strategies such as Climate Strategy and Agriculture (FOAG, 2011), the Strategy for Biodiversity in Switzerland (FOEN, 2012) and strategy for quality. In addition, it is geared to the basic provisions governing federal research.

The subject of this strategy is federally supported plant breeding and the conditions governing it on the basis of Article 140 of the Federal Act on Agriculture (LwG). Plant breeding consists in genetically bringing about desired characteristics in plants with the aim of creating direct or indirect value for man and environment. At the heart of the strategy is the breeding of cultivated plants for a sustainable agricultural and food industry in Switzerland. It pursues the goal of developing new, improved varieties for large-scale cultivation and bringing these to market so as to meet the challenges to agriculture and the use of its products. By providing different suitable plant varieties of the most varied plant species it can exert a positive influence on biodiversity.

The core of the present strategy does not include the fields of “promotion of agricultural biodiversity” or “maintenance and sustainable use of genetic plant resources for food and agriculture”. The federal government supports these through biodiversity promotion based on LwG Article 73[2] and the NAP-PGREL[3] based on LwG Article 147*a, b*. These two fields are complementary to the foregoing plant breeding strategy and provide synergies.

1.2.2 Time Frame

The breeding of new varieties takes a long time: 10 to 20 years depending on the plant species. Anticipated developments must therefore be recognized and taken into account in timely fashion. From the start of a new breeding program to the first marketable variety takes more than 20 years. The strategy therefore spans a period which in terms of intended effects extends to the year 2050. This temporal dimension underscores the importance of forward-looking, effective management of breeding programs.

[1] Constitution of the Swiss Confederation BV SR 101

[2] Federal Act on Agriculture LwG SR 910.1

[3] NAP-PGREL : National Action Plan for the Maintenance and Sustainable Use of Genetic Plant Resources for Food and Agriculture

1.2.3 International context

Plant breeding is based on cooperation – national and international – between organizations and institutions, e.g. in research, in developing methods, in the exchange of genetic resources or in breeding work per se. The varieties market is likewise international: the varieties of important cultigens grown in Switzerland (potatoes, rapeseed, sugar beets, barley, most vegetables) all originate abroad. By the same token, the products of Swiss breeding (e.g. forage crops and wheat varieties) have attained international importance. The strategy therefore considers these forms of cooperation.

2 Situation analysis

2.1 Plant breeding in Switzerland

2.1.1 Development of plant breeding

Switzerland has a long tradition in plant breeding. At the beginning of the 20th century, research institutes in Lausanne and Oerlikon (both today Agroscope) began systematic collection of seeds from local populations (Kleijer et al. 2012).

This was also the beginning of concerted, state-financed breeding of a broad range of cultigens at federal research stations. The breeders worked closely with farmers, their collaboration in the breeding work being supported by federal subsidies.

This period also saw the beginning of apple breeding at the Wädenswil research station. Initially it was cider apples, but from the 1920s on, eating apples came to the fore. Further breeding programs for vegetables and ornamental plants were later added. The clonal selection of grape varieties cultivated in Switzerland since the 1940s marked the beginning of grape breeding. Breeding of new grape varieties started in 1965.

As of the 1970s plant breeding was confronted with a series of challenges. Marketing of varieties outside Switzerland required compliance with the new standards set by UPOV for varietal purity and its maintenance. This and the rising number of newly bred varieties took the existing system to its limits. Delays arose between approval of varieties and their availability on the market, thus impairing the economic success of newly bred varieties.

In order to strengthen plant breeding the Swiss Seed Growers Association (today swiss-sem) decided in 1975 to restructure and to build and finance a breeding business in support of public breeding projects for wheat, maize and forage crops, today the DSP AG (Delley Samen und Planzen AG). Activities were subsequently expanded to include other field crops and vegetables.

Some public breeding programs (winter barley, maize, spelt, triticale, pears, berries, vegetables and ornamental plants) were given up in the course of cost-cutting measures starting in the 1980s and the genetic material was in some cases passed on to private breeders.

2.1.2 Current product portfolio of breeding programs in Switzerland

A survey in 2013 revealed that there are in all ten organizations active in the breeding of new plant varieties. A total of about 50 plant species are subject to breeding. Agroscope is the sole public institution and currently breeds about 20 plant species (cf. Annex, Table 1). The breeding and marketing for Agroscope programs are carried out in collaboration with private organizations (public-private partnership, PPP). For field crops and forage plants it is DSP, for fruit varieties VariCom GmBH and for medicinal and aromatic plants mediSeeds GmBH. The other ten breeders are organized on a private basis and process about 36 species in all (cf. Annex, Table 2).

Plant breeding in Switzerland is currently carried out by 30 scientists and 47 technical collaborators (in full-time posts). Thus, for each species of plant the available full-time work force is only about 1.5. From the survey it appears that the breeders class 30 of the 50 breeding programs as small to very

small, 13 medium and only 7 as large on an international scale. A total area of 165 hectares is required for the breeding work.

On average the breeding of a new plant variety costs about 345,000 Swiss francs. However, the expense can vary markedly depending on the plant species. With field crops it will be 200,000 to 500,000 Swiss francs, with perennial plants such as fruit or grapes 1.2-1.7 million francs per variety.

Despite their limited size the breeding programs yield a remarkable number of varieties. Each year a total of about 30 new varieties are released at home and abroad from these breeding programs. In 2013 there were in Switzerland 297 approved varieties from Swiss breeding, abroad 209.

There is little evidence of interaction between the individual breeding programs, especially not beyond plant groups. In the case of publicly co-financed breeding, prioritizing is determined primarily by the available resources.

2.1.3 Legal foundation

The federal involvement in plant breeding is based on Article 104 of the Swiss Constitution with regard to agriculture[4] and on Article 140 of the LwG[5] for plant breeding. Accordingly, the federal government can promote plant breeding, direct contributions to private breeding firms and trade organizations and support the production of seeds and seedlings.

2.1.4 Financing of breeding

For the breeding of these 50 plant species the organizations spend altogether about 10 million Swiss francs annually (full costs: personnel, infrastructure, etc.) (cf. Figure 2). The portion of publicly financed plant breeding amounts to about 40%. At 5.6 million Swiss francs, field crops consume the largest part of the breeding budget (59%). Among field crops, wheat breeding assumes the most significant share at 3.2 million Swiss francs (57%).

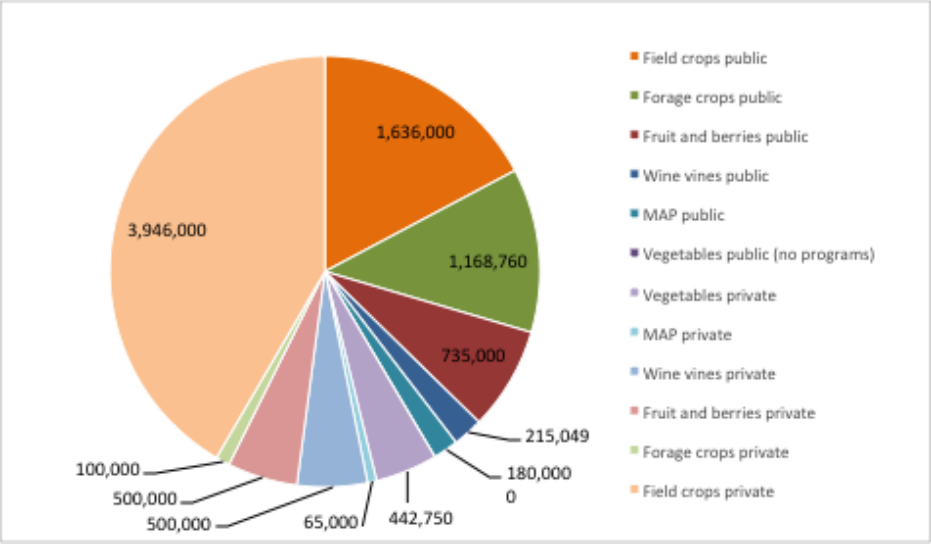

Figure 2: Private and public investment (in Swiss francs) in plant breeding in Switzerland, by individual crop groups. Annual investment totals about 10 million (source: Survey 2013).

2.2 Plant cultivation in Switzerland

2.2.1 Agricultural acreage

Agricultural acreage in Switzerland amounts to about one million hectares. The largest part (58%) consists of natural pastures and meadows (610,000 hectares, Figure 3). Tilled farmlands constitute

[4] Federal Constitution of the Swiss Confederation BV SR 101
[5] Law on Agriculture LwG SR 910.1

about 25% (262,000 hectares), followed by artificial grasslands (12%). This ratio of grassland to farmland distinguishes Switzerland from most other countries.

Specialty crops claim but a small portion of the area: viticulture (1.2%), vegetable gardening (0.9%) and fruit (0.7%, predominantly apples). “Exotic” crops such as pseudocereals (e.g. buckwheat, 100 ha), biofuel plants (e.g. miscanthus, 100 ha) and medicinal and aromatic plants (250 ha) do not play a big role at this time but do have an interesting potential.

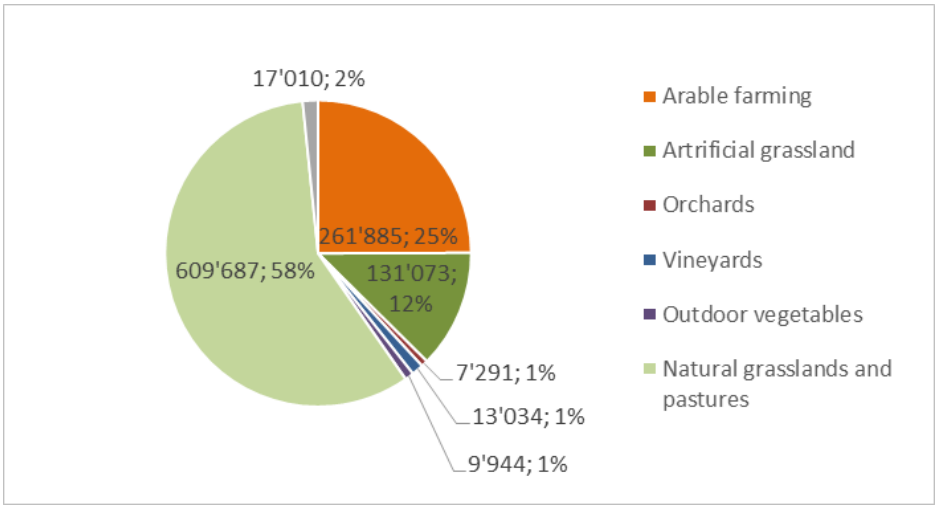

Figure 3: Percentage of agricultural acreage (AA) in hectares, by crop group for 2013 (Source: Federal Statistical Office, 2014).

2.2.2 Value of production

The value produced by these crop groups depends essentially on the area under cultivation and the value of the main product. For 2013 the value of all plant products of Swiss agriculture, at current prices (“production value”), was about four billion Swiss francs.

Field crops (incl. silage maize) accounted for 23% of that and forage crops (artificial grasslands, natural meadows and pastures) 19%. The specialty crops, small in area, yielded substantial portions of the production value: vegetable gardening (17%), viticulture (10%) and fruit growing (8%) (Figure 4).

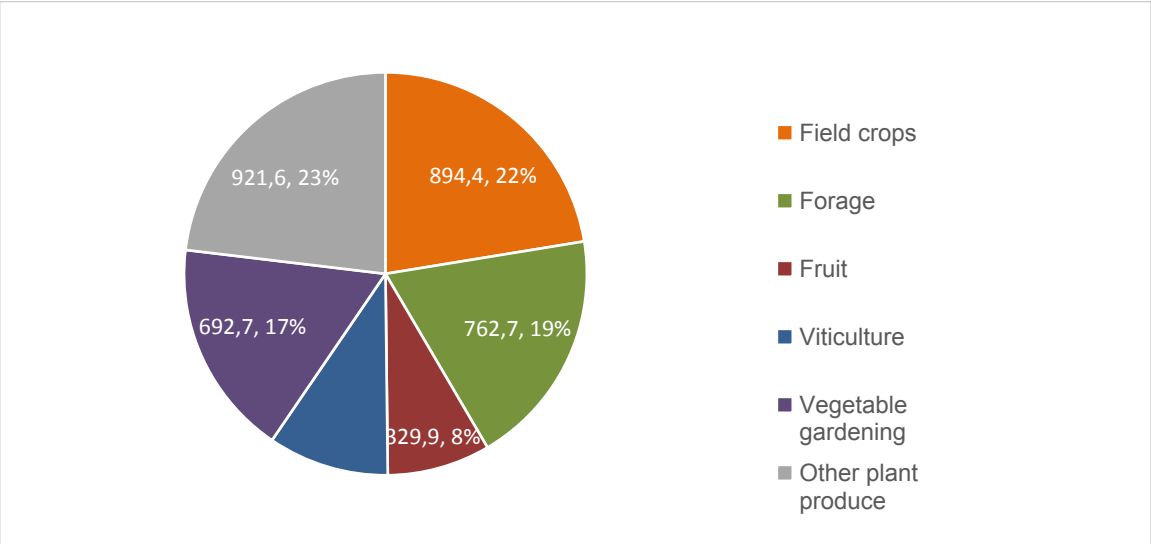

Figure 4: Production value of plant produce in millions of Swiss francs by crop groups in 2013. Other plant produce comprises horticultural produce such as that of tree nurseries, flowers, etc. (Source: Federal Statistical Office, 2014).

2.3 Access to varieties and their seed and plant material

A large number of different practitioners are active in providing Swiss agriculture with varieties and their respective seeds and seedlings, from breeding research through breeding and variety testing to propagating seeds and seedlings. An overview of the organization of the seed and seedling industry is given by the publication “Sorten, Saat- und Pflanzgut in der Schweiz” (FOAG 2008). Specific aspects of seed and seedling regulation in Switzerland are discussed in greater detail in the Annex.

2.3.1 Access to varieties and their seeds and seedlings from the EU

Legal situation

Access to varieties, seeds and seedlings from the EU is of great importance to the Swiss agricultural and food sector. In Switzerland there is neither breeding nor seed or seedling production of many important plant species cultivated in Switzerland today (e.g. rapeseed, sugar beets, sunflowers, many kinds of vegetables). Even among forage plants bred in Switzerland the extent of self-supplied seed material is only about 8%, as basic seed material is used by DSP AG to propagate abroad worldwide and reimport.

In Switzerland’s interest, varieties, seeds and seedlings are also part and parcel of the agriculture agreement with the EU.[6] Thus, Swiss agriculture has a legal right to seeds and seedlings of all EU released varieties of the indicated types – excepting GMO varieties. The aim of the federal government is to extend this simple access to all plant species used in agriculture.

Conversely, all varieties released in Switzerland are registered in the varieties catalogue of the EU. Thus, all varieties recorded in the national catalogue of Switzerland are marketable in the EU with no need to file separate variety release requests in the EU for these varieties.

Breeding activity

The number of EU released varieties of a species can in some sense be taken as an indicator of breeding activity with this species. The number of grants of varietal protection per unit of time is most informative about breeding activity with a species. The proportions among newly released, protected and generally available varieties of a species give an indication of the breeding work of the most recent past and of the anticipated progress in breeding of the species in question (see Annex, Table 3).

Among the major types of crops (crops with large areas of cultivation) there are many varieties and a relatively high level of breeding activity, whereas for minor crops it is rather low. As a result, a circular process comes into play whereby the competitiveness of minor crops is continuously worsened vis-à-vis the major crops. In consequence the range of cultivated species is diminished.

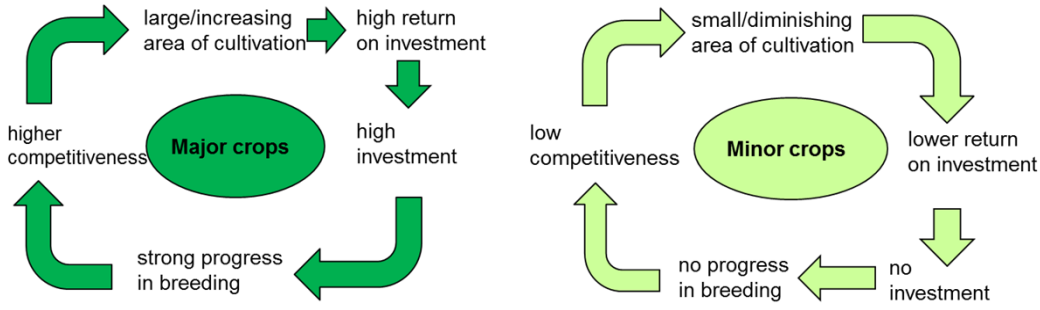

Figure 5: Comparison of driving forces for progress in breeding major and minor crops.

[6] Agriculture Agreement CH-EU SR 0.916.026 Annex 6 “Seeds”

2.3.2 Global trade in seeds and seedlings

The OECD with its international standard of “Seed Schemes” makes possible the global trade in certified seeds of released varieties (currently about 49,000 varieties of 200 species) within the 58 states participating in the “Seed Schemes”. Varieties, then, must be allowed nationally or regionally to enter into circulation to the stage of “end user”. At present Switzerland participates in this system with the following species: grasses, legumes, oil and fiber plants, cereals, maize, sorghum and vegetables.

2.4 Development assessment

Assessment of developments relevant to breeding was carried out on the basis of an environment analysis (ETH 2014), the results of the Resource Efficiency for Food Security project (Becker et al. 2014; Kopainsky et al. 2013), the Crop Farming Vision 2050 (SGPW 2008), the Foresight Study (ETH 2015) and the appraisal of experts.

2.4.1 Natural resources (soil, water, nutrients)

The availability of natural resources in Switzerland will decrease. Agricultural acreage is diminishing and soil quality in the long run is endangered. Also irrigation water can run short due to climate change, at least in risk areas. Greatly increasing importance will be attached to reducing undesirable emissions into the environment from agriculture, conserving scarce and nonrenewable resources (e.g. phosphorus) as well as breaking circular processes (Kopainsky et al. 2013; ETH 2015).

2.4.2 Climate change

In the course of the 21st century, climate change will in Switzerland effect a rise in temperatures, especially in summer, a decrease in summer precipitation and a greater variability in winter precipitation. In general, a greater number of extreme events are to be reckoned with. Summer will see longer warm periods and more heat waves and increasingly droughts. Heavy precipitation events will also occur more frequently than today. This will lead to climatic conditions that today obtain in the south of France and northern Italy. The consequences are, on the one hand, a lengthening of vegetation periods, on the other drought-conditioned losses of yield in high-risk areas as well as more rapid development of diseases and pests (ETH 2014; pp. 78-84).

2.4.3 Technological developments in cultivation and processing

Technological development in cultivation continues to advance due to the needs of cost-saving, environmentally friendly plant production and new technological possibilities. For example, increasingly larger and hence heavier machines are employed, which can lead to problems of soil compaction. Soil-preserving methods of cultivation (e.g. direct seeding) and various forms of “precision farming” are increasingly widespread. The automation of field operations and the harvesting of vegetables and fruits using field robots that function with optical recognition and GPS are just beginning. The processing of foodstuffs is also continuing to develop as a result of changing consumption patterns, or on the basis of new technological developments and the demands of logistics (ETH 2014; pp. 85-89).

2.4.4 Agricultural policy

The criteria and objectives of agricultural policy can directly or indirectly have a great influence on the direction of agricultural enterprises, including the choice of cultigens and animals. The existing moratorium on genetic techniques is another way that policy influences what breeding methods are applied. Societal conceptions of how the benefits of Swiss agriculture ought to be produced can change within just a few years. However, given the long-term orientation of plant breeding, the strategy for breeding must extend beyond the time frame of agricultural policy.

2.4.5 Access to genetic resources

Plant breeders not only use their own genetic material but also exchange with other breeders nationally, regionally and internationally. Because of the high expectations placed on plant breeders to solve a multitude of problems, the availability of important genetic resources in the simplest possible way assumes increasing significance.

Access to and utilization of genetic resources is regulated at the international level by the Convention on Biological Diversity (CBD)[7], the Nagoya Protocol to the CBD, the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGFA)[8] as well as the International Union for the Protection of New Varieties of Plants (UPOV)[9]. The ITPGFA (currently 134 treaty states) now provides for a multilateral system for 64 crops, including all the relevant grain and fodder plant species in Switzerland as well as apples, in order to facilitate the exchange of these genetic resources. All non-ITPGFA species such as soybeans, vines, some vegetables, fruit trees and all medicinal and aromatic plants that are not governed by such a specific agreement are covered by the Nagoya Protocol.

It appears that access to genetic resources is more strictly regulated for the non-ITPGRFA species. The importance of private collections would have to decline and the exchange of genetic material between breeders in different countries become more expensive depending on the cultigen. This lends greater importance to genetic resources from government programs such as NAP-PGREL or international research centers, for instance those of the CGIAR centers. Especially for small and medium breeding enterprises the public breeding or pre-breeding programs will play an important role as sources of genetic material.

The current concentration processes in the seed and seedling markets (see 2.4.7) bring about a reduction in breeding programs and thus a decrease in the diversity of breeding material for the breeder (Howard 2009).

2.4.6 Technological development in breeding

Technological developments in the most varied constituent processes of plant breeding will open up new possibilities. The overall process of plant breeding will in future depend on broad genetic diversity. The importance of access to genetic resources is amplified by the fact that DNA fingerprint methods make it possible to better characterize and employ genetic diversity targeted to plant breeding. It is to be expected that the natural genetic diversity available to plant breeding will be enhanced through induced diversity (TILLING, targeted genome editing).

As for breeding methods, progress in breeding research will make it possible to extend hybridization, which already provides the basis for the breeding of important vegetables and field crops such as rice, maize, sugar beets, rapeseed and rye, to other crops such as wheat, millet and fodder plants (Hund et al. 2014). Cell and tissue culture processes make it possible to shorten the (often biologically limited) generation time and raise the progress of breeding per generation and year. A significant role in this is the crossing of transgenic features, e.g. “early flowering” to accelerate apple breeding.

The greatest technological progress is to be expected in the marker and sequencing technologies, which – combined with new methods in statistics and modeling bioinformatics – will additionally raise selection efficiency and thus breeding progress. This will require genomic data as well as complex statistical models and corresponding computational capacity. The developments in bioinformatics (greater computational capacity, efficient processing, use and storage of large volumes of data) will also be critical for new methods of phenotyping.

Genetic technology can be used to transmit to plants specific properties (e.g. disease resistance, tolerance to heat, dryness and salt, added plant ingredients such as vitamins, omega-3-fatty acids, etc.) that are not at all transmissible by means of classical breeding or else only with difficulty (or only long-term).

Besides genetic methods, many new technologies have been developed in the past ten years that provide much more precise intervention in the DNA structure (site-specific mutagenesis, TILLING) or the regulation of genetic expression (methylation processes) than does classical genetic technology. Plants modified using new plant breeding methods differ scarcely at all from at the molecular level from classically bred plants, which is why the standard screening methods for proof of GMO are inconclusive. At present it is unclear whether or not these new plant breeding methods are legally covered under GMO laws.

[7] Convention on Biological Diversity SR 0.451.43
[8] International Treaty on Plant Genetic Resources for Food and Agriculture SR 0.910.6
[9] Federal Act on the Protection of Plant Varieties SR 232.16

Technological progress in breeding depends on investment in basic research, applied research and technology transfer. Legal parameters as well as the acceptance of new technological possibilities in the population will play a major role.

2.4.7 Economic concentration in breeding, seeds and seedlings

Globally over the past 100 years the seed industry has undergone great structural changes. These developments have been shaped by the dynamic interplay between scientific breakthroughs, business strategies and policy. Particularly strong drivers have been: advances in plant science and in plant breeding as well as the increasing costs for research and development for seed companies and the resulting pressure to find new markets in order to remain competitive. This concentration process was accelerated at the beginning of the 1980s when some multinational pharmaceutical and agrochemical firms in the US and Europe began to make significant investments in biotechnology and particularly gene technology and to protect their varieties with patents. The attendant business takeovers and mergers aimed at pushing vertical integration of the seed business changed the structures of the business landscape markedly (Schenkelaars et al. 2011; Howard 2009). Compared to the market in the US the European seeds market is still heavily diversified. Small and medium enterprises make up a large part of European seed companies. Further developments in the economy have an impact on the availability of seeds and seedlings as does the vertical integration of seed propagation by breeding firms to the exclusion of propagation entities.

2.4.8 International cooperation

Basic research - and thus the advancement of innovation and exchange of knowledge – is international and geared to scientific excellence. Open access to the results of basic research becomes increasingly significant also with respect to cooperation with developing countries. Interdisciplinarity will play a growing role. Cooperation in international research consortiums will be supported through transnational financing. In breeding research, transdisciplinary or integral approaches will assume greater importance, approaches that integrate scientific methods with practical knowledge in material relevant to breeding. The exchange of breeding material between public and private institutions across national borders is governed by material transfer agreements (MTAs), which however often include secrecy clauses or prohibit the use of the material outside the designated trials. The importance of the international exchange of pre-breeding material, commercial seeds or material from national or international gene banks is growing but is subject to increasingly complex regulation (s. 2.4.5).

The trend to globalization is also obvious in the breeding process itself and in seed propagation (s. 2.4.7). Breeding firms more and more breed at different locations (worldwide), not only to increase the number of possible generation cycles per year, but also to adapt breeding material to multiple environments. Moreover, the varieties are propagated where costs can be minimized and yields maximized. New varieties are marketed far beyond national borders and access to international markets is critical for successfully establishing a variety.

2.4.9 Food and consumer behavior

Food consumption in Switzerland has changed markedly in the past thirty years: the consumption of vegetables, vegetable fats and oils, and fish has greatly increased. Marked decreases have been seen in the consumption of meat, milk (products), eggs, animal fats and oils, domestic fruit and wine, the drop-off in the consumption of animal products having taken place before 2000 and leveling off since then. Consumption of cereals, potatoes, legumes, sugar, (herb) tea, nuts and seeds has been subject to only minor fluctuations (ETH 2014, pp. 96-100; Keller et al. 2012). The most important criteria in the buyer’s decision are origin, price and quality. Keeping quality, taste and health aspects also play a role. While the sale of industrially manufactured ready-cooked meals and foods enriched with additives appears to be reaching its limits, the preparation outside the home of healthy ready-to-serve meals with fish products is increasingly important (ETH 2014, pp. 96-100).

2.4.10 Demand – Supply – Price

According to FSO (2015) prognoses, the resident population of Switzerland will grow from 7.9 million in 2010 to about 10 million in 2045. Because pre capita consumption decreases with increasing age, the rising demand will in the coming years be partially attenuated by the changing age structure of the

population (Kopainsky et al. 2013). Domestic production will decrease by about 5% up to 2050; in view of the growing resident population, the level of self-sufficiency will correspondingly decline (Kopainsky et al. 2013).

The prices of Swiss products, then, would rise as a result of the countervailing development of supply and demand. However, lower prices would be likely if the present protectionist controls for Swiss agricultural products were to be removed. Yet this development would in any case be counteracted by globally rising prices for food due to growing world population with increasing consumption need, global climate change and increasing scarcity of resources worldwide (Kopainsky et al. 2013; FOAG 2010). Basically the prognoses assume that price volatility on agricultural markets will increase (FOAG 2012). The development of demand abroad is relevant for Swiss export products like cheese and in future possibly meat (ETH 2014, pp. 90-100). It is, then, difficult to predict the course of factors influencing supply, demand and price and their interaction over time.

3 Need for action

Need for action describes the current and future challenges for plant breeding. These follow from the analysis of the existing situation, analysis of the immediate environment and assessment of future development for the most important factors bearing on plant breeding. To provide a better overview, need for action is thematically divided into seven sections.

3.1 Portfolio of breeding programs

Context

The portfolio of publicly co-financed breeding programs has a direct influence on the development of varieties of plant species that are suited to the location and cultivation preconditions in Switzerland. The determination of the portfolio therefore assumes a key place within the strategy. In view of the means needed, it is unrealistic to pursue breeding programs for all suitable types of crops. Therefore, the availability of varieties of suitable species on the international – mostly European – seed market has to be taken into account in building the portfolio. The criteria for the current portfolio of publicly co-financed plant breeding have yet to be communicated. The use of public funds for plant breeding must, however, be recognized in the interested public and the criteria for a portfolio be known and supported as broadly as possible in order to secure the financing of breeding programs long-term.

A public interest resides, for instance, in secure supply of food for the population and in the breeding of “environmentally friendly” varieties (e.g. to reduce the use of plant protection agents). In view of scarce natural resources and growth in population it is essential that in the coming decades more efficient plant production systems are generated for a sustainable intensification of agriculture. These developments are given added impetus by the anticipated impacts of climate change. Overall, then, the objectives in the breeding programs must rest on plants of high resilience that continue to deliver high yields under future prevailing conditions. Great potential is attributed to plant breeding for meeting these challenges (ETH 2014).

In view of global developments, the minor crop species run the danger of being neglected and hence increasingly less competitive for cultivation (see Annex Fig. 6). Moreover, attention should be paid to species that today are not cultivated and subject to breeding but can in future become interesting because of their characteristics. Public investment is especially important with such cultigens since the time frames for return on investment are usually too long for private breeding. However, public investment in the breeding for these kinds of crops can be worthwhile (Maredia et al. 2010) and has great potential with regard to the resilience of our agricultural systems as well as the diversity of the breeding portfolio and the diet of consumers.

Need for action

There is thus a need to develop further the existing portfolio of publicly co-financed breeding programs on the basis of transparent criteria on objective foundations with participation of the different stakeholders. This raises a conflict of aims between major and minor crops that has to be resolved. Transparent communication supports decision makers in allocating financial means, informs the strategic orientation of practitioners and serves to strengthen coordination in plant breeding and optimize the efficient application of means.

3.2 Variety testing and marketing

Context

To enable agriculture to profit from advances in breeding, new and improved varieties must be brought into the market as rapidly as possible. This makes imperative an efficient variety testing that, under the superintendence of the federal government, tests the varieties on the basis of uniform criteria and cultivation conditions and publishes the results in a transparent manner. This is highly relevant both for plant breeders and for the entire value creation chain – from seed production to processing and consumption.

Need for action

As practiced in Switzerland the interplay of mandatory testing for variety release and the non-mandatory testing of varieties already released in the EU has proven itself in the cooperation of federal government, trade organizations, breeders and cantonal consultation, but it is expensive and should be re-examined with a view to efficiency and the potential for greater international cooperation. The extent to which measures for sales promotion could support the marketing of public and private breeding should also be examined.

3.3 Cooperation among the practitioners

Context

The fact that most breeding programs in Switzerland are small has in many areas a negative effect on their competitiveness. It takes a critical mass for a program consistently to launch improved varieties.

One important factor for success is the efficient transfer of technology and expertise from breeding research to applied breeding. In only nine of the 50 crops currently subject to breeding procedures are new methods (molecular markers (e.g. MAS), cell and tissue cultures, etc.) applied. These are primarily small and medium firms whose collaborations give them *inter alia* access to new breeding methods that can strengthen their competitiveness vis-à-vis the key players on the market.

Strengthening the network within the breeder community, regular exchange of knowledge and structures for the coordination of common projects can give rise to great potential for synergies. Professional associations, communities of interest and knowledge platforms can perform a key function in organization and coordination. In Switzerland and in Europe there are already various professional associations in the realm of plant breeding (Swiss Academy of Natural Sciences (SCNAT), Swiss Society of Agronomy (SGPW), Coordination Group for Organic Breeding, European Association for Research on Plant Breeding EUCARPIA, national organizations, etc.). Yet there still exists no network that unites the entire breeder community.

Need for action

While focusing on strategically important crops (cf. 3.1), breeding programs must increasingly and actively seek cooperation with other practitioners. In particular, the public-private cooperation now successfully practiced in some cases can be expanded.

In terms of efficient use of means with infrastructures for applying new methods and technologies, it makes sense to coordinate investments and make them available to the broadest possible circle of users from research and applied breeding. The building of a center of competence for plant breeding can play a decisive role here. In this regard, potential synergies with animal breeding should be examined.

3.4 Research and exchange of knowledge

Context

An important prerequisite for successful breeding is the efficient exchange of knowledge between research and applied breeding.

Technological developments are an important motor for innovation and ultimately progress in breeding. In particular, molecular and other new methods of breeding offer great potential.

Centers of competence which bring together breeding research, technological development and applications, practical plant breeding and training of qualified personnel at the nexus of plant breeding have proven to be particularly successful. Such centers offer an ideal platform for successfully initiating and realizing inter- and transdisciplinary approaches in plant breeding.

Need for action

Compared with its immediate neighbors, breeding research in Switzerland has a weak foundation. To change this, the position of breeding at universities must be strengthened and a center of competence for breeding research established. This also includes securing the training and continued education of qualified personnel so as to ensure the continuation of competence in plant breeding. The Chair in Breeding being instituted at the ETH is therefore a positive development.

An efficient transfer of knowledge is succeeding today only in the well-integrated programs of Agroscope. Private practitioners have scarcely any links with research. To foster exchange of knowledge with small and medium firms as well will require new promotional tools along with close networking in the breeder community (see 3.3). Today there is a gap between the promotion of basic research (SNF) and applied research (KTI). Incentives for common projects of research and applied breeding are currently lacking and in urgent need of being initiated.

3.5 Legal parameters

Context

Because of its long time horizon, plant breeding is especially dependent on stabile framework conditions. Many of these conditions are the object of international and bilateral agreements or national laws (No. 2.3).

Access to varieties from abroad, particularly from the EU, is of signal importance for the setting of priorities for plant breeding in Switzerland. Access to the EU varieties market thus brings advantages for Swiss agriculture.

International access to and exchange of genetic resources is of vital importance for breeding. Switzerland must make greater efforts toward appropriate framework conditions.

The orientation of agricultural policy is relevant to breeding because it exerts a crucial influence on the spectrum of crops and the demand for suitable varieties with distinct characteristics. Plant breeding can respond only slowly to changes in basic agricultural policy or consumer behavior. Nevertheless, a breeding program must be capable of responding as speedily as possible to new requirements.

In the case of various new breeding methods, plants so modified scarcely differ at the molecular level from classically bred plants. At present it is therefore unclear whether or not they are legally covered by GMO legislation. This results in legal uncertainty and puts a brake on investments in these technologies.

For research there should preferably be no restrictions in the application of individual breeding tools, as this makes Switzerland less attractive for breeding researchers and seed companies. It hampers potential innovation at the national level and in the long run has a negative impact on international competitiveness. Appropriate measures need to be taken in dealing with risks specific to application and technology.

Need for action

Mutual access to the EU varieties market should be sustained and in future broadened to more plant species used agriculturally.

To facilitate the access of breeders to genetic resources, further crops should be integrated into the ITPGRFA. Together with the actual access to genetic material, the availability of genomic data by way of breeding material will in future be of increasing significance and must more and more be included in drafting good framework conditions for breeding.

In the international context Switzerland should stand up for legal certainty with respect to new breeding methods.

3.6 Value placed on plant breeding in society

Context

For investment in plant breeding to be well founded, plant breeding depends on acceptance and a positive image in society. At present, modern plant breeding is often perceived negatively and is frequently equated with genetic technology, use of pesticides, loss of biodiversity and being contrary to the interests of consumers. The role and the potential of plant breeding for a resource-conserving production of high-quality foods and diversified agriculture are largely unknown in government, politics and society.

Need for action

The significance of plant breeding has to be clarified and conveyed in an intelligent and balanced manner throughout the agricultural knowledge system, to all practitioners in the value creation chain and in broad strata of the population. The services provided by plant breeding has to be better communicated, and in the process attention must be paid to transparency on breeding methods used. To this end Swiss plant breeding must have stronger organization, structurally and institutionally.

3.7 Financing plant breeding

Context

Due to the long time horizon and the need for high-level investment, plant breeding depends on secure planning. Investment in plant breeding yields great economic benefits for society through advances in production. For Germany the market effects start from a return of 20 to 40%. Taking into account further positive effects, say food security or resource conservation and climate protection, it amounts to 40 to 80%. Currently, however, plant breeding is underfinanced (Noleppa et al. 2013). If one compares total investment in plant breeding in Switzerland with the value of plant production (more than four billion Swiss francs) the result is an investment of 0.25%. In Germany (roughly five times Swiss GDP) annual investment of about 200 million Euros in plant breeding is 20 times the Swiss level. The portion of public financing there is 50 to 75% (ETH 2014).

Breeding is supported either through government breeding programs or by promotion and research programs (PLANT 2030, BREEDWHEAT, etc.). Such programs often make possible the development and application of cost-intensive but innovative technologies for plant breeding. These can be made accessible to smaller and midsized breeding firms and can contribute to their success (ETH 2014).

In Switzerland there is today too little financial security for breeding work. Publicly financed breeding is periodically affected by budget cuts. In the past, various successful breeding programs have therefore had to be given up. The majority of public and private programs are small. Small programs lack the critical mass continuously to develop improved varieties, to market them efficiently and to come up with the necessary investment in new technologies. Certain programs are shaped by or dependent on a few individuals, which represents a risk for an assured continuity of the program.

Need for action

If Swiss breeding programs are to bring forth internationally competitive varieties in future, investment in plant breeding must grow and financing must have long-term security. If it is determined that the portfolio of breeding programs needs to be expanded, then additional financial means will be required.

Along with increased public funding, new models of financing and promotion need to be developed and greater involvement of the value chain examined. In particular, in the realm of promoting smaller crops, innovative models of financing must be considered.

4 Vision and objectives

As a discipline, plant breeding is in no way a self-serving pursuit. Improvements in cultivated plants by breeding serve plant production and this in turn is an important pillar in the overall system of agriculture, the economy, the environment and society. Vision and objectives for plant breeding must therefore be geared to an ideal model of future plant production and a future food and agriculture industry.

4.1 Vision

As an ideal model for the time frame up to 2050 the Swiss Strategy for Plant Breeding is guided by the following vision:

Vision 2050 for Swiss Plant Breeding

Swiss plant breeding with its outstanding varieties and competence is a basic pillar of a sustainable and innovative agriculture and food sector.

4.2 Objectives

From Swiss plant breeding it is expected that its distinct services contribute to the food and agriculture sector and helps to meet other societal needs such as supply security and environmental protection. To illustrate this connection, the strategy presented here rests on systematic objectives in the following three areas:

- Target area 1: Products and Benefits of Plant Breeding
- Target area 2: Plant Breeding and Sustainable Food and Agriculture
- Target area 3: Plant Breeding and Demands of Society

The individual target areas contain core objectives (CO) and supporting goals (SG). In sum the strategy comprises 9 core objectives and 21 supporting goals. All describe intended contributions of plant breeding in relation to the three target areas indicated. For subsequent evaluation they are delineated as narrowly as possible. In addition, possible indicators and target values are proposed for the individual core objectives. These need to be reviewed and specified at the point of evaluation.

Target area 1: Products and benefits of plant breeding

This area comprises the objectives for the immediate products and services of plant breeding.

CO 1.1	**Swiss varieties are of high quality and very well adapted to the diverse local conditions and cropping systems of Switzerland.**
SG 1.1.1	The varieties are characterized by high and stable yields as well as outstanding internal and external quality.
SG 1.1.2	The varieties show resistance to/tolerance of diseases, pests and environmental influences.
SG 1.1.3	The varieties are resource-efficient and location-appropriate. They exploit especially nutrients and water in optimal ways.
Indicator	Number of Swiss varieties from publicly supported breeding programs that are cultivated in Switzerland.
Target	Maintain or raise the number.

CO 1.2	**Swiss plant breeding contributes to a diverse spectrum of cultivated species and varieties.**
SG 1.2.1	Breeding optimizes the spectrum of cultivated species bred based on a portfolio of breeding programs that is defined according to transparent criteria.
SG 1.2.2	Breeding augments the supply of varieties of selected cultivated species in line with demand and consistent with supply in the international context.
Indicator	Gaps identified in the spectrum of cultivated species and varieties.
Target	Close or reduce gaps.

CO 1.3	**Swiss Varieties are successful in the market for seeds and seedlings.**
SG 1.3.1	The varieties are in demand domestically and meet with interest in the international seeds and seedlings market.
SG 1.3.2	The varieties with their specific features offer added economic value.
SG 1.3.3	The varieties can be propagated with economic value.
Indicator	Share of Swiss varieties in the domestic seeds and seedlings market.
Target	Maintain/increase market share. Increase market volumes.

Target area 2: Plant breeding and sustainable food and agriculture

This area comprises the objectives for the expected contribution of plant breeding to a sustainable food and agriculture sector. They describe predominantly the effects that newly bred varieties should have for purchasers of the varieties, for producers and in the upstream and downstream domains.

CO 2.1	**Swiss plant breeding promotes a sustainable and resource-efficient agriculture and supports its adaptation to climate change.**
SG 2.1.1	The varieties make an important contribution to production systems with secure yields at a high level and of high quality.
SG 2.1.2	The varieties make possible cropping systems that use low levels of adjuvants, especially pesticides as well as nitrogen and phosphorous fertilizers.
SG 2.1.3	The varieties contribute to raising resource efficiency in production.
Indicator	Resource efficiency of cropping systems with Swiss varieties.
Target	Raise resource efficiency.

CO 2.2	**Swiss plant breeding supports further development and innovation in the Swiss food and agriculture sector.**
SG 2.2.1	Swiss plant breeding takes a proactive position toward developments in agriculture, processing of foodstuffs and consumer behavior.
SG 2.2.2	Swiss plant breeding encourages new developments in agriculture, processing and consumption. It opens up new perspectives for the Swiss food and agriculture industry.
Indicator	Number of innovative leaps[10] that take hold in the food and agriculture sector.
Target	Two to three innovations over the next 30 years.

CO 2.3	**Swiss plant breeding strengthens the competitiveness of Swiss food and agriculture sector.**
SG 2.3.1	The varieties increase value creation in the nutrient and food chain.
SG 2.3.2	The varieties increase productivity in Swiss agriculture.
Indicator	Value creation of plant production with Swiss varieties.
Target	Increase value creation.

[10] Innovation according to the criteria of innovation foundations, innovation process and impact of innovation as proposed in Aouinait et al. (2014).

Target area 3: Plant breeding and societal demands

This area comprises the objectives for the requisite contribution of plant breeding to meet the further-reaching demands of society. The objectives pertain to the targeted impact of plant breeding on the state of nutrition in Switzerland and worldwide as well as on preservation of the natural foundation for life.

CO 3.1	**Swiss plant breeding contributes to securely providing the population with healthy, sustainably produced foods.**
SG 3.1.1	Breeding contributes to making available to the population sufficient food of high quality for balanced nutrition.
SG 3.1.2	Breeding contributes to making food and fodder healthy.
SG 3.1.3	Breeding yields varieties taking into account the demand for food and fodder produced in location-appropriate and resource-efficient ways.
Indicator	Market share of Swiss varieties in domestic food consumption.
Target	Maintain and raise market share.

CO 3.2	**Swiss plant breeding contributes to the maintenance of the natural foundations for life.**
SG 3.2.1	The varieties cultivated optimally preserve natural resources and increase ecosystem services[11].
Indicator	Agrarian environmental indicators in cropping systems.
Target	Raising the average values of agrarian environmental indicators (over time and relative to systems without Swiss varieties).

CO 3.3	**Swiss plant breeding contributes to a sustainable mode of agricultural production beyond the nation's borders.**
SG 3.3.1	Plant breeding makes its varieties available in the framework of international cooperation.
SG 3.3.2	Plant breeding brings its know-how to bear in solving problems in the world food system.
Indicator	Market volume of Swiss varieties in target foreign markets.
Target	Increase market volume.

[11] Ecosystem service describes the benefits of ecological systems to humans. According to Millennium Ecosystem Assessment (FOAG 2010)

5 Strategic thrust and action points

The strategic thrusts and action points listed below describe, as the heart of the strategy, the most urgent interventions and intended approaches to achieving the objectives envisaged (on the design of the strategy cf. 1.1). This proceeds along seven identified fields of action available to the federal government in shaping plant breeding in Switzerland.

Fields of action fall into two distinct groups: The structure of the product portfolio (FA 1) has a *direct* impact on plant breeding activity, especially on the spectrum of cultigens bred and thus on the output in varieties. The other fields of action (FA 2 to FA 7) are concerned with the basic conditions that are necessary for successful plant breeding: from the cooperation of practitioners, through education and research, to information and legislation.

Field of Action 1: Further development of the portfolio on breeding programs

Further development of the portfolio of publicly co-financed breeding programs is designed to close the gaps in the spectrum of cultivated species and varieties for a sustainable agriculture and food sector in Switzerland. This should entail a prioritizing of investments in those species for which breeding in Switzerland should be done with the input of public resources. Further, it must be determined by whom and in what time frames this is to be done.

The studies should be carried out by a broadly based, equitably representative commission of experts (breeding, breeding research, value chain, agricultural associations, FOAG, consumers, etc.).

Strategic thrust (ST)	Action points (AP)
ST 1.1 **Establishing an evaluation system for determining the product portfolio.** Applying a knowledge-based evaluation system, the breeding programs should have such long-term definition as to make available a supply of cultivated species and varieties commensurate with demand and geared to the future.	AP 1.1.1 Determine transparent criteria for the evaluation of the portfolio of breeding programs. AP 1.1.2 Validate and refine the evaluation system by an expert commission.
ST 1.2 **Evaluating the current program portfolio and exploiting new opportunities.** The current breeding programs should be reviewed according to the evaluation criteria and concerted efforts made to exploit new opportunities.	AP 1.2.1 Review the current portfolio of breeding programs with a view to realizing their greatest possible benefit. AP 1.2.2 Focused utilization of possibilities for new breeding programs to close gaps in the supply of cultivated species and varieties.
SST 1.3 **Actively manage the portfolio of breeding programs.** The portfolio should be periodically evaluated and actively controlled in a forward-looking manner. The planning horizon covers at least 15 years.	AP 1.3.1 Periodic validation and strategic control of the breeding programs portfolio by a commission of experts.

Excursus: Criteria for refining the breeding programs portfolio

For future assessment and prioritization of the product portfolio of breeding programs, six criteria (C1 to C6) are proposed. The comparative quality assessment uses a 5-point scale.

Criteria	Scale
C1 "Food security" Potential importance of the crop for the secure supply of the Swiss population with the production of food and forage (area, quantity, production of energy and/or protein per unit of area).	1 = unimportant (small area, low production, niche species) 5 = very important (large area, significant production of energy and/or protein).
C2 "Value creation" Potential importance of the crop for the economic success of the Swiss food and agriculture sector.	1 = unimportant (niche market) 5 = very important (principal source of revenue)
C3 "Ecosystem service" Potential importance of the crop in providing ecosystem services[12] (apart from net agricultural production, covered by C1).	1 = preponderantly negative ecosystem service (unsustainable production) 3 = balanced ecosystem service (neutral) 5 = positive ecosystem service (high-level and relevant ecosystem services)
C4 "Nutritional quality" Potential contribution of the crop to a balanced supply of healthy foodstuffs (e.g. rich in essential nutrients).	1 = no contribution 5 = large contribution
C5 "Necessity of breeding" Necessity of a breeding solution for a crop with a view to meeting an objective (needs of the value chain or of cultivation, e.g. resistance, quality, etc.). The criterion should not discriminate against existing breeding programs but rather should indicate important gaps in the supply of varieties.	1 = little necessity (cultigen meets the needs arising from the value creation chain and for a sustainable agriculture) 5 = great necessity (there are major deficiencies in the value creation chain and for a sustainable agriculture)
C6 "Domestic breeding demand" Future availability of varieties of the crop for sustainable production in different regions and for different systems of cultivation and intended purposes in Switzerland (location appropriateness).	1 = high availability of varieties (varieties bred abroad or by private firms provide for optimal cultivation of the species) 5 = no available varieties (suitable varieties are not or only marginally available for solving one or more of the crop's important problems)

The evaluation process

The evaluation of a species or species group is done in three stages: (1) the evaluations of criteria C1 to C4 are aggregated and used to gauge the potential future importance of the cultigen for the Swiss food and agriculture sector. (2) Criteria C5 and C6 serve to assess the breeding demand in the international context and focus on the "best" according to C1 to C4. (3) Prioritizing the cultivated species in the overall context as an iterative process in the expert commission.

[12] An *ecosystem service* describes the benefits of the ecological systems for humans. According to Millennium Ecosystem Assessment (BLW 2010).

Evaluating the criteria for determining the portfolio

The application of the proposed criteria by the project team in multiple test runs within an iterative process showed that they are a sound basis for determining the portfolio. The criteria are to be taken as a recommendation. A further specification of the criteria and a detailed evaluation at the level of cultivated species and intended purpose must be conducted by the proposed body of experts.

Field of action 2: Introduction of new varieties

The positive impact of plant breeding does not come to bear until what are currently the best varieties are used in agriculture. Their improved properties must however be proven in neutral trials. These trials must be carried out under conditions that fit the model of a sustainable agriculture.

Even the best variety will not find its way into practice in the absence of available seeds and seedlings and successful marketing thereof. As propagation and marketing activities are not government activities, the continuation and strengthening of cooperation with the private sphere is proposed.

Strategic thrust (ST)	Action points (AP)
ST 2.1 **Guarantee basic conditions for rapid entry of new varieties into the market.** New, high-performing varieties are objectively tested for their fitness for cultivation and rapidly introduced in the market.	AP 2.1.1 Securing rapid introduction of new varieties through efficient and independent variety testing under different systems and conditions of cultivation in Switzerland. AP 2.1.2 Active searches for suitable varieties of species not bred in Switzerland.
ST 2.2 **Pursue efficient marketing of varieties.** The federal government propagates and markets its varieties with private partners (PPP).	AP 2.2.1 Propagation and marketing of the varieties from public breeding programs through private partners. With concerted marketing of varieties private partners at home and abroad take care of market presence and sale of varieties from public breeding programs.

Field of action 3: Cooperation among practitioners

The breeding programs in Switzerland are small by international standards. Relative to large programs they have a disadvantage in access to technologies, as a result of which their capacity for innovation is limited. This cannot be easily remedied with a breeding strategy. This disadvantage should be offset as much as possible by optimal cooperation, networking and shared use of infrastructure. Today already there exists a successful division of labor between publicly and privately financed breeding in the form of public-private partnership (PPP). Existing partnerships and new, promising models of cooperation should be resolutely pursued and expanded. Field of action 3 is closely linked with field of action 4 (research and development, training and continuing education, transfer of knowledge).

Strategic thrust (ST)	Action points (AP)
ST 3.1 **Strengthen cooperation at the level of breeding.** The exploitation of synergies, facilitated access to new methods and shared use of infrastructure should be improved.	AP 3.1.1 Closer cooperation between public and private breeding programs. AP 3.1.2 Closer cooperation at the international level. AP 3.1.3 A breeding platform permits coordinated development and shared usage of technologies.
ST 3.2 **Improve networking within the breeding community.** The exchange and coordination of activities within the breeding community should be improved.	AP 3.2.1 A trade association for plant breeding guarantees regular exchange, coordination of activities and cooperation among practitioners. AP 3.2.2 Better coordination of breeding activities at the international level.
ST 3.3 **Strengthen linkage in the value creation chain.** The entire value creation chain of research through production into processing and consumption should be better integrated in breeding.	AP 3.3.1 Stronger linkage of the partners of the value creation chain in breeding programs.

Field of Action 4: Research and development, training and continuing education, knowledge exchange

Switzerland is very poorly positioned when it comes to breeding theory and research as well as in the training of plant breeding personnel. As a result, possibilities for access to the latest scientific findings, rapid access to innovative technologies and the recruitment of personnel are limited. The following strategic thrust and action points are designed to eliminate these deficiencies. Field of action 4 is closely linked with field of Action 3 (cooperation among practitioners).

Strategic thrust (ST)		Action points (AP)	
ST 4.1	**Secure access to international breeding know-how.** Qualitatively high-level research on breeding opens up access to international breeding know-how	AP 4.1.1	Build breeding competence at institutions of higher learning and expand cooperation with international breeding research.
ST 4.2	**Secure training and continuing education.** The field of plant breeding should have available an attractive and qualitatively high-level offering of training and continuing education.	AP 4.2.1	Attractive and qualitatively high-level training and continuing education offerings in the field of plant breeding at institutions of higher learning and in close cooperation with applied breeding.
ST 4.3	**Promote knowledge exchange between research and practice.** New methods and technologies from research should be speedily implemented in applied breeding.	AP 4.3.1	Promotional instrument for implementing new methods and technologies from research into applied breeding.
ST 4.4	**Strengthen cooperation of university research with applied breeding.** The parameters for cooperation should become more attractive.	AP 4.4.1	Promotional instruments to make cooperation of applied breeding with university research more attractive.
ST 4.5	**Innovative breeding reseach.** Qualitatively high-level breeding research gives rise to innovative solutions that are of global importance for breeding.	AP 4.5.1	Appropriate measures to promote the innovative potential of Swiss plant breeding.

Field of action 5: Legislation, norms, standards

Successful breeding depends on straightforward access to genetic engineering and information about it. In addition, because of the long time frames of plant breeding it needs correspondingly long-term reliable legal parameters, particularly in the evaluation of new breeding methods.

Swiss legislation is embedded in bilateral and multilateral agreements with other countries. It is therefore imperative that Switzerland actively participates in the discussions and internationally stands up for a balanced middle way between patent and variety protection on the one hand and use of and equitable advantage from genetic resources on the other. This in order optimally to promote innovation and its resulting societal benefits.

Strategic thrust (ST)	Action Points (AP)
ST 5.1 **Simplify exchange of genetic resources.** In negotiations in the context of international agreements the Swiss delegation advocates a simple exchange of genetic data and resources.	AP 5.1.1 Advocacy of optimally unencumbered exchange of genetic resources, including in the framework of international agreements. AP 5.1.2 Devise framework conditions for the provision and simple exchange of genomic data from public breeding programs and databases.
ST 5.2 **Devise parameters for plant breeding that are stable in the long term.** In Switzerland laws, norms and standards should create prerequisites for innovation and the protection of innovative changes in breeding that are secured in the long term.	AP 5.2.1 Ongoing updating of the legal status of new breeding methods AP 5.2.2 Advocacy of reliable standards for the release of varieties in the context of international agreements. AP 5.2.3 Guarantee of compensation for breeding services.

Field of action 6: Information and raising awareness

The importance of plant breeding is little known in the public, indeed even in agricultural circles and thus among those who directly benefit from improved plant varieties. On the contrary, breeding is clothed in notions of monotonous supply, tasteless and standardized products, international monopoly and other negative attributes. This needs to be counteracted by actively conveying information and raising awareness. A well-integrated breeder community and a competence center for plant breeding could play an important role here.

Strategic thrust (ST)	Action Points (AP)
ST 6.1 **Communicate the services rendered by plant breeding.** Related branches, political stakeholders and decision makers as well as the general public should be informed about and sensitized to the importance of plant breeding for a sustainable food and agriculture sector. Plant breeding as essential investment for securing long-term provision of foodstuffs as well as adaptation to climate change and changing framework conditions is anchored in the mind of the public.	AP 6.1.1 Creation of a communication concept to strengthen the image of plant breeding. AP 6.1.2 In communication, consistent mention of the importance and efficiency of plant breeding for sustainable plant cultivation and adaptation to climate change. AP 6.1.3 Transparent information about the methods used in plant breeding, their benefits and risks.

Field of action 7: Financial resources

Because of the long-term time frame and the need for high-level investment, plant breeding also depends on financing with long-term security. However, this can only be justified and attained if the work is of the highest possible efficiency. In addition to the existing financing, new models of financing should be examined to include downstream partners to agriculture.

Strategic thrust (ST)	Action points (AP)
ST 7.1 **Securing financial resources.** The requisite resources for successful development of the priority portfolio of breeding programs are secured for the long term.	AP 7.1.1 Furnish the indicated strategic thrusts with the appropriate resources that is for the long-term breeding programs of the portfolio. AP 7.1.2 Efficient application of means and use of synergies by means of cooperation and shared utilization of infrastructure. AP 7.1.3 Complementary models of financing to involve other partners in the value chain in the financing of breeding.

6 Further course of action

Switzerland's Strategy for Plant Breeding will be adopted by the management of the FOAG in the fall of 2015. This strategy serves as a basis for elaborating a plan of action, which will be worked out under the aegis of the FOAG and the indicated action points concretized. The elaboration will be done with broad inclusion of interested circles. The plan of action should be in place at the latest 18 months following adoption of the strategy.

The plan of action will be designed to prioritize the most important strategic thrusts, to determine structures and timetable and to indicate the requisite means entailed. In addition, it remains to be clarified whether the legal prerequisites are in place for the actions to be taken.

Switzerland's Strategy for Plant Breeding defines the objectives up to 2050. The strategy should be reviewed (external evaluation) in 2025 and adjusted as necessary for further implementation.

7 Annex

Glossary

Agroscope	Swiss federal research institute for agriculture, nutrition and the environment
CBD	Convention on Biological Diversity
CGIAR	Consultative Group of International Agricultural Research
DSP	Delley Samen und Pflanzen AG
DUS	Distinctness, Uniformity, Stability (test of homogeneity and stability for release of a variety)
Ecosystem service	An ecosystem service describes the human benefits of ecological systems. According to Millennium Ecosystem Assessment.
ETH	Swiss Federal Institute of Technology
EUCARPIA	European Association for Research on Plant Breeding
FiBL	Research Institute of Organic Agriculture
FOAG	Swiss Federal Office for Agriculture
GMO	Genetically Modified Organism
GZPK	Getreidezüchtung Peter Kunz
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
KTI	Commission for Technology and Innovation
Major crops	Important crops with a high level of breeding activity
MAP	Medicinal and aromatic plants
MAS	Marker assisted selection
mediSeeds	Company for introducing new varieties of medicinal and aromatic plants on the market
Minor crops	Crops of low importance and little breeding activity
Nagoya Protocol	Settlement on access to genetic resources and the balanced and fair apportioning of the benefits deriving from their use
NAP-PGREL	National action plan for the preservation and sustainable use of plant genetic resources
NFP	National research plan
Niche varieties	Crops of niche status and insignificant or no breeding activity in the sense of neglected crops or orphan crops. They benefit from simplified release under Article 29 of the Seed and Plant Ordinance.
OECD	Organization for Economic Cooperation and Development

PGREL	Preservation and sustainable use of plant genetic resources for food and agriculture
Plant breeding	Activity for improving cultivated plant species with the aim of developing new varieties for large-scale cultivation that meet the release requirements
PPP	Public private partnership
Pre-breeding	Basic breeding and exploitation of plant genetic resources
SBV	Swiss Farmers' Union
SCNAT	Swiss Academy of Natural Sciences
SGPW	Swiss Society of Agronomy
SNF	Swiss National Research Foundation
swiss granum	Branch organization for cereal, oilseed and protein plants
swisspatat	Potato industry association
Swiss-Seed	Swiss Association for Seed Trade and Plant Breeders' Protection
UPOV	International Union for the Protection of New Varieties of Plants
Varicom	Society for Marketing of New Fruit Varieties
Variety	Variety that meets the requirements for inclusion in the Catalogue of Varieties
VCU	Value for cultivation and use (test for cultivation and use value in the context of variety release)

Tables

Table 1: Overview of the publicly financed breeding programs in Switzerland. The cultivated area for forage crops is not known precisely. The proportion of Swiss varieties of seeds sold for fodder is estimated to be about a third. The breeding program for pears was discontinued; at present only very promising breeding numbers from the former program are tested. (*) The soybean, wheat and fodder programs of Agroscope are conducted in cooperation with DSP (Source: Survey June 2013).

Breeder	Crop	*Scientific Name*	Manpower Scientific (Technical)	Full costs in Swiss francs	Varieties released Switzerland (Abroad)	Cultivated area in ha Switzerland (Abroad)
Field crops						
Agroscope	Soybean*	*Glycine max*	0.8 (0.6)	233,000	19 (11)	800 (5,218)
Agroscope	Wheat*	*Triticum aestivum*	3.2 (5.9)	1,403,000	76 (44)	67'670(130,000)
Forage crops						
Agroscope	Bastard ryegrass*	*Lolium x hybridum*	0.2 (0.6)	116,876	11 (10)	unknown
Agroscope	English ryegrass*	*Lolium perenne*	0.3 (0.9)	175,314	13 (11)	unknown
Agroscope	Sainfoin*	*Onobrychis viciifolia*	0.05 (0.2)	29,219	2 (1)	unknown
Agroscope	Italian ryegrass*	*Lolium multiflorum*	0.3 (0.9)	175,314	11 (15)	unknown
Agroscope	Orchardgrass*	*Dactylis glomerata*	0.1 (0.3)	58,438	3 (3)	unknown
Agroscope	Tall fescue*	*Festuca arundinacea*	0.1 (0.3)	58,438	4 (3)	unknown
Agroscope	Red clover (purple clover)*	*Trifolium pratense*	0.3 (0.9)	175,314	14 (12)	unknown
Agroscope	Red fescue*	*Festuca rubra*	0.1 (0.3)	58,438	- (-)	unknown
Agroscope	Birdsfoot trefoil*	*Lotus corniculatus*	0.05 (0.2)	29,219	- (-)	unknown
Agroscope	White clover*	*Trifolium repens*	0.1 (0.3)	58,438	3 (3)	unknown
Agroscope	Meadow grass*	*Poa pratensis*	0.2 (0.6)	116,876	- (-)	unknown
Agroscope	Meadow fescue*	*Festuca pratensis*	0.2 (0.6)	116,876	6 (7)	unknown
Medicinal and Aromatic Plants (MAP)						
Agroscope	Various Herbs		0.5 (0.5)	180,000	13 (6)	120 (60)
Fruit crops						
Agroscope	Apple	*Malus x domestica*	0.8 (2.0)	450,000	10 (5)	400 (10000)
Agroscope	Apricot	*Prunus armeniacae*	0.5 (1.0)	215,000	1 (-)	- (-)
Agroscope	Pear	*Pyrus communis*	0.3 (0.3)	70,000	2 (-)	- (-)
Viticulture						
Agroscope	Wine vines	*Vitis vinifera*	1.0 (3.7)	215,049	9 (1)	820 (10)

Table 2: Overview of the privately financed breeding programs in Switzerland. (*) The soybean, wheat and fodder programs are conducted by DSP in cooperation with Agroscope (Source: Survey June 2013).

Breeder	Crop	*Scientific Name*	Manpower Scientific (Technical)	Full costs in Swiss francs	Varieties released Switzerland (Abroad)	Cultivated area in ha Switzerland (Abroad)
Field crops						
DSP	Maize	*Zea mays*	>1 (>1)	>1,000,000	7 (37)	1,250 (25,000)
DSP	Soybean*	*Glycine max*	<1 (<1)	>100,000	11 (8)	720 (4300)
DSP	Wheat*	*Triticum aestivum*	>1 (>1)	>1,000,000	76 (44)	67,670(130,000)
GZ Peter Kunz	Spelt	*Triticum spelta*	>1 (>1)	>100,000	5 (1)	200 (500)
GZ Peter Kunz	Peas	*Pisum sativum*	<1 (<1)	>10,000	- (-)	- (-)
GZ Peter Kunz	Maize	*Zea mais*	>1 (>1)	>100,000	1 (1)	30 (50)
GZ Peter Kunz	Sunflowers	*Helianthus annuus*	<1 (<1)	>100,000	- (-)	- (-)
GZ Peter Kunz	Triticale	*Triticale*	<1 (>1)	>100,000	- (-)	50 (50)
GZ Peter Kunz	Wheat	*Triticum aestivum*	>1 (>1)	>100,000	7 (2)	2'000 (8000)
Forage crops						
DSP	Var. Forage crops*		<1 (<1)	>100,000	70 (67)	120,000 (unkn.)
Vegetables						
Sativa Rheinau	Aubergines	*Solanum melongena*	<1 (<1)	>1,000	no data	n.d.
Sativa Rheinau	Broccoli	*Brassica oleracea var italica*	<1 (<1)	>10,000	n.d.	n.d
Sativa Rheinau	Chinese cabbage	*Brassica rapa subsp. Pekinensis*	<1 (<1)	>10,000	n.d.	n.d.
Sativa Rheinau	Carrots	*Daucus carota*	<1 (<1)	>10,000	n.d.	n.d.
Sativa Rheinau	Fennel	*Foeniculum vulgare*	<1 (<1)	>10,000	n.d.	n.d.
Sativa Rheinau	Celeriac	*Apium graveolens*	<1 (<1)	>10'000	n.d.	n.d.
Sativa Rheinau	Kohlrabi	*Brassica oleracea var. Gongylodes*	<1 (<1)	>10,000	n.d.	n.d.
Sativa Rheinau	Brussels sprouts	*Brassica oleracea var. Gemmifera*	<1 (<1)	>10,000	n.d.	n.d.
Sativa Rheinau	Tomatoes	*Solanum lycopersicum*	<1 (<1)	>10,000	n.d.	n.d.
Sativa Rheinau	Zucchetti/Zucchini	*Cucurbita pepo*	<1 (<1)	>10,000	n.d.	n.d.
Sativa Rheinau	Sweet corn	*Zea mays var. Saccarata*	<1 (<1)	>10,000	n.d.	n.d.
Sativa Rheinau	Onions	*Allium cepa*	<1 (<1)	>10,000	n.d.	n.d.
Medicinal und Aromatic Plants (MAP)						
Breeding Botanicals International	Java tea	*Orthosiphonis stamineus*	<1 (>1)	>10,000	- (6)	
Mediplant	Annual mugwort	*Artemisia annuan*	n.d.	n.d.	n.d.	n.d.
VitaPlant AG	Valerian	*Valeriana officinalis*	>1 (>1)	>10,000	- (-)	- (-)
VitaPlant AG	Klamath weed	*Hypericum perforatum*	>1 (>1)	>10,000	- (-)	- (5)
VitaPlant AG	Butterbur	*Petasites hybridus*	>1 (>1)	>10,000	- (1)	- (30)
Fruits and Berries						
Lubera AG	Var. fruit & berries		- (>1)	>100,000	40 (40)	10 (40)
Poma Culta	Apple	*Malus x domestica*	n.d.	n.d.	n.d.	n.d.
Viticulture						
Valentin Blattner	Wine vines	*Vitis vinifera*	>1 (>1)	>100,000	unknown(30)	unknown (300)

Table 3: Number of varieties in the EU Common Catalogue compared to newly protected varieties of selected species for the period 2009-2013. The significant fruit and forage grass crops as well as vines are not given for want of an EU common catalogue of varieties for fruit and vines and from the difficulty of distinguishing varieties of grass crops by their use for forage or lawn (Source: Catalogue of Varieties: EU Commission, Grants of Variety Protection: Community Office of Plant Protection of the EU CPVO, FOAG selection as of September 2014).

Crop	Number of Common Catalogue Varieties	Number of varieties released 2009-2013	Protected varieties 2009-2013: current varieties %
Maize	5035	829	16.5
Wheat	2132	384	18.0
Potato	1627	338	20.7
Sugar beet	1467	no data	no data
Sunflower	1426	237	16.2
Barley	1336	279	20.8
Rapeseed	1247	342	27.4
Field pea	409	113	27.6
Soybean	386	25	6.5
Lucern	384	10	2.6
Oats	336	40	11.9
Red clover	217	7	3.2
Rye	169	26	15.4
White clover	138	7	5.0
Spelt	46	4	8.7
Lupine	35	3	8.6
Sainfoin	22	no data	no data
Tomato	3752	228	6.1
Lettuce	2119	429	20.2
Onion	988	31	3.1
Cucumber	887	71	8.0
White cabbage	718	17	2.3
Carrot	584	22	3.7

Excursus: Regulation of seeds and plant materials in Switzerland

The production and bringing into circulation of propagation material (seeds and seedlings) for commercial agriculture is regulated in various ordnances.[13] The thoroughness of the regulation differs among the various categories of crop depending on their importance for food security and the areas of cultivation.

Field and forage crops

- Obligatory release of variety: It consists essentially of testing a new variety for its distinctness, uniformity and stability (known as DUS testing) and of testing for its cultivation and use value (known as VCU testing: value for cultivation and use).
- Obligatory recognition of seeds: variety authenticity and purity, presence of foreign seeds or seed-transmissible diseases as well as marking and backtracking are regulated and monitored by the government. Seed recognition is done only with released varieties. Only recognized seeds may be put into circulation (exception in the case of niche varieties – see below). The use of one's own harvest for sowing in one's own business is permitted.

Vegetable, fruit and vine crops

- Obligatory variety release: It consists of DUS testing (with new varieties). VCU testing is not carried out. With fruit the regulation applies only to varieties by which material should be recognized.
- Optional recognition of propagation material. With fruit and vines unrecognized material (standard material) must also satisfy minimum legal requirements for seeds.
- The same rules apply to niche varieties as to food and fodder crops.

Medicinal and ornamental crops

- There are no regulations governing seedlings in Switzerland.

Besides regulations on seeds, propagation material is also subject to plant protection rules insofar as it can be a carrier of particularly dangerous pests.

Market situation

With many of the available EU varieties (whose suitability for Switzerland is unknown, since they were only tested in EU countries) it is incumbent on branch organizations (e.g swiss granum or swisspatat) to test these EU varieties and to recommend those that meet the cultivation and use requirements (VCU) in Switzerland. Varieties of field and forage crops are tested by Agroscope in cooperation with the branches in the same trial networks in which the tests for variety release are conducted in Switzerland. This guarantees that all varieties undergo an identical variety testing procedure. From the test results lists are compiled of recommended varieties, which have a binding status with different label productions (e.g. "Suisse Garantie").

[13] Federal Council Ordinance on Propagating Material SR 916.151
EAER Ordinance on Seeds and Seedlings SR 916.151
EAER Ordinance on Fruit and Small Fruits Planting SR 916.151.2
EAER Ordinance on Vines 916.151.3
FOAG Ordinance on Varieties 916.151.6

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