DIVERSIFOOD

Embedding crop diversity and networking for local high quality food systems

Grant agreement n°: **633571**

H2020 - Research and Innovation Action

D2.1
Inventory of Underutilised Crops

Due date: M30 – 28th February 2018

Actual submission date: 30

Project start date: March 1st, 2015 **Duration:** 48 months

Workpackage concerned: WP2

Concerned workpackage leader: Ambrogio Costanzo (ORC)

Lead Beneficiary: LUKE

Dissemination level:

- X **PU:** Public (must be available on the website)
- ☐ **CO:** Confidential, only for members of the consortium (including the Commission Services)
- ☐ **CI:** Classified, as referred to in Commission Decision 2001/844/EC

Contents

Contributors

Field bean story in The Netherlands
-Boki Luske, Luis Bolk Institute, the Netherlands

Traditional beans varieties in Portugal: Challenges and opportunities due to their underutilization status" - Literature and farmers interview survey
-PMR Mendes-Moreira (IPC) and MC Vaz Patto (ITQB NOVA), Portugal

Broccoli in Brittany, France
-Veronique Chable, INRA, France

Story of Buckwheat in Finland
-Marjo Keskitalo, Natural Resources Institute Finland (Luke)

Buckwheat in France
-Veronique Chable, INRA, France

Carrots – neglected genetic resources: an overview from Switzerland
Philipp Holzherr, ProSpecieRara PSR, Switzerland

Chestnut in France
-Veronique Chable, INRA, France

Einkorn, Reintroduction of ancient grain into organic markets
-Zoltán Dezsény, Christy den Hertog, Dr. Dóra Drexler, Hungarian Research Institute of Organic Agriculture (ÖMKi)

Emmer, Rediscovering ancient grains
-Zoltán Dezsény, Christy den Hertog, Dr. Dóra Drexler, Hungarian Research Institute of Organic Agriculture (ÖMKi)

The lupine story in The Netherlands
-Boki Luske, Luis Bolk Institute, the Netherlands

Lupins in Switzerland
-Christine Arncken, Monika Messmer, Forschungsinstitut für biologischen Landbau FiBL, Switzerland

Traditional maize varieties in Portugal: Challenges and opportunities due to their underutilization status" - Literature and farmers interview survey
- MC Vaz Patto (ITQB NOVA) and PMR Mendes-Moreira (IPC), Portugal

Rivet Wheat (in France)
-Veronique Chable, INRA, France

Tomatoes – neglected genetic resources: an overview from Switzerland
Philipp Holzherr, ProSpecieRara PSR, Switzerland

Introduction: A Working Definition of Underutilised Crops

Ambrogio Costanzo, WP2 Leader, Organic Research Centre

ambrogio.c@organicresearchcentre.com

Why "Underutilised Crops"?

Of a total of 250,000 identified plant species, 7,000 have been used in agriculture throughout human history. However, currently, 75% of the world's food comes from just 12 plant and 5 animal species, and 60% of total worldwide caloric input comes from just three plants: rice, wheat and maize (FAO, 1997).

These numbers are alarming. In fact, utilisation of such a minimal diversity leads to excessive homogeneity and oversimplification of both farming and food systems, disrupting the ecological, biological and social drivers of sustainable, resilient and healthy agriculture and food.

The bulk of the 7000 plant species which have been crops in history fall into the category of underutilised crops, which DIVERSIFOOD is focusing on as an asset of opportunities to diversify and improve farming and food systems. We have conceptualised a working definition of "underutilised crops", fed by our experimental and documentation work and aimed at providing replicable conceptual tools.

The DIVERSIFOOD working definition of "Underutilised Crop"

A working definition is not supposed to be printed in dictionaries: but rather to help address a challenge in an effective way. Our definition of "Underutilised Crops", informed by two years of fieldwork and documentation across the DIVERSIFOOD consortium, needs to be

tested over time and in different scenarios. The focus is not on the plants, but rather on the process to build opportunities across a wide range of neglected or unexplored resources.

1. **A plant genetic resource …**
    - *Be that either a species or a germplasm, or a crop genetic structure*

2. **… with limited current use …**
    - *having been either forgotten or abandoned, or not yet explored*

3. **… and potential to improve and diversify …**
    - *the focus is set on the advantages we expect*

4. **… cropping systems and supply chains …**
    - *able to improve systems resilience and sustainability, as well as to provide a diversification of diets and markets*

5. **… in a given context.**
    - *the reality, in geographic, historic, social, economic terms, in which the case for the underutilised crop is embedded.*

Categories of Underutilised crops

There are different possible categories of underutilised crops. After two years' working on several case studies, during the 2nd Annual Meeting in February 2017, the DIVERSIFOOD consortium held an exercise aimed at identifying and characterising three distinct categories of challenges related to underutilised crops:

- **Promote the introduction of novel, 'outsider' species**
- **Revive the cultivation of old, 'forgotten' species**
- **Promote the cultivation of 'neglected' germplasm of common species**

In different contexts, a 'crop' may fall into different categories, or even not be 'underutilised'. In the following pages the outcomes of the February 2017 exercise will clarify this concept, including examples, benefits and bottlenecks of the three categories.

The challenge of introducing "outsider species"

Growing Quinoa in Europe, growing Chickpeas in the United Kingdom, growing Buckwheat in northern Finland: these examples and many other have in common the challenge of *shifting a cultivation areal*. This areal shift can either (i) cross a geographical discontinuity (e.g. Quinoa from South America to Europe) or (ii) extend the borders of cultivation areal (e.g. moving Chickpeas and Buckwheat northwards).

In most cases, the primary interest can arise from professional or home growers/gardeners (study from the UK Midlands)[1], and 'outsider' plants can be primarily grown, alongside food production, for ornamental purposes.

	Benefits and opportunities	**Bottlenecks and Challenges**
Ecological	Novel abiotic and biotic stress resistance and tolerance traits; potential to improve resource use efficiency; adaptability to marginal areas; cropping system diversification	Risks of invasiveness; Difficulties in adaptation/acclimatisation; Exposure to new stressors; Lack of adequate pollinators
Technical	Potential for automation: new technologies can make challenges easier to address	Limited availability of seeds; Problems related to dealing with low volumes; Machinery adaptation and difficulties with harvest
Socio-economic	Novel local production systems; Nutritional benefits and more diverse diets	Time and cost-intensive activities; Lack of knowledge; Legal issues; Lack of public interest

[1] See for instance: Kell S., Rosenfeld A., Cunningham S., Dobbie S., Maxted N. *Benefits of Non-Traditional Crops Grown by Small-Scale Growers in the Midlands* – Final Report of the "Sowing New Seeds" Project. 2013, Garden Organic, Ryton, Coventry (UK). See also http://www.gardenorganic.org.uk/sns-resources

The challenge of reviving "old, forgotten species"

The starting point is to understand *why* these species, *e.g.* old minor cereals, have been "forgotten", and why has it been so easy to "forget" them. Although specific answers are related to specific cases, abandonment is generally an overall result of the Green Revolution, i.e. the widespread diffusion of high yielding varieties and related 'technological packages'[2] starting from the post-World-War-2 period. This has led to a standardisation of environments, cropping techniques, processing and supply chains, that most of these "abandoned" species do not fit into.

	Benefits and opportunities	**Bottlenecks and Challenges**
Ecological	Adaptation to low-input environments, therefore potential compatibility with marginal conditions and organic production systems; Generally bear traits of high competitiveness against weeds and good resource use efficiency, as well as stable yield, which make them a resource to tackle climate change effects	May bear some disadvantageous traits, e.g. diseases susceptibilities or very tall habits, that modern breeding has worked against (e.g. very tall straw in cereals); may be not adapted to more fertile environments: it is crucial to aim to specific, rather than wide adaptation[3]
Technical	A wide range of small-scale growing and processing methods can be made effective, sustainable and rentable	Access to genetic resources is a bottleneck, as low amounts of seeds are kept either in informal in-situ conservation or in genebanks; Techniques and know-how have been lost and/or need to be regenerated both to fit into contemporary cropping techniques (e.g. harvesting of buckwheat) and to enable effective processing
Socio-economic	Adaptation to marginal environments can make it easier to maintain farming in such areas; They often provide nutritional advantages and can enlarge the range of food choices and tastes	Lack of knowledge among the wider public about uses (e.g. recipes) can limit their market appeal

[2] Yapa L (1993) *What are improved seeds? An epistemology of the Green Revolution*. Econ Geogr 69:254–273

[3] Ceccarelli S (1989) *Wide adaptation: how wide?* Euphytica vol. 40, pp. 197–205; see also: Ceccarelli S (1994*) Specific adaptation and breeding for marginal conditions.* Euphytica vol. 77, pp. 205–219.

The challenge of "neglected germplasms of common crops"

A typical example is that of open-pollinated varieties (OPVs) of currently hybrid-dominated crops which went through the same process of abandonment as "forgotten species" during the Green Revolution,, such as Maize, Tomatoes, Broccoli. Increasing use of OPVs would broaden the genetic diversity of these common crops.

	Benefits and opportunities	**Bottlenecks and Challenges**
Ecological	Increasing the genetic basis of common crops is expected to provide better adaptation to low input systems and marginal areas, better fitness in agroecological systems and underlying ecological processes (e.g. interactions with pollinators) and better resilience to deal with uncertainty and climate change	As with old forgotten species, it is wise to consider the re-emergence of disadvantageous physiological and/or morphological traits. - it is crucial to aim to specific, rather than wide adaptation
Technical	A wide range of small-scale growing and processing methods can be made effective, sustainable and rentable, e.g. traditional and artisanal milling and bread-making with old wheat varieties.	Although seeds are generally available in genebanks, this does not solve the problem of the lack/loss of knowledge. This knowledge has to be re-constructed to deal with heterogeneous crop stands and to address technical bottlenecks, such as adapting mechanisation and processing.
Socio-economic	Potential adaptation to marginal environments can make it easier to maintain farming in such areas and to develop local economies; They often provide nutritional advantages and can enlarge the range of food choices and tastes.	Lack of knowledge among the wider public about uses (e.g. recipes) can limit their market appeal; Branding tools supporting local economies (e.g. geographical origin branding) are not an adequate support when they do not clearly address the genetic resources used

Field bean story in The Netherlands

Boki Luske
Louis Bolk Instituut
b.luske@louisbolk.nl

LOUIS BOLK INSTITUTE
the natural source of knowledge

1. Crop production in The Netherlands

The Netherlands is a relatively small country. Most of the agricultural area (1,8 million hectares) is in use as grassland for dairy production. The area in use for arable cropping is around 710.000 hectares. Mais silage for dairy production is the main crop, followed by cereals, potato and sugarbeet production (Figure 1). The acreage cultivated with legumes which are harvested dry decreased from 47.000 ha in the 1950's until 2.820 ha in 2015. This is around 0,4% of the land which is in use for arable cropping.

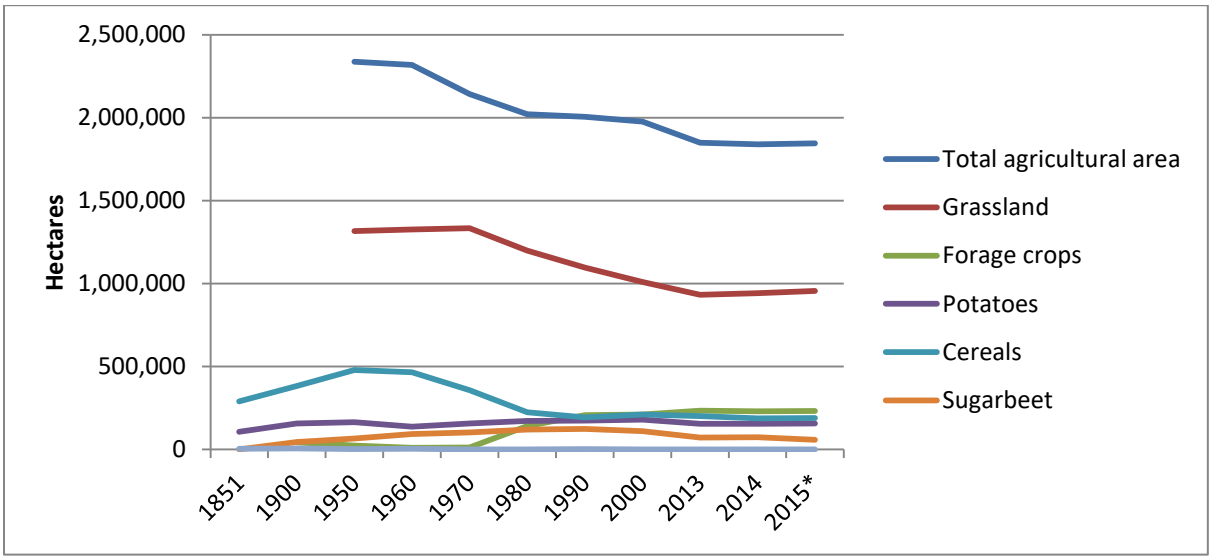


Figure 1. Acreage of the main crops in The Netherlands (CBS, 2017)

At the moment several types of legumes are cultivated in the Netherlands. Of the dried harvested legumes, field beans are ranked second. In 2015, around 360 hectares of field beans were cultivated. Other dried legumes in The Netherlands are: brown bean (1570 ha), capuchin and grey pea (340 ha), feed pea (270 ha) and pea (200 ha) and sweet lupine (80 ha in 2015). Freshly harvested legumes in the Netherlands is mostly pea (3490 ha) and fresh bean (3280 ha) (Figure 2).

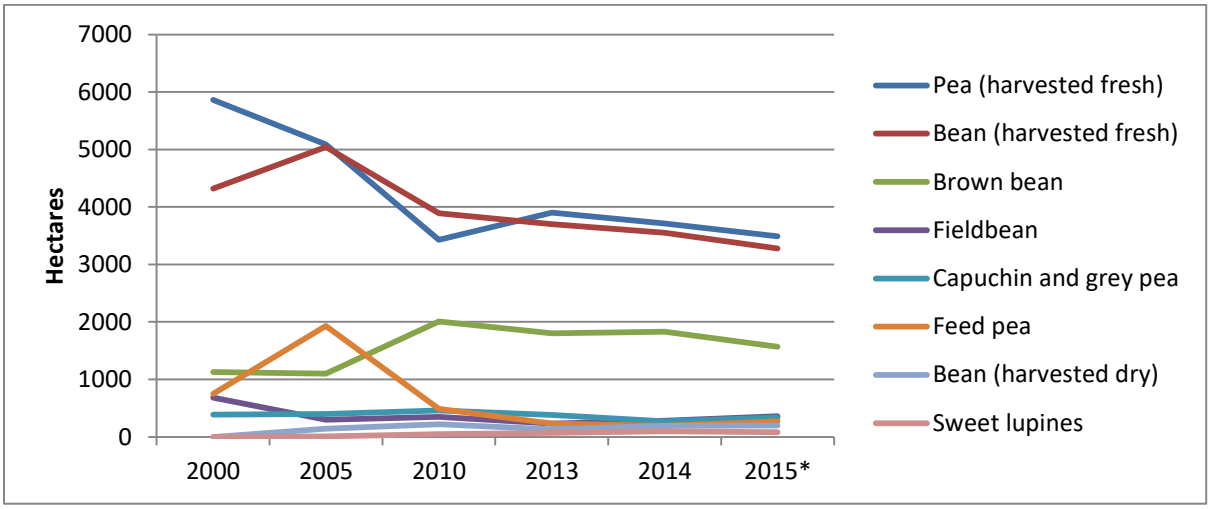


Figure 2. Acreage of different types of legumes in The Netherlands (CBS, 2017)

2. Background of field bean

Traditionally, field beans (*Vicia faba*) were cultivated in Northern Europe including The Netherlands for human food and animal feed purposes.

Due to several reasons the cultivation of field beans was marginalised. One important reason was the Blairhouse agreement, a trade agreement in 1992 between the USA and Europe, which protected the unlimited export of wheat in Europe and unlimited import of legumes from overseas. This caused a steep increase of -relatively cheap- soy import from latin america, and a marginalisation of the cultivation of legumes in (Northern) Europe. Only some niche markets of legumes survived like the cultivation of brown beans in the south of The Netherlands. Also the earlier introduction of artificial fertilizers diminished the role of legumes in the crop rotation as a natural fertilizer. These developments together caused a steep decline of legumes in crop rotations and at the same time a halt of selection and breeding programmes of field beans.
Recently this situation changed. New economies in China and Brazil have an increasing demand for soy. Worldwide the prices for protein feeds for livestock are increasing. In Europe there are raising concerns for insufficient protein supply for animal production. Cultivation of protein crops is adopted as one of the greening measures of the Common Agricultural Policy, also in The Netherlands: as a third crop for dairy farmers and as nitrogen binder for arable cropping. At the same time the transition from animal protein (in meat) towards more vegetable proteins in the human diet is promoted, for environmental and health reasons. Therefore there is a growing attention for the production of vegetable protein within Europe.

3. Field beans and the environment

As for most legiminous species, field beans live in symbiosis with nitrogen binding bacteria in root nodules. Therefore the plant is able to live on nitrogen poor soils. Due to the excretion of root exudates, it also mobilizes phophates from the soil for plant uptake.

Before field beans developes its protein rich seeds, it blooms and in this period of time it is attractive for pollinators like bees, bumblebees, butterflies and hoverflies. Visitation of different

type of insects depends on flower morphology, size and is therefore dependent on field bean variety.

Honeybees visit the the flowers, but they often use perforations of the flowers that are previously made by bumblebees. Their role for cross-pollination is limited, but they might do initiate selfpollination of field beans by shaking the flowers during nectar robbery (Free 1962) .

4. Breeding and seed management

The breeding of field beans focusses mainly on yield and winter hardiness (Link et al. 2010). Growth habit Furthermore selection takes place for the removal of antinutritional factors (like tannins) in the seeds as this will have a positive effect on digestibility of field beans as a feed stock. However, removing condensed tannins may have adverse effects on resistance to diseases and cold tolerance (Van der Poel et al. 1992). Resistance to Anthracnose is since the 1980s a permanent attention in breeding (Ondrej and Huñady 2007).

5. Agronomy

The nitrogen binding capacity and the mobilization of phosphate makes field beans suitable in crop rotations on poor soils and in crop mixtures with for instance cereals. In the organic cropping system, faba bean plays a more imported role than in concentional systems. However, it is not the most easiest crop to grow. There are several pests and diseases that may occur. Anthracnose causes the highest yield losses. Winter beans are relatively more resistant to Anthracnose than spring beans, but still this disease causes the highest losses in field bean accessions (Ondrej and Huñady 2007). Aphids and different fungi and nematodes can also be harmfull for the plant.

The soil needs to have good drainage but on the other hand the crop is susceptible for drought. The crop rotation with other legumes needs to be at least 1:6. Field beans can also be intercropped with wheats, which helps to reduce manage weeds (Prins 2007; Prins 2015).
Field bean is a flowering crop and is partly dependent on visitation by pollinators (partially cross-pollinated crop). The plant is genetically variable (Duk 1997). The range of natural cross-pollinations is very wide (1 - 79%) depending on variety, location and year (McVetty & J Nugent-Rigby 1984). Field beans plants that are accessible for pollinators produce more pods, larger pods and more seeds (Free 1966; Aouar-Sadli et al. 2008). Recently researchers found that pollination of field bean reduces yield loss following heat stress (Bishop et al. 2016).

As the crop is suitable for a temperate climate, there is sufficient time for ripening. The yields vary between races but are in between 4 and 7 tonnes per hectare. Crop residues can be used as animal fodder or left on the field for extra fertilisation. The seeds can be stocked as such or conserved by different treatments (crushed, milled, silaged).

6. Composition and quality factors

Field bean can be used as a protein rich animal feed (substitute for soy) for ruminants. The seeds contain anti nutritional factors (ANFs) like tannins that can be harmfull in for pigs and chickens

when fed in large proportions. White field beans are preferred over coloured, as they contain lower ANF levels.

Tabel 1. Crude protein and carbohydrate levels in peas, field beans and lupine (CVB 2001).

	Peas	Field bean (coloured)	White field bean	Lupine
Crude Protein	**215**	**255**	**297**	**335**
Carbohydrates	**445**	**359**	**290**	**93**

7. Uses

The different field bean varieties can be used for different purposes: fresh pods can be used for human nutrition, dried seeds can be used as a protein rich animal feed. Furthermore the plant can be used as a green manure in the crop rotation.

8. Interview:

Interview with Pieter van der Burg, broiler- and arable farmer in Oostwold, Groningen, The Netherlands. **04-05-2017**

How and when did you came across field beans as a crop?
A friend of mine came across field beans in the UK, where the crop is much more common. It seemd to fit very well with my broiler chicken farm, as I was already producing my own winter wheat for feeding purposes. In 2015, the new greening measures for the Common Agricultural Policy were introduced, and crop diversification was one of the greening measures. Therefore it was the right moment to try field beans on my farm.

Why would you recommend the cultivation of field beans to other farmers?
I can reconment the cultivation of field beans, if a farmer can use the field beans at his own farm. In my case, we replace 5% of the broiler feed with 5% milled field beans. That saves me 10 eurocents per kilo of broilerfeed. Secondly, field beans fit very well in a crop rotation. I noticed higher wheat yield on fields where the field beans grew the year before. Thirdly, field bean is a beautifull flowering crop.

What are your experiences untill now?
After the first year I changed the timing of sowing. At my farm, at the heavy clay of Groningen, the soil is ready for sowing at the end of april, which is too late for field beans. Therefore we switched to sowing in winter. This year, I have 8 hectares of the race Tundra, ánd a field trial of 2 ha which I developed in cooperation with the Louis Bolk Institute. In the trial we compare different seed densities and new field bean races from the UK. Some races have cultivation benefits, but have a low nutritional value as a feed due to high tannin levels. I rather have white flowering field beans, as they have lower tannine levels than coloured flowering field beans.

Which challenges are there for the cultivation and further selection of field beans?
Winter survival of winter field beans in the Dutch climate is still a challenge. As the cultivation in Germany and UK is much more common, it should be possible in The Netherlands too. If the demand for field bean would increase, further selection of the crop will come probably automaticly.

Which developments in the animal husbandry will increase the demand for field beans?

I believe that the animal husbandry sector will develop more towards local feed resources. More and more people say: we import too much soy from America. We can also produce protein crops in Europe! Soy isn't the best feed anyways. It needs to be processed before feeding. Soy has a protein content of 33% and a yield of 4 tonnes per hectare. Field beans have lower protein level of 27%. However, with a yield of 6,5 tonnes per hectare, the protein yield per hectare of field bean is higher than that of soy.

Fig. 1 Field bean seedling (Foto Udo Prins, Louis Bolk Institute)

Fig. 2. Coloured flowering field bean (Foto Udo Prins, Louis Bolk Institute)

Fig. 3. White flowering field bean (Foto Udo Prins, Louis Bolk Institute)

9. References and links

Aouar-Sadli M, Louadi K & Doumandji S-E (2008). Pollination of the broad bean (Vicia faba L.var. major) (Fabaceae) by wild bees and honey bees (Hymenoptera: Apoidea) and its impact on the seed production in the Tizi-Ouzou area (Algeria). African Journal of Agricultural Research 3 (4): 266-272

Bishop J, Jones HE, Lukac M & SG Potts (2016). Insect pollination reduces yield loss following heat stress in faba bean (Vicia faba L.) Agric Ecosyst Environ 15 (220): 89–96.

CVB (2001). Tabellenboek Veevoeding 2001: voedernormen landbouwhuisdieren en voederwaarde veevoeders, Centraal Veevoederbureau, Lelystad, 110 p.

Duk G (1997). Faba bean (*Vicia faba* L.). Field Crops Research 53 (1–3): 99–109.

Free JB (1962). The Behaviour of Honeybees Visiting Field Beans (Vicia faba). Journal of Animal Ecology 31 (3): 497-502.
Free JB 1966. The pollination requirements of broad beans and field beans (Vicia faba). Journal of Agricultural Science 66: 395-397.

McVetty PBE & J Nugent-Rigby (1984). Natural cross *pollination* of faba beans (.*Viciafaba* L.) grown in Manitoba. Canadian Journal of plant Science 64: 43-46.

Prins U (2007). Peulvruchten voor krachtvoer. Krachtvoereiwit voor melkkoeien, melkgeiten, kippen en varkens. Louis Bolk Institute, Driebergen, The Netherlands.

Prins U (2015). Teelthandleiding peulvruchten op natuurgronden. Louis Bolk Institute, Driebergen, The Netherlands.

Van der Poel AFB, Dellaert LMW, van Noreland A & JPFG Helsper (1992). The digestibility in piglets of faba bean (Vicia faba L.) as affected by breeding towards the absence of condensed tannins. Britisch Journal of Nutrition 68: 793-800.

Traditional beans varieties in Portugal: Challenges and opportunities due to their underutilization status- Literature and farmers interview survey

PMR Mendes-Moreira[1] & MC Vaz Patto[2]
[1] IPC (pmm@esac.pt)
[2] ITQB NOVA (cpatto@itqb.unl.pt)

1. **Origin of this neglected resource from a commonly cultivated species**
Beans (*Phaseolus vulgaris* L.)

Beans are the most consumed grain legumes in Europe by humans. Beans have been introduced following the arrivals of the first Europeans in America (Ferrão, 1992) and its adaptation to semiarid and subtropical climates, made this crop very popular around Mediterranean basin especially on spring/summer production as in Portugal. Common bean belong to the Fabaceae family. Although this family is the second most important family of the cultivated plants after the Poaceae, grain legumes account for 27% of the global production, with a production area of ca 85.6 Mha worldwide and a total production of 77.6 Mt (FAO, 2014). Lack of competitiveness of grain legumes in Europe (including Portugal) resulted in a continuous reduction of the production area of these crops.
In order to overcome these constraints, national and international consortia have been established. These consortia are contributing to overcome the lack of knowledge in the breeding sector, the need for food security as well as for reduction of dependence on inputs in nitrogen fertilizers, drawing consumers' attention to sustainable production, and creating a favorable political environment for legumes breeding (Vaz Patto & Araújo, 2016a).

Grain legume seeds are rich in protein (up to 40%) and could improve Europe's autonomy for this commodity, as it imports ca 70 % of its requirements in protein-rich products used for feeds (20-25 Mt of meals + 15 Mt of soybean seeds). Grain legumes are also key components of the Mediterranean diet (Vaz Patto et al, 2015). In addition to proteins, legume seeds are rich in slowly digestible starch, soluble sugars, fibre, minerals and vitamins as well as secondary metabolites such as isoflavonoids, and can play a major nutritional role with the further benefit of anticancer and other health-promoting compounds (Arnoldi et al., 2015).

Beans are the most important legumes in Portugal and their use in mainly as "grain legumes", *i.e.*, for dry grain, but also as green pods or dry green pods with seed set for food.

Portugal has relevant genetic resources, with the biggest common beans collection maintained in Portuguese genebanks with a total number of 3262 accessions (Mendes Moreira & Veloso, 2009). Some of these accessions have been studied under different perspectives such as morphological diversity (Veloso et al., 2015), seed protein content (Palha et al., 1988) and seed content of 8 minerals (K, P, Ca, Mg, Fe, Mn, Zn and Cu) (Pinheiro et al., 2007). A high degree of variability was observed in these studies. The genetic diversity of landraces still grown in the north of the country was studied through RAPDs (Martins et al., 2006). Rodiño et al., (2001) using the phaseolin marker concluded that the Portuguese germplasm is important to widen the genetic base of currently cultivated bean varieties in Europe (Mendes-Moreira and Veloso, 2009). Portugal has scientific capacity to increase legume cultivation (Vaz Patto and Araújo, 2016a), however political incentive measures are still lacking.

Similarly, to what happened in the New World, the system of the three sisters (common beans, corn and pumpkins in consociation) remained in traditional systems in Portugal. These cereal rich cropping systems, combine the possibility of atmospheric nitrogen fixation by the legume crop with the transfer to the associated crops, reducing the nitrogen inputs, as well as reducing pesticides application. This resulted on an overall reduction of the negative impacts of agriculture on the environment.

A decrease in legume cultivation in Europe has been recorded since 1961, and Portugal has followed the same course. Paradoxically, its agroecological and health benefits have been discovered during the same period. National common bean consumption over the last 3 decades follow the half reduction observed in legumes consumption being presently 3.1Kg/inhabitant/year (with a total of 32 000 t).
Portuguese food balance (2008-2012) indicated that grain legumes represented on average 0.6% of the daily food intake (INE, 2016), versus 4%, the advisable daily food intake.

The Portuguese level of self-sufficiency on grain legumes has decrease dramatically from ca 100% during 1985/86 to 11.5% in 2013/14 and with low fluctuation since the year 2000 (INE, 2016). This situation is overcome with an 88.5% of legume importation by Portugal, i.e., few national genetic resources are being used and Portuguese industries rely completely on foreigner raw materials.
The Green revolution impact in Portugal, during the 60's, contributed to dramatic socio-economic modifications that deeply contributed to relevant changes in agricultural systems and in the legume production. These changes included the availability of chemical fertilizers and mechanization, which impact drive to the abandonment of the poorest land and associated cool season grain legumes (such as faba bean, chickpea, lentil, grass pea and lupins) that were used in cereal rotations, for human but especially for draught animal feed. Warm season grain legumes, such as beans that were mainly done in intercropping with traditional maize varieties, were replaced by maize hybrid monocropping due to intensive labor needs.

After the entry of Portugal in EU (1986), the Portuguese agriculture that used to be highly protected from external market competition suffered radical changes with the removal of many importation barriers (Sedlmayr, 2008). Grain legumes imports, and specially soybean (meal and also seeds) grown continuously until nowadays, creating an extreme dependency on the external market.

Common bean suffered a strong reduction (96%) in the national production from the 60's onwards (68 629 Mg in 1961 to 2350 Mg in 2014). More than 425 000 ha dedicated to common beans production were lost. Importantly, the Portuguese common bean yield has more than triplicated during the last 50 years (from 159.8 kg/ha to 567.6 kg/ha in 2014). However this yield improvement was not enough to reduce huge external dependency (more than 3000%) from 1150 Mg in 1961 to 36921 Mg in 2013.

Portuguese grain legumes potential has been underexploited. As a result of little breeding efforts, grain legumes still present low and variable yields, being less attractive to farmers. Even the known benefits for health are not being enough to change consumer's gastronomic preferences, which are reflected by the poor diversity on food products indicating an important area to explore.

The Portuguese common bean research on the last 25 years represented 15% of the legumes research with 47 papers. The majority of studies in common beans were focused on the nutritional and quality aspects of seeds for human consumption (Vaz Patto, 2015).

Farmers' survey
Common beans are definitely a deep-rooted crop in the Portuguese rural tradition and the available genetic variability of its landraces offers an important challenge for breeding for special quality traits, dynamic management of diversity, polycropping systems and PPB programs.

During a field expedition to the Central region of Portugal, during winter 2005, with the aim of collecting maize landraces, 107 bean varieties were also collected (Vaz Patto et al., 2007).

During the collection of common beans germplasm, the farmers' crop system was simultaneously analyzed. In this way the seeds and the knowledge associated with them were collected through several interviews to farmers still cultivating traditional varieties (Fig 1). Around 23 farmers were interviewed using the questionnaire described in Table 1.

Figure 1. Collection mission in 2005 (Vaz Patto et al., 2007)

Table 1. Farmers interview questionnaire

1. Farmer name	
2. Field location (Municipality, Village, and Place)	
3. Beans traditional variety sample information	
3.1. Plant traits	*3.1.1. What plant type: determinate or indeterminate?*
3.2. Agronomical practices	*3.2.1. When and how do you sow your beans traditional variety? Manually or mechanically?*
	3.2.2. When do you harvest your beans traditional variety?
	3.2.3. Do you perform any rotation in time with your beans crop? What are the other crops included in the rotation?
	3.2.4. Do you cultivate your beans in an intercropping system simultaneously with other crops? With which crops?
	3.2.5. Do you apply any fertilizer? What kind of fertilizer?
	3.2.6. What are the main problems/concerns of this traditional

	beans variety? Pests? Others?
	3.2.7. Do you perform any selection on your beans traditional variety? What kind of selection?
	3.2.8. How long have you or your family cultivated this beans traditional variety?
3.3. Production uses	*3.3.1. Why do you keep cultivating a traditional bean variety?*
	3.3.2. With what objective do you produce your beans traditional variety?
4. Associated stories, memories, cultural heritage	

The 107 different beans landraces collected (Fig 2) during these interviews were later characterized using beans SOLIBAM characterization guidelines. This characterization was very important to be able to select the best accessions to increase the use value of this traditional germplasm promoting in-situ/on-farm conservation and decrease their serious genetic diversity erosion.

The types of common beans were divided in climbing and bush beans, with determinate and indeterminate flowering. These traits were later validated through a comparative field trial that took place under the same environmental conditions at Coimbra, Portugal.
For long time the climbing beans, but specially bush beans, were part of the polycrop system with maize and pumpkins. In this polycropping system common beans provided nitrogen to maize and in many cases together with pumpkins help to control the weeds. However these traditional polycrop systems needed high labor inputs, which make mechanization difficult contributing to its strong decline. These systems that were rapidly replaced by mono-cropping technologies adapted to mechanization and where nitrogen needs were provided by chemical fertilizers.

Figure 2. Sample of collected populations in 2005 (Vaz Patto et al., 2007).


Figure 3. Field trials multiplication and evaluation at Coimbra (2010) and Valada do Ribatejo (2012).

The 107 different common bean traditional landraces sampled in this expedition, revealed different patterns and colors. These traditional varieties had been cultivated by the farmer's families for more than 200 years in some cases. The majority of the interviewed farmers cultivated one to six different traditional beans landraces, depending on their different precocities, soil types, different resistances and especially, different end-uses.

In relation to the used **agronomical practices and adaptation to low input systems**, interviewed farmers indicated that the most common sowing-harvesting times were May-September or April-August. When beans were intercropped with maize, bean harvest is done before maize before the rain causes damages to common beans.
In about 60% of the cases sowing was manually performed. Common beans were the most common companion crop of maize (with 70% of the cases).

About 80% of the farmers interviewed cultivated the intercropping system of maize and beans landraces and the farmers that were not performing these intercropping systems had at least use them in the past (Fig 4).


Figure 4. Intercropping maize with common beans (VASO Program).

Several pests and diseases, and in particular virus, were among the **beans farmers' main concerns**. These farmers kept their seed for sowing the following season.

In a study conducted by Dinis et al. (2011), aiming at the identification of the traits that organic and low input farmers identified as main reasons for choosing a specific variety of common bean,

highlighted **Plant morphology and crop architecture (47%), as well as Organoleptic features (43%) and yield (39%) as the most relevant traits, when** a total of 23 farmers were interviewed.

Common beans uses

The farmers' interviews performed in the Central Portuguese region, indicate that climbing beans are generally used as green pods) and the bush beans are more frequently used for drying beans for traditional dishes (e.g. "feijoada", soup).

Research

During SOLIBAM FP7, several trials were done involving multiplication, co-breeding of maize and beans and evaluation trials according to the SOLIBAM Deliverable D1.1 (Chable, 2011).

The results obtained were presented in the deliverables SOLIBAM_D4.1 to D4.4. and the main conclusions were:

- Data from intercropping trials indicate a variation in LERM (Land Equivalent Ratio for maize) data, which could indicate variability in response to consociation from different maize and beans combinations. LERM was determined firstly than LERT (Land Equivalent Ratio Total) (Mead and Willey, 1980)
- The co-breeding indicate us some of the best beans that can be used by maize farmers. From the SOLIBAM_D4.2, in average the 'Pigarro' maize OPV showed a LERM of 0.6, which can be related with fasciation expression. This indicates that fasciation will probably be a useful tool for maize and beans consociation, but more detailed studies on densities and row distances are needed.
- Bean patterns, colors, growing habits, pods per plant, seeds per pod, viable seed and yield are very important to define crosses to be made in order to adapt to farmers and consumer's needs, increasing yield and maintaining quality.

References

Arnoldi A, Zanoni C, Lammi C, Boschin G (2015). The role of grain legumes in the prevention of hypercholesterolemia and hypertension. Critical Reviews in Plant Sciences, 34(1-3), 144-168.

Chable V (2011) Deliverable 1.5_Determination of traits most relevant for model species of cereals, grain legumes and vegetables. SOLIBAM, FP7- KBBE-245058.

Dinis I, Brites C, Santos D, Mendes-Moreira P (2011). On-farm seed production practices of organic and low-input farmers in Portugal. 20th meeting of the EUCARPIA Section Genetic Resources. April 5-7, Wageningen, The Netherlands

FAOSTAT (2014) – Production (Crop) and Trade (Crop and Livestock production. Organization of the United Nations Statistics. [cit. 2016-11-21]. http://www.fao.org/faostat/en/#home

Ferrão JEM (1992) A aventura das plantas e os descobrimentos portugueses. Programa Nacional de Edições Comemorativas dos Descobrimentos Portugueses, Portugal

INE (2016) Balanços de Aprovisionamento de Produtos vegetais. Instituto Nacional de Estatística [2017-05-02]

Martins SR, Vences FJ, Sáenz de Miera LE, Barroso MR, Carnide V (2006). RAPD analysis of genetic diversity among and within Portuguese landraces of common white bean (*Phaseolus vulgaris* L.) Scientia Horticulturae, 108, 133-142

Mead R, Willey RW (1980) The Concept of a "Land Equivalent Ratio" and Advantages in Yields from Intercropping. Experimental Agriculture, 16, 217-228. http://dx.doi.org/10.1017/S0014479700010978

Mendes-Moreira PMR, Veloso MM (2009) Landrace Inventory for Portugal. In Veteläinen M, Negri V and Maxted N.(Eds). European landraces onfarm conservation, management and use. Bioversity Technical Bulletin No. 15. Bioversity International, Rome, Italy.

Palha MG, Ricardo CPP, Baeta JMP (1988) O teor proteico da semente de linhas nacionais de feijoeiro. Agronomia Lusitana 43: 115-131.

Pinheiro C, Baeta JP, Pereira AM, Domingues H, Ricardo CP (2007) Mineral elements correlations in a Portuguese germplasm collection of *Phaseolus vulgaris* L.Book of Abstracts 6th European Conference on Grain Legumes. Lisbon, Portugal 12-16 November. pp125

Rodiño AP, Santalla M, Montero I, Casquero PA, de Ron AM (2001) Diversity of common bean (Phaseolus vulgaris L.) germplasm from Portugal. Genetic Resources and Crop Evolution 48: 409–417

Sedlmayr A. (2008) The flooding of the foodshed: how cheap imports undermine local food systems in rural Portugal. VII Colóquio Ibérico de Estudos Rurais, Coimbra 23-26th October 2008

Vaz Patto MC, Moreira P, Carvalho V, Pego S (2007) Collecting maize (Zea mays L. convar. mays) with potential technological ability for bread making in Portugal. Genetic Resources and Crop Evolution, 54(7): 1555-1563.

Vaz Patto MC (2015) Reinventando as leguminosas de grão na vanguarda da qualidade alimentar. Boletim de Biotecnologia da Sociedade Portuguesa de Biotecnologia. 6: 19-21.

Vaz Patto MC, Araújo S (2016a) Grain legumes in Portugal: Quo vadis?. Revista de Ciências Agrárias. 39(4): 471-489

Vaz Patto MC, Amarowicz R, Aryee ANA, Boye JI, Chung HJ, Martín-Cabrejas MA,Domoney C (2015) Achievements and challenges in improving the nutritional quality of food legumes. Critical Reviews in Plant Sciences 34: 105-143.

Vaz Patto MC, Araújo SS (2016b) Positioning Portugal into the context of world production and research in grain legumes. Revista de Ciências Agrárias 39(4): 3-21.

Veloso MM, Passarinho JA, Matos CR, Carneiro LC, Leitão ST, Vaz Patto MC (2015) Common bean (*Phaseolus vulgaris* L.) landraces in Portugal: morphological diversity of the seed. Landraces 3: 14-15.

Broccoli in Brittany, France

The issue about broccoli in Brittany for organic farming is about ancient and traditional forms of this Brassica crop. There are either forgotten, either underutilized. Modern F1 hybrid variety of broccoli has introduced a new type which has dominated the market in which all other forms had been forgotten. In Brittany, French farmers organized within a seed network called Kaol kozh (Breton word that means “vieux chou” in French and “old cabbage” in English) have tried several strategies to diversify this Brassica type.

1. Broccoli in West of France

With 48 000 ha of land, Brittany ranks first among French regions for vegetable production (20% of national areas). The vegetable sector represents 3% of the UAA of the region and contributes 20% of the value of vegetable crops with 70 million euros in 2014. The region produces 85% of the French tonnage of cauliflower, artichokes and shallots, half of spinach, one quarter of peas, green beans or tomatoes[4]. The cultivation of broccoli is mainly located in Brittany, region in which it was introduced in the 1980s among cauliflower fields. The temperate and humid climate is well-adapted to ensure the growth and quality of this newly attractive green vegetable[5].

The agricultural statistics often mention only cauliflower, but this crops includes in reality several types of the same species including broccolis which represents only 10% of the cauliflower production.


Photo APFLBB http://www.biobreizh.org/liste-des-adherents-du-finistere?view=adherent&id=22:creignou-nicole-et-philippe&catid=22

Type per year	White cauliflower	Colored cauliflower	Green cauliflower	Romanesco	Broccoli
Nb of curds	140 million	80 000	1.4 million	2 million	16 million
Weight in tons	300 000				10 000
Surface in ha	18 000				

The agricultural area of the North of Brittany is specialized in vegetable production and mainly cauliflowers. The region benefits from the oceanic climate and allows cauliflower production in autumn, winter and spring. Since the end of the nineteenth century, Brittany has developed this production which increased mainly since 1960 when developments in communications opened up

[4] http://draaf.bretagne.agriculture.gouv.fr/IMG/pdf/PDF_web_cle04a37a.pdf

[5] http://www.lesfruitsetlegumesfrais.com/fruits-legumes/choux/brocoli/carte-identite

the national and then international markets to farmers in the region and then, when the hybrid types were generalized, at the end of the eighties (Chable, 2005). By 2015[6], the rate of organic surfaces in relation to total vegetable areas was 5% for fresh vegetables. With 692 farms, Brittany still holds first place in the production of fresh organic vegetables in France (20% of the national surface area).

Two production systems are described in the literature on Breton territory (Réseau GAB / FRAB 2015, IBB 2016 in Le Daoré 2017), with intermediaries: (1) a "large area system" in the open field of more than 10 ha, often specialized in the cultivation of a few vegetable species such as cauliflowers, globe artichoke, shallots or potatoes and grown alternately with cereals or grasslands. These farms, mostly located on the North coast, tend to diversify. They mainly sell their productions in long food chain. (2) A "gardening system" on less than 10 ha (more often less than 4 ha), more diversified, growing more than thirty species, often with greenhouses. These farms, which represented 66% of the organic vegetable farms in 2011, are located throughout the territory of Brittany. Most of them use short food chain and local market. (3) Intermediate systems exist, using both long and short marketing channels in varying relative proportions.

2. History of Broccoli in Europe

The situation of the broccoli group is particular, because the current commercial form of broccoli was created with the first F1 hybrid selection. Modern broccoli, in its form of a green semi-spherical curd, is a recent creation of plant breeders. The first variety, an F1 hybrid based on self-incompatibility and showing this current curd morphology and compact head was 'Shogun' created by Sakata seed in Japan in 1989. It was rapidly improved the following F1 hybrid 'Marathon' (Sakata, Japan, registered in 1991) to obtain a true "crown type". It was really different from the landraces, named 'calabrese' in Italy, which shows small and low density curd (spear type whose top is flat (Doré and Varoquiaux 2006).

The story of broccoli is nearly as ancient as all Brassica species used as domesticated as vegetable. The cabbage form has been cultivated since ancient Egypt, would have arrived in Great Britain with the Romans and then become known all over Europe in the Middle Ages (Gates 1953). Broccoli and cauliflower probably came from the same gene pools (Giles 1941; Gray 1989). Sprouting broccoli was described by Pliny in the first century and, according to the botanist Dodoens (16th century), cauliflower and broccoli would have been known for 1500-2000 years. They were imported to Great Britain in this period (Gray 1989). Two main centres of diversification were then described for cauliflower by Allen et al. 1986: Northern Europe with annual white type and Italy with more diversified forms and colors, with annual to biennial cycles. For a long time, the term "broccoli" designated several forms of plant, mainly the flowering stem of many Brassica species. The term became more specific with "sprouting broccoli", the "calabrese" and also the biennial form of white cauliflower in Great Britain and Brittany during the 19th and 20th centuries. The classification became stabilised with registration in the official catalogue of varieties. "Cape broccoli » or « purple cape » were particular designations for violet broccoli, and would have been selected in

/wp-content/uploads/IBB-LePointSur-FicheFiliere-Fruits-legumes-Bio-2016.pdf

South Africa from Italian forms during the 19th century. They came to Europe under the name « Early Cape » (Maher 1808 in Gray 1989). Thus the history of the species shows frequent exchanges and transportations of cultivated forms of *B. oleracea*, which nowadays offer a great available variability, conserved mainly in genetic resource centres.

3. Breeding and seed management

Calabrese and sprouting broccolis are mainly self-incompatible and their allogamous character has maintained heterogeneous populations. Nowadays, the advantages of heterogeneous situation had been recognized to bring stability under organic and low-input situations (Torricelli et al, 2015).

Few hybrid varieties are produced by a natural system, like self-incompatibility, most of them are multiplied thanks to a cytoplasmic male sterility obtained by protoplast fusion (Doré and Varoquiaux 2006) which is not compatible with Organic Farming principles.

Several years ago, a first attempt consisted in breeding organic varieties of broccoli which would look like modern forms to fit to the standard of the market and to what it is known by the consumers. The experience did not succeed. Breeding populations were obtained combining three types of Violetto di Sicilia for selection of green and “crown” form of broccoli. In populations in segregation, we have not yet reached a level of quality compatible with the market (Chable et al, 2008). A second attempt was initiated during SOLIBAM project (FP7, 2010-2014) during which a breeding population was created combining violet type (for the colour diversification), modern type (to get the form) and sprouting type (for the taste). First generations of selection were based on taste and form. The experience was performed with the collaboration of several partners of SOLIBAM (Gautier semences, Kaol kozh, INRA, PAIS and ITAB). Seeds were easiest to obtain in South of France, at Gautier semences place. The results were very interesting for them, but we did not succeed to adapt the plants then in Brittany. Last trial in spring 2017 on a Kaol kozh farm in Chavagne has ended the experience. Other strategies have been designed in parallel based on (1) diversity and on-farm breeding for adaptation of landraces and (2) local and on-farm selection based on crosses performed in one farm.

4. Agronomical practices

The action involved farmers who are still producing their seeds and seedlings on farm. Two cropping periods for green broccoli are possible in Brittany one for a spring harvest and the other for end of summer and autumn harvest. Nevertheless, one type like Cape broccoli is producing in winter (January/February) after an 8-9 months cycle, which is longer than green and modern type.

Density of plantation

The sowing of broccoli occurs from February to June, depending on the harvest time. The technique is the same as for all forms of Brassica vegetable. The plant, sown in a nursery, then covers after plantation in the field with a net to protect the crop against insects. The plant thus obtained will be planted at the earliest two months after sowing. Culture is weeding by hoeing and possibly a butting (bringing the soil back on the row).

5. Quality aspects and uses

Organoleptic quality was the first objective of the Breton farmers' group and partners of SOLIBAM. Modern broccoli has lost the fine taste of sprouting broccoli. Organic farmers, mainly those involved in local marketing, wish to offer a more typical broccoli that could be distinguished from modern and conventional one. In the literature, differences are also observed between both types. "There are clear examples showing different phytochemical contents of different species of the same genus and of different cultivars of the same species. As exemplified by broccoli, the green spear type has higher contents of the anti-oxidative effective carotenoids lutein and β-carotene than the crown type and violet cultivars (Schreiner, 2005)".

6. Peasant points of view and perspectives

The organic farmers involved in broccoli breeding are either on large or local markets. Finally two strategies are emerging following our SOLIBAM experience and first years of DIVERSIFOOD project.
1 – Large market are still asking for green heading broccoli (crown and modern form). Some farmers have then engaged their own selection from either SOLIBAM progenies either landraces crossed by 'Marathon', the variety which is the reference of quality on the market, for its form and colour. Each of them are selecting for local adaptation.
2 – Local market and consumers associations are more curious for diversity and asking for good taste. Farmers wish to propose very different broccolis and to come back to "historical or patrimonial" types. Then, they will try to adept locally coloured broccoli and sprouting broccolis to their agronomical criteria and consumers wishes.

7. Recipe

Roquefort broccoli quiche from Biobreizh[7]
Ingredients:
1 puff pastry,
125 gr of grated Gruyere,
1 head of broccoli (500 gr)
10 cl fresh cream or 1 yoghurt
3 eggs,
Pepper and nutmeg.
250 gr of Roquefort cheese

Preparation:
Preheat the oven to 200-220 ° C. Put the dough in the mold. Cut the broccoli into bouquets and steam them for 5 min (they should be crisp). In a salad bowl mix eggs, cream or yoghurt, crumbled Roquefort. Pepper and add nutmeg (a pinch). Place the broccoli florets on the Paste, and cover with

[7] http://www.biobreizh.org/v1/images/4/brocoli.pdf

egg / fresh cream or plain yoghurt. Cover the tart of grated Gruyère cheese. Put in the oven for about 30 minutes.

8. References

Chable, V. (2005) Conserving and Developing Crop Biodiversity – Biodiversity and Local Ecological Knowledge in France, Bérard L, Cegarra M, Djama M, Louafi. S, Marchenay P, Roussel B, Verdeaux F, eds, édition Cemagref, Cirad, Ifremer, Inr ; Iddri, IFB, 276 pages

Chable, V., Conseil, M., Serpolay, E., Le Lagadec, F. (2008) Organic varieties for cauliflowers and cabbages in Brittany: from genetic resources to participatory plant breeding. Euphytica 164:521-529 http://dx.doi.org/10.1007/s10681-008-9749-7

Chaux, C., Foury, C. (1994) Productions légumières, Tome 2 Légumes feuilles, tiges, fleurs, racines et bulbes. Lavoisier Tec et Doc Ed, Londres, Paris, New York

Doré, C. and Varoquiaux, F. Eds (2006). Histoire et amélioration de cinquante plantes cultivées. Paris, INRA: Collection Savoir-faire, 812p.

Gates, R.R. (1953) Wild cabbages and the effects of cultivation. J. Genet. 51:363-372

Giles, W.F. (1941) Cauliflower and broccoli. What they are and where they come from? J. Royal Hortic. Soc. 66:265-278

Gray, A.R. (1989) Taxonomy and evolution of broccolis and cauliflowers. Baileya 23(1):28-46

Le Doaré, N. (2017) Les producteurs de légumes bio bretons face à leurs semences et variétés : Quelles pratiques, quels déterminants ? Mémoire présenté par Master Agrosciences, Environnement, Territoires, Paysage, Forêt Parcours « De l'Agronomie à l'Agroécologie » pour l'obtention du diplôme de Master Agrosciences, Environnement, Territoires, Paysage, Forêt. Université Paris-Saclay, AgroParistech, 7 July 2017

Schreiner, M. (2005) Vegetable crop management strategies to increase the quantity of phytochemicals. Eur J Nutr (2005) 44: 85–94 DOI 10.1007/s00394-004-0498-7

Torricelli, R., Ciancaleoni, S., Negri, V. (2015) Performance and stability of homogeneous and heterogeneous broccoli (Brassica oleracea L. var. italica Plenck) varieties in organic and low-input conditions. Journal of Agricultural Science 1:17. doi:10.1017/S0021859614001269

Story of Buckwheat in Finland

Marjo Keskitalo
Natural Resources Institute Finland (Luke)
Management and Production of Renewable Resources Planta,
FI-31600 Jokioinen,
Mob +358 (0)29 532 6237
Email marjo.keskitalo@luke.fi
web www.luke.fi

1. Overview of crop production in Finland

Located between 60 and 70°N, alongside the other Nordic countries Finland is one of the northernmost agricultural regions in the world and its agriculture is dependent on the favourable effects of the Gulf Stream. In Finland, grasses, cereals and many special crops can be produced close to the Boreal Zone (65°N). However, the short growing season, which lasts from the beginning of May to the end of September, long days, low mean temperatures (12–16°C) and high risk of frost are characteristic features which affect crop growth. Occasional regional variations, for example in mean degree-days (temperature above 5°C varies) from 800°Cd to 1,300°Cd in South-Finland (Peltonen-Sainio 2012), make forecasting and planning challenging with respect to farming.

Barley, oats and wheat are the most important cereals, covering more than 1.1 million hectares in 2017. Farms specialising in animal husbandry are mainly located in the eastern and northern parts of the country, where most of the 0.7 million hectares of grasslands are cultivated. In 2016, around 65% of the total of 50,000 farms were plant producers and 25% reared livestock (Luke Statistics database).

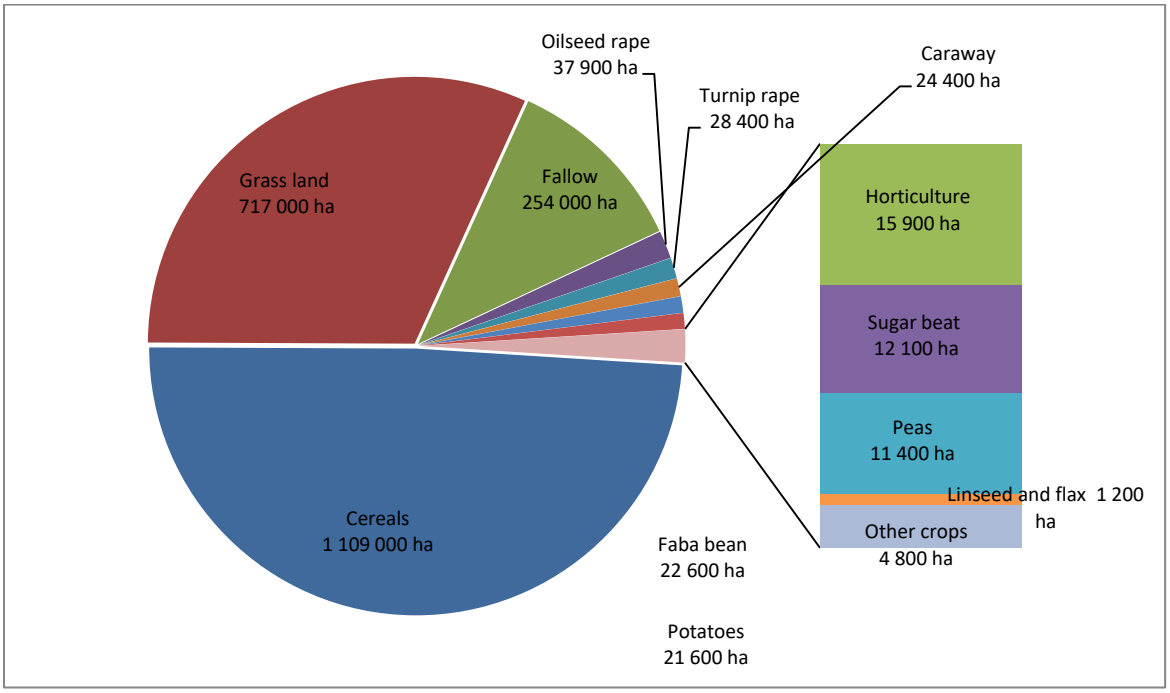


Figure 1. Utilised agricultural area in Finland 2017. Around 4,800 hectares were devoted to other, minor crops such as buckwheat, oil hemp and quinoa (Luke Statistics database).

The areas allocated to grasses and other crops have been increasing over the last few years. One of the driving forces behind this is the need for more profitable and diverse farming methods. Oil crops (turnip rape and oil seed rape), caraway, faba bean, potatoes, sugar beet and peas cover around half of the area classified as other crops (Fig. 1.). New, special or niche crops such as buckwheat, oil hemp, quinoa and sweet lupines account for around 4,800 hectares in total.

In Denmark, buckwheat played an important role in farming and the national diet over 250 years ago, when around 30,000 hectares may have been under cultivation. However, buckwheat has been of minor importance in recent years (Christensen 1989) and no data is available on production. On the other hand, interest is increasing in gluten-free raw materials and the production of buckwheat is about to resume (PROTEIN2FOOD).

Table 1. Cultivation areas (ha) of buckwheat in Estonia and the Nordic Countries.

Country	**2014**	**2015**	**2016**
Denmark	nd.(no data)	nd.	nd.
Estonia	800	1400	2900
Finland	1110	1370	1850
Norway	nd.	nd.	nd.
Sweden	138	188	nd.

In the case of Estonia, the figures refer to the total production area of other cereals, such as buckwheat, millet and canary seeds (Eurostat). In Finland, the cultivation area of buckwheat has been increasing during the last ten years, while new research projects (ScenoProt, FutureCrops) have begun in order to strengthen this area in the future.

In Norway, buckwheat production is minimal, but around 120,000–213,000kg of buckwheat has been imported to the country in recent years (Statistics Norway). Buckwheat farming has resumed in Sweden (Wermlands Bovete) and the cultivation area increased from 4 hectares in 2006 to 188 hectares in 2015 (Jordbruksverket).

2. Background of buckwheat

Buckwheat (*Fagopyrum esculentum*), or 'tattari' as it is known in Finnish, has a long history and may be the oldest crop in the country. In 2010, prehistoric buckwheat pollen was identified using high-resolution analysis in sediment taken from Lake Huhdasjärvi, which is located in Southeast-Finland. The pollen was dated back to 5,300BC, to the same period when the tree coverage, *Pinus* and *Betula,* was decreasing, suggesting increased human activity and forest clearances. In combination with nutrient-poor, sandy soils favourable to buckwheat, it may the case that early agricultural steps had already been taken during this period (Alenius et al. 2013). It has also been proposed that buckwheat was brought from the Himalayas to Finland and Northeast Europe, rather than from Eurasia as has been commonly suggested.

Figure 2. Buckwheat leaves are initially kidney-shaped (cotypedons), after which they resemble a pointed heart (Photo Marjo Keskitalo, Natural Resource Institute Finland).

Finland is mainly covered by forest and its field areas were originally limited. One way of creating more arable land for food production was to 'borrow' it from the forest on the basis of the slash-and-burn culture. Since buckwheat tolerates nutrient-poor soils, it was often planted as the last crop after a couple of years spent cultivating rye, barley and/or oats. After buckwheat, the area was usually abandoned for 20–40 years for reforestation (Korhonen 2004). In some cases, buckwheat was chosen as the first crop, especially if the field was recovered from a burned swamp area and was not properly tilled, as would be required for other crops (Jortikka 1922). As part of the slash-and-burn culture, buckwheat was an important crop in the 14th–18th century, particularly in eastern Finland (Grotenfeldt 1922). In southern Finland, where the clay content of the soil is high and much more sophisticated equipment would have been required for contemporary tilling practices, attempts to cultivate buckwheat usually failed.

While buckwheat may have been a fairly important food source for people living in self-sufficient households, no statistical information is available that describes the situation before 1878 (Anon 1917). At the turn of century (1896–1905) the consumption of buckwheat per person and per year was relatively low (0.7kg) compared to peas (3.5kg) and rye (200kg), the latter of which was the most important crop at the time. The relationship between the seed yield and the amount of sowed seeds reveals that the yield potential of buckwheat (5.4–8.7) was as good as or even better than rye (6.2–6.9) or oats (4.9–5.7) (Anon 2017). However, the annual variation in yields was already being observed at the time. As the Finnish saying goes 'Tattari tuottaa taalareita, tattari myös talon riistää', meaning that buckwheat production can provide a quick buck, but can also ruin the farm (Grotenfeldt 1922).

As the slash-and-burn culture became rarer during the 19th century, buckwheat gradually became less important. Estimating the size of cultivated areas over a hundred years ago is complicated, since statistics were produced on the basis of the seed amount used for sowing, rather than hectares. It has been mentioned that 1,999 hectolitres of buckwheat seeds were used between 1893 and 1895 (Anon. 1917). According to the weight of the seeds (1 hectolitre corresponds to 68kg) and the amounts used for sowing (68kg/ha) (Grotenfeldt 1922), the cultivation area may have been around 1,999 hectares. Fifteen years later (1910), the cultivation of buckwheat had fallen close to zero (Anon. 1917). About one hundred years later, in the 1990s, farmers and consumers gradually rediscovered the crop. By 2016, buckwheat accounted for 1,800 hectares of arable land (Luke Natural Resources Institute Finland), with more than one hundred farms cultivating it.

Buckwheat production is concentrated in Pirkanmaa, which lies between southern and central Finland, and Uusimaa, the area adjacent to the capital city of Helsinki. Production is mainly based on contract farming.

Figure 3. Abiotic stresses and maturation can cause strong coloration of the leaves (right picture) in comparison to normal conditions (Photo Marjo Keskitalo, Natural Resource Institute Finland)

3. Buckwheat and the environment

Buckwheat is a crop suited to temperate climates. If the weather is too warm and dry during flowering, the seed can be inhibited from setting. One of the key challenges, however, lies in the plant's sensitivity to frost, which can be detrimental during the early stage of growth. In the later stages, a cold season with night frost may even favour killing the leafy plant, bringing an end to flowering and making harvesting easier. Despite its sensitivity to cold, buckwheat has adapted to the short growing season typical of high latitudes and can produce yields of up to 1,500-2,000 kilogrammes (Keskitalo et al. 2010).

Buckwheat requires relative low amounts of nutrients (Hakala et al. 2009) and chemical inputs. The mycotrophy status of the roots has also been studied (Vestberg et al. 20112). The crop tolerates poor soil and resistance to harmful insects or plant diseases has been observed. The crop itself contains phenolic compounds, which may have allelopathic effects on weeds (Zou et al. 2014) and buckwheat is therefore almost perfect for organic production. As a flowering crop, it is a good source of nectar and pollen and provides a possible habitat for many insects. On the other hand, because pollinators are a prerequisite for a good yield and can increase seed production by 30% (Keskitalo et al. 2008), many buckwheat farmers collaborate with beekeepers. Buckwheat's potential for assisting in the maintenance of a diversified agriculture and landscape has been studied (Berg 2015).

Figure 4. Some pinkish flowers were found from a local accession in 2006, although most of them were white (Photo Marjo Keskitalo, Natural Resource Institute Finland).

4. Breeding and seed management

Because no varieties of buckwheat are bred purely for Finnish growth conditions, local accessions are commonly used (Fig. 4). Some old Finnish accessions have been stored in The Nordic Genetic Resource Centre (NordGen). In line with larger growing areas, enquiries about improved cultivars have been increasing. Since Finnish breeding actors cannot start breeding programmes for buckwheat, one solution would be international collaboration. Varieties from different parts of the world have been tested over the last fifteen years, revealing that imported cultivars could be potential alternatives and might adapt to Finnish growing conditions (Keskitalo and Jauhiainen 2013).

Figure 5. Variation at the seed set is typical for buckwheat in Finland. In some years, most of the flowers in the comb fade away and no seeds are formed (left picture), whereas in others the yield formation is more successful. Pollinating insects may improve the yield formation by up to 30% (Photo Marjo Keskitalo, Natural Resource Institute Finland).

5. Agronomy of the crop

The easiest way to obtain seeds is to contact the cooperative (North Pirkanmaa buckwheat cooperative) or mills that upgrade seeds (Keskinen Mills, Virtasalmen viljatuote). The sowing time is usually at the turn of May and June, and during the two first weeks of June. The key issue is to avoid the cold period, although frost may still kill the plants later in the growing season. Buckwheat benefits from well prepared and warm soil conditions, which enable rapid germination and growth (Fig 2 and 3.). Around 50–70kg/ha of seeds should be drilled to a depth of 2–4cm with row spacing of 12–15cm. The nutrient requirements are low and less than 60 kilograms per hectare of nitrogen is enough. In organic soils, where nitrogen is mobilised during the growing season, cultivation without nitrogen fertilisation is possible. At least part of the required phosphorous buckwheat may mobilise from the soil bound form in the root excretion. In practice, a small amount (5-7kg/ha) of P has been yielded in mineral form during sowing (Keskitalo and Jauhiainen 2013).

Flowering occurs around 40–45 days after sowing, which is usually in mid-July in Finland. During the first weeks of flowering, sunny and warm weather is needed to make the work of pollinators easy and effective (Fig. 5–6.) (Keskitalo et al. 2008). Flowering is most abundant during the first month after it begins, although new clusters may form until the end of the season, since continuous flowering is characteristic of buckwheat. For this reason, many farmers wait until the first frost, which macerates the crop and makes harvesting easier.

Figure 6. Buckwheat production in central Finland, where the fields are surrounded by forest. Flowering usually occurs in mid-July, around 40–45 days after sowing.

Buckwheat has fairly small root systems, which means that extremes in soil moisture conditions – if they are waterlogged or too dry– may lead to failure to grow (Fig 3.). Direct drilling may be possible in organic soils and in dry season, in particular, unploughed soil may hold moisture longer for the crop (Keskitalo and Jauhiainen 2013).

The harvesting period is September to October and harvesting can be managed using the farm's typical harvesting machinery. The seed yield can be up to 1,500 kg/ha, but yields below 500kg/ha are also common. After the harvest, the yield should be dyed to a moisture content of 11–12 percent.

The key factor when ensuring quality is to avoid contamination by cereals at every step, if the seeds are to be used for gluten-free products. Rotation crops other than cereals are therefore currently being sought. In this context, cereals are considered contaminating weeds, which should be eliminated manually or chemically using herbicides.

6. Composition and quality factors

Buckwheat is gluten-free and therefore provides domestic raw material for special diets. Although the total carbohydrate content of buckwheat flour and quinoa, another gluten-free alternative, are comparable, there are also differences. The glycaemic and C-peptide responses of foods rich in dietary fibre from buckwheat and other sources were studied. Buckwheat porridge having relatively high glycaemic index (GI) had a low C-peptide index. The fibres of buckwheat were suggested to provide new alternative for low GI foods (Rokka et al. 2013). Another compound, *D-Chiro*-inositol, lowered serum glucose concentrations in rats and may therefore to be useful in treating diabetes (Kawa et al. 2003.). The *D-Chiro*-inositol content was observed to vary between varieties and cultivars (Keskitalo et al. 2007, Keskitalo et al. 2010). Buckwheat and tartary buckwheat (*Fagopyrum tataricum*) characteristically contain rutin, which is an antioxidant phenolic compound. The consumption of tartary buckwheat cookies, in particular, was observed to reduce myeloperoxidase, which is an indicator of inflammation. On the other hand, the consumption of both types of raw materials may lower cholesterol levels (Wieslander et al. 2011).

The consumption of buckwheat may also have some negative effects. As consumption has increased in recent years, more cases of buckwheat allergy have appeared in Europe (Heffler et al. 2014). Possible buckwheat allergy should also be taken into consideration when handling and processing the crop (Wieslander 1995).

Table 2. The nutritional composition of buckwheat and quinoa (Fineli, National Food Composition Database in Finland).

	Buckwheat (Flour)	Quinoa (seeds)
Energy, KJ	1350	1492
Carbohydrates, g	60.5	57.2
Fat, g	2	6.1
Proteins, g	11.9	14.1
Fibre, g	5.8	7.0
Folates, µg	35.0	92.0
Ca, mg	18.0	47.0
Fe, mg	3.8	4.6
K, mg	460	563.0
Mg, mg	178	197.0
Na, mg	2	5.0
P, mg	320	457.0
Se µg	5	8.5
Zn mg	2.5	3.1

7. **Uses of buckwheat**

Buckwheat has been traditionally used by people suffering from coeliac disease (CD). It is estimated that around 2% of Finnish people may have a minor bowel disorder caused by proteins known as glutens, which are abundant in wheat, rye and barley (Finnish Coeliac Society). In recent years, other consumers have also discovered buckwheat, as part of a healthy and vegetable-rich diet. Buckwheat has typically been used in porridges, breads, pies and biscuits, and new research has been carried out on its combination with other raw materials (Jantunen et al. 2006). One of the most famous buckwheat dishes is blini, a small savoury pancake originating in Russia. Blinis are usually served in restaurants in February and can be eaten together with caviar, hacked onion and smetana.

Figure 7. One of the most famous buckwheat dishes is blini, a small savoury pancake originating in Russia. Blinis are usually served in February and can be eaten together with caviar, hacked onion and smetana.

To make eight blinis, you need:
2dl sour cream
2dl thick yoghurt (natural)
20g yeast
1ts dark sugar
2½dl buckwheat flour
(Photo Arjan Ruokatieto Oy)

Warm up the sour cream and yoghurt slightly (until hand warm), soak in the yeast and then mix-in the dark sugar and buckwheat flour. Allow the dough to rise for two hours at room temperature. You can use cold ingredients; in such a case allow the dough to ferment for longer – overnight, for example. Before baking the blinis, mix hot milk (1½dl) into the dough, and then melted butter (2 table spoons), salt (1½ts) and one egg yolk. Whip one egg white into a foam and add it to the dough. Bake thick blinis with butter on a mild heat in a frying pan. Serve each hot blini with caviar/roe, smetana and chipped onion (Arjan Ruokaviestintä Oy).

8. Buckwheat from the farmer's and upgrader's perspective

The North Pirkanmaa buckwheat cooperative was founded in 2003 and is a good example of a successful project partly funded by the EU. From the ten founding members, the number of contract farms has increased to more than eighty. The cooperative provides seeds, gives instructions on cultivation, organises educational events and field days, and handles marketing. The key aspect of production is maintaining high quality standards, which means a commitment to cereal-free cultivation methods. 'The raw materials are used entirely for gluten-free products, a value chain which starts in the field', underlines Juha Anttila, the long-term chairman of the cooperative. Anttila goes on to answer the following questions.

How has the business changed over the years? Buckwheat production has doubled during the last 14 years and the crop is considered an interesting alternative to cereals, particularly during times when the price of traditional crops is low. We are, however, seeking new members, since our products are popular and we could produce more buckwheat in Finland.

What are the greatest challenges at the moment? The greatest challenge is coping with the yield variation between years. In a good year, yields can be as high as 1,500–2,000 kilogrammes per hectare, but we sometimes have to content ourselves with yields below 500 kilogrammes. Yield variations challenge not only farmers, but also the entire production chain. There are still open questions concerning the production technology. For example, why is the seed set sometimes weak,

even after good growth and plenty of pollinators. Each year we have to work harder to ensure the quality of cereal-free production, since there are fewer accepted herbicides for weed control.

What are the future prospects? In the long term, we need improved cultivars in addition to the local accession commonly used in Finland. In this context, international collaboration would be invaluable.

Hopes and observations regarding this special crop? More attention should be paid to crops where high quality and special attention to production is needed, since our climate is too harsh to compete with high yield crops.

The family-run Keskinen Mills has been rolling and processing Finnish buckwheat in central Finland since 1995. The company buys its raw materials from the North Pirkanmaa buckwheat cooperative, which makes contracts with farmers around Finland. Processing and upgrading are completely gluten free. The key products are flours, flakes, crushed and ground seeds, and buckwheat grits, whereas macaronis and fusillis made from wholemeal buckwheat flours are the latest products. These are widely available in a variety of shops belonging to different chains around Finland. Managing Director Markku Vitikainen responded to our questions as follows.

How has the business changed over the years? 'We are lucky that interest in buckwheat and gluten-free products has increased during this period. One of the reasons for this may be the higher number of people suffering from coeliac disease and other allergies based on cereal-rich food. Alternatives to gluten-rich cereals, such as wheat, rye and barley, are therefore needed. In addition, vegetarian diets have become more popular and buckwheat is a good option when reducing meat consumption.'

What are the greatest challenges at the moment? A key challenge in buckwheat production lies in yield variations between years, which impacts on upgrading and the entire value chain. To some extent, uncertainty in the supply of raw materials is making it more difficult to develop new products and plan for the future.'

What are the future prospects? 'We are looking positively to the future, since there are markets for the products we can provide for consumers. We are also considering the development of the business, but this will require new and improved methods of primary production, in order to narrow the yield gap between years.

Hopes and observations regarding this special crop? 'In Finland, we are unable to make the best use of our growth conditions, such as our extremely short growing season with 16–24 hours of daylight during the summer months. In these harsh conditions, we need to identify our own way of farming with these special crops – rather than copying such methods from locations with conditions we can never enjoy.

9. Literature cited and important links

Alenius, T., Mökkonen, T., Lahelma, A. 2013. Early Farming in the Northern Boreal Zone: Reassessing the History of Land Use in Southeastern Finland through High-Resolution Pollen Analysis. Geoarchaeology 28 : 1–24.

Anon1917. Suomen tilastollinen vuosikirja. Annuaire Statisque de Finnlande, Quinzieme Anne 1917. Helsinki, Suomen Senaatin Kirjapaino.

Arjan Ruokaviestintä Oy, https://www.ruokaviestinta.fi/

Eurostat, http://ec.europa.eu/eurostat/data/database

North Pirkanmaa Buckwheat cooperative, http://www.tattariosk.fi/index.php

Berg, I. 2015. Swedish buckwheat production, cultivation, conditions, and impact on biodiversity. Institutionen för växtproduktionsekologi. Självständigt arbete.
Uppsala 2015.

Christensen, C.P. 1989. Buckwheat growing in Denmark. Fagopyrum 9: 66-67.

Fineli, National Food Composition Database in Finland, https://fineli.fi/fineli/fi/index

Finnish Coeliac Society, https://www.keliakialiitto.fi/liitto/in_english/

FutureCrops, New crop species for the future, www.luke.fi/futurecrops

Grotenfelt, G. 1922. Tattarin viljelys. Suomalainen peltokasviviljelys pp. 118-122.

Göthe, C.J., Wieslander, G., Ancker, K., Forsbeck, M., 1893. Buckwheat allergy: health food, an inhalation health risk. Allergy 38(3):155-9.

Hakala, K., Keskitalo, M., Eriksson, C., Pitkänen, T. 2009. Nutrient uptake and biomass accumulation for eleven different field crops. Agricultural and Food Science 18 3-4: 366-387.

Heffler, E., Pizzimenti, S., Badju, I, Guida, G., Rolla, G., 2014. Buckwheat Allergy: An Emerging Clinical Problem in Europe. J. Allergy. Ther. 5:2.

Jantunen, S., Sontag-Strohm, T., Keskitalo, M. 2006. Crumb and flavour characteristic of buckwheat-oat bread. In: Abstracts from the 29th Nordic cereal congress: Nordic cereal interests, June 9-11, 2006, University of Helsinki, Finland/Abstracts edited by Fred Stoddard and Fred Gates. Finnish Association of Cereal Technologists. p. 26-27.

Jordbruksverket, https://jordbruketisiffror.wordpress.com/2015/08/11/odlingen-av-bovete-okar/

Jortikka, M. 1920. Tattarin viljelys, kokeiluja, havaintoja ja tutkimuksia. Maatalous. pp 88-93.

Kawa, J.M., Taylor, C.G., Przybylski, R. 2003. Buckwheat Concentrate Reduces Serum Glucose in Streptozotocin-Diabetic Rats. J. Agric. Food Chem. 51: 7287-7291.

Keskinen Mills, http://www.keskisenmylly.fi/english/index.htm

Keskitalo, M., Jauhiainen, L. 2013. Direct drilling and different seed rates on the accumulation of biomass and nutrients for buckwheat. In: The book of abstracts: 12th international symposium on buckwheat, Lasko, August 21-25, 2013. CIP - Katalozni zapis o publikaciji, Narodna in univerzitetna knjiznica. p. 30.

Keskitalo, M., Ketoja, E., Kontturi, M., Korpela, S. 2008. Alkukukintakauden hyönteispölyttäjät tärkeitä tattarin pähkyläsadolle. In: Maataloustieteen Päivät 2008, 10.-11.1.2008/Toim. Anneli Hopponen. Suomen maataloustieteellisen seuran tiedote 23: 5 p.

Keskitalo, M., Ketoja, E., Kontturi, M., Mäki, M., Pihlava, J-M. Rantamäki, P. Tupasela, T. 2007. Buckwheat - an old crop with new health prospects. In: NJF Seminar 399: Beneficial health substances from berries and minor crops: how to increase their concentration in cultivated species, eliminate losses in processing and enhance dietary use, Piikkiö, Finland, 14-15 March 2007. NJF Report 3 1: 23-26.

Keskitalo, M., Ketoja, E., Kontturi, M., Pihlava, J-M. 2010. Seed yield and soluble carbohydrates of buckwheat (*Fagopyrum esculentum*) varieties in log day growth conditions. In: Advances in buckwheat research: Proceedings of the 11th International Symposium on Buckwheat, July 19-23, 2010, Orel, Russia/Chief Editors: V.I. Zotikov, N.V. Parakhin. All-Russia Research Institute of Legumes and Groat Crops. p. 610-611.

Korhonen, T. 2004. Historiallinen maatalous, Helsingin yliopisto, Humanistinen tiedekunta.

Luke Natural Resources Institute Finland, Statistics database, http://statdb.luke.fi

The Nordic Genetic Resource Centre (NordGen), https://www.nordgen.org/en/

Peltonen-Sainio, P. 2012. Crop production in a northern climate. In Proceedings of a Joint FAO/OECD Workshop / Edited by Alexandre Meybeck, Jussi Lankoski, Suzanne Redfern, Nadine Azzu and Vincent Gitz, p 183-216.

PROTEIN2FOOD http://www.protein2food.eu/research/

Rokka, S., Ketoja, E., Järvenpää, E., Tahvonen, R. 2013. The glycaemic and C-peptice responses of foods rich in dietary fibre from oat, buckwheat and lingonberry. International Journal of Food Science and Nutrition 64 (5): 528 – 534.

ScenoProt, Novel protein sources for food security, www.luke.fi/scenoprot

Statistic Norway, https://www.ssb.no/en/sok?sok=piano

Vestberg, M., Palojärvi, A., Pitkänen, T., Kaipainen, S., Puolakka,E., Keskitalo, M. 2012. Neutral lipid fatty acid analysis is a sensitive marker for quantitative estimation of arbuscular mycorrhizal fungi in agricultural soil with crops of different mycotrophy. Agricultural and Food Science 21(1): 12-27.

Virtasalmen Viljatuote Oy, https://www.viljatuote.net/

Wermlands Bovete, Råglanda gård, http://www.wermlands-bovete.se/

Wieslander, G. 1995. Allergy to buckwheat. Current Advances in Buckwheat Research (1995): 951 – 955.

Wieslander, G., Fabjan, N., Vogrinčič, M., Kreft, I., Janson, C., Spetz-Nyström, U., Vombergar, B., Tagesson, C., Leanderson, P. Norbäck, D. 2012. Eating buckwheat cookies is associated with the

reduction in serum levels of myeloperoxidase and cholesterol: a double blind crossover study in day-care centre staffs. Tohoku J. Exp. Med. 225 (2):123 – 130.

Zou, L., Santanen, A., Tein, B. Stoddard, F.L., Mäkelä P.S.A . 2014. Interference potential of buckwheat, faba bean, oilseed hemp, vetch, white lupine and caraway to control couch grass weed. Allelopathy Journal 33 (2): 227-236.

Buckwheat in France

1. Buckwheat's origin

Buckwheat (*Fagopyrum esculentum*) is pseudo-cereal of the Polygonaceae family (thus related to sorrel, knotweed or rhubarb). Its ancestor (*Fagropyrum cymosum)* originates from south-western provinces of China. After a domestication process dated around 3000 BCE, this old East Asian crop spread to Far and Middle East. Its cultivation is documented in Europe since the end of the XVth century, after seeds were brought back from crusades. Buckwheat crossed the Atlantic with European migrants and thus extended its influence to North America.

Its etymology evokes the resemblance of Buckwheat's grain with the seeds of the beech tree (bok in Germanic languages) and its similarity with wheat regarding the use.

2. Buckwheat limits and benefits

2.1. Buckwheat limits.

After an apogee in Europe in the mid-nineteenth century, buckwheat cultivation dropped sharply in the sixties with the generalization of nitrogen fertilizers that increased the profitability of other crops.

Because of its sensitivity to lodging - partly due to its hollow stem - , buckwheat doesn't tolerate high nitrogen residues. It is also vulnerable to both frost at early stages - flowers abort under 3°C - and temperature variations in July and August.

Randomness of yields - highly dependent on weather conditions but incompletely understood - is a major challenge for farmers, as they can vary between 0,2 and 3,5 tonnes per hectare. On the other hand, the gradual ripening of grains makes harvesting rather delicate and brings impurities into the crop.

An effective drying is required within 48 hours to reduce grain's humidity from 25% to less than 15%. Datura and Tartarian Buckwheat are the main competitors, the post-harvest sorting of the latter requires sophisticated technological means.
Lastly, buckwheat's complex mechanisms for sexual reproduction and the smallness of areas involved are an obstacle for modern private selection. Public breeding work on buckwheat stopped in 1989 so that research efforts focused on a few species of economic importance.

The role of the French institute of agronomic research (INRA) was subsequently limited to maintaining a few local varieties genetic resources conservation. Millers encouraged the use of varieties with coarse grains and cooperatives initiated a tendency to buy the crops only if the farmer has purchased the seed. Ever since, many local varieties disappeared and a single one - called "La Harpe", obtained by mass selection in 1962 - occupies the entire French market of buckwheat seeds.
This erosion of biodiversity compromises the adaptive potential of the species and causes risks for diseases development.

The current niche situation should not hide buckwheat's potential for development in Europe. Since the 2000s, buckwheat cultivated areas more than quadrupled. This new dynamism can be explained by several factors: requirements for input reduction and encouragement for diversification - along with a premium on catch crops in France -, a search for taste and nutritional qualities, the valorisation of local products. Often in a collective approach, some farmers are looking for local varieties consistent with their practices, adapted to specific environment and uses.

2.2 Buckwheat benefits

Relative abandonment of buckwheat occurred in spite of many qualities.
Suitable for low-fertile, acidic but well-drained soils, buckwheat can be grown as main, back or substitute crop, for its grain-like seeds or as a cover crop - be it for green manure, as a melliferous flowery cover or to house game, for pasture or silage.

Its itinerary requires zero input and little intervention: "you sow, you harvest" as one says. Thanks to a superficial root system, it establishes quickly and bears shallow soil. In the explored horizon, certain forms of phosphorus are made available for other crops. It has a beneficial effect on succeeding potato crops, significantly reducing populations of bacteria causing Verticillium. It is often used at the head of rotation for its ability to reduce weed pressure. Its cropping cycle is time-compatible with winter cereals, it can also remedy to a crop implantation failure.

Some varieties are appropriated for high latitudes or northern areas; all have a vigorous health and a strong weed competitiveness, attributed to their covering power and allelopathic effects. Regarding global health of the farm-system, introducing a Polygonaceae - a family little cultivated today - in a rotation is a way of breaking the reproductive cycles of pests and diseases.

Buckwheat has a short vegetative cycle but a long blooming period - at a time when many other plants no longer produce nectar - that confers it good melliferous qualities.

3. Buckwheat qualities and uses

In many mountainous areas, poor or acidic lands, buckwheat is an important subsistence crop in addition to feeding livestock. Worldwide, most of the production is used near the place of production.

3.1 Buckwheat in gastronomy

Flour and shelled grains are the basis of a wide variety of food including Slav "kasha", Russian "blinis", Japanese "soba", Italian" pizzoccheri", Breton "galettes"...

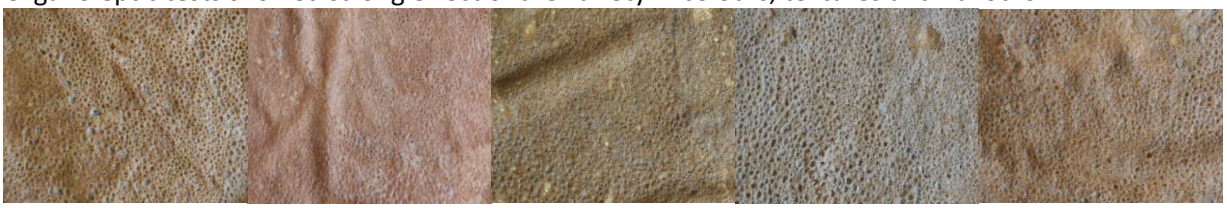
Appreciated for its slightly bitter hazelnut taste, buckwheat is particularly popular in Japan, Corea, China and Russia. In Europe, it has been forgotten in the West but remains one of the favourite dishes in Eastern and Northern parts of the continent, where it is mainly eaten shelled and roasted (kasha) or boiled. Buckwheat grains can be eaten whole, crushed, or transformed into flour of different grinds used in pancakes, breads and noodles (soba). In India, some recipes includes the young shoots and leaves of the plant.

In Brittany, where buckwheat is firmly rooted in many traditions, some cooks are attached to a "crêpe" - or "galette", the name is not unanimous - strictly made of buckwheat flour, water and salt, some others may add eggs and oil.
This panorama should not forget beverages - since herbal teas, bear and whiskey can be made from buckwheat - and honey - amber to dark brown, with intense flavours, that crystallizes little and remains quite supple.

3.2 Buckwheat's taste

The diversity of tastes finds for sure its echo in buckwheat's cultivated diversity, but also in a wide range of contexts, practices and uses.

Organoleptic tests showed strong effect of the variety in colours, textures and flavours.



Lileja Spacinska Billy Petit Gris La Harpe

Influence of the variety on “galette” aspect
The composition of nutrients and aromas roots in the interactions between the effects of variety, pedoclimatic conditions, year and cultural practices. It is influenced afterwards by the methods of harvesting, drying, milling, storing and processing.

For instance, mowing and drying on the field, mechanic harvesting and use of a dryer, manual harvesting and sun drying are three methods that underlie different transfers of assimilates to the grain.

Then, fineness of the flour, crushing of the pods, fragmentation of the teguments won't be the same with a rolling mill or a stone grinding mill and will vary according their settings. The aromatic compounds that plays a major role in the organoleptic qualities of buckwheat seed are predominantly located in its peripheral parts. In its turn, freshness of flour determine its rate of oxidation, influencing lipids and minerals content.

3.3 Buckwheat and health

On top of the absence of gluten that makes it suitable for people with celiac affliction, buckwheat is notorious for its health benefits

Buckwheat proteins contain all the essential amino acids in a balanced proportion and have a high biological value. Their qualities have been associated with a cholesterol-regulating activity (Kayashita J, et al.). An alimentation rich in soluble fibres - present in large proportion in buckwheat - contribute to normalizing blood levels of cholesterol, glucose and insulin. Buckwheat grain is peculiarly rich in micro-nutrients of interest: antioxidants (characteristic flavonoids like rutine, phenolic acids), vitamins, minerals. The total content of buckwheat antioxidant compounds is influenced by several factors, such as variety and cultivation conditions. Certainly because of the synergy between fibers, antioxidants, vitamins and minerals contained in the bran and germ, the consumption of whole grains is linked to a lower risk of developing cardiovascular diseases, diabetes, obesity and some cancers (Zielinski H et al.). Lastly, prebiotic effects - stimulation of growth and activity of good intestinal bacteria - have been found on animals (Préstamo G. et al.).

3.4 Other uses of buckwheat

Hulls can be used as filling for upholstered goods - pillows' padding for example - or as an organic mulch.

4. Buckwheat and environment

Qualities of interactions in a cultivated ecosystem - and more largely within a food system and its diverse functions - are a key issue for sustainability.

4.1. Interactions with Tartarian buckwheat

Tartarian buckwheat is another species of the gender Fagopyrum. It competes Common buckwheat on the field because of its autogamy, cold resistance and exuberance of vegetation. By the way, it tends to settle in farm seed lots, in a growing proportion year-on-year. Its exclusion requires an optical sorter: an heavy investment at farm scale. On the other hand, it shows a greater rutin contend and is known to give a characteristic bitter taste.

To what extend can it be tolerated without altering the taste of end products? Does is presence have something to do with the peculiar taste of local varieties?

Tasting sessions including it in different doses revealed that Tartarian buckwheat integration in small proportions - lower than 20% of total flour - would be neutral, or even appreciated as a typical trait. Technically, the preparation of galettes with a high content (50% and more) of Tartarian buckwheat

does not raise any peculiar difficulty. However, they were judged too bitter and their yellowish colour little appetizing.

100% sarrasin commun 0% sarrasin de tartarie	90% sarrasin commun 10% sarrasin de tartarie	80% sarrasin commun 20% sarrasin de tartarie	50% sarrasin commun 50% sarrasin de tartarie	0% sarrasin commun 100% sarrasin de tartarie

Five kinds of galettes proposed to the test panel

4.2 Interactions with bees and honey production

Buckwheat's melliferous qualities are often evoked, thanks to a long flowering that occurs after the one of many other major crops. However, in the fields, foraging and honey production are random and the factors of their success have not been elucidated. Is "la Harpe" less visited, as one can listen sometimes? If variety plays a role, it is not the only parameter to take into account. Melliferous qualities of a buckwheat field depend on nectar production, itself linked to the pedoclimatic conditions (temperature, humidity of the air and soil, humus richness, acidic nature, clay grade) and cultural practices (mineral fertilization).

5. Managing Buckwheat diversity on the field

5.1 Exploring diversity

From a research perspective, a first step to promote buckwheat's renewal was to explore diversity within available populations, either marketed, local, or from genetic resources centres. Due to the self-incompatibility and heterostyly of buckwheat, all varieties are populations (a group of hybrids created at each generation by random crosses). According morphological and genetic criteria, varieties currently cultivated in France differ little from one another. The greatest diversity can be found at intra-varietal level.

Throughout evolutionary history, seed exchanges and cross-pollination of this allogamous and entomophilous specie underlay frequent gene flows between populations, creating country-wide metapopulation structures where interconnected subpopulations are subject to local colonization and replacements.

5.2 Agronomy of buckwheat

In the field, one can recognize buckwheat by its branched reddish stems, large heart-shaped leaves, and clustered inflorescences.

Even if buckwheat is little influenced by its precedent, it is preferable to opt for a crop with low nitrogen residues such as cereals. Grasslands and legumes should be avoided. Regarding tillage, a light ploughing - not compulsory - is sufficient, then the soil must be refined and loosed on the surface. Heavy, humid and rich soils are not recommended. At the time when buckwheat is sown, it is possible to use until four stale seedbeds.

Buckwheat is generally sown from mid-May to late June, 2-3 cm deep with a 15-20 cm spacing between rows. Depending on the variety, sowing density ranges between 20 and 50 kg per hectare. A compromise is to be made between the foliar development, favourable to fruiting, and the density of cover, factor of competitiveness against weeds.

Buckwheat grows as long as conditions are favourable, without requiring any intervention. Weeding would be challenging because buckwheat stems are brittle. If buckwheat implantation is poor in comparison with weeds, it is possible to hoe at the start of vegetation.

Time for harvesting generally comes four months after sowing, when ¾ of the grains are mature (hard and gray-brownish) to limit seed shedding, on a sunny day, after a frost that dried stems and leaves.

5.3 Breeding strategies

Once diversity, quality and uses have been characterized for buckwheat, how can this knowledge be translated into a coherent array of selection strategies?

Within participative research projects, two methods of selection based on the same five initial varieties, are being compared: (1) mixtures provided by spontaneous crossings within a “dynamic population” and (2) Cross Composite Populations (CCP), created by hand crossing the 5 different populations. Trials are managed in UK, France and Cyprus.

Contrasted effects on phenotypic and genetic diversity of buckwheat have been identified, and the respective interest of the two strategies have to be considered for on-farm selection. Thus, the mixture based on natural open pollination within the five populations did not present an intermediate phenotype between his original parents, but has behaved like a new population with an intrinsic diversity of the same level as their parents.

6. Previous projects: « Sarrasin de Pays » and the organization of participatory research

"Sarrasin de Pays" was a participatory research project aiming to broaden the cultivated diversity of buckwheat, to improve its agronomic performance, ecosystem services, and quality of products for organic and peasant farming. It was funded by the Fondation de France in response to call for projects in 2013: "Ecosystems, Agricultures, Food". The dynamic at work in "Sarrasin de Pays" is carried out by the team "Crop Biodiversity and Participatory Research (BCRP)" (of INRA Bagap unit in Rennes), in partnership with four regional groups: the Regional Federation of Agrobiologists of Brittany (FRAB), the association for peasant seeds Triptolème, the Agrobiological Platform of Brittany (PAIS) and the Economic Interest Group for breeding in Brittany.

By gathering farmers, millers, processors, beekeepers and researchers, ”Sarrasin de pays” emerged at the crossroads of several actors' preoccupations and skills: relocation and securing of production,

promotion of local products, managing the complex reproductive system and good use of melliferous capacities.

7. Ongoing projects: « Renaissance of Minor Cereals »

Started in 2017, "Renaissance of Minor Cereals" (“Rennaissance des céréales mineures”) wants to continue the dynamic initiated by “Sarrasin de Pays”, and to extend it to other so-called minor cereals: spelt, rye, einkorn and rivet wheat. Priority objectives are to make an inventory of available varieties and to multiply peasant varieties. Agronomic trials will be set up to study these varieties and to tests them in mixtures or associations. Transformation trials and sensory analyzes will test their abilities in bread-making, milling and production of pasta, cakes and biscuits. After these stages, the seeds may be disseminated more widely - with the associated knowledge and practices - within the peasant seed networks. To inventory, multiply, evaluate and disseminate, the initiative relies on the formation of local groups in Brittany, Normandy and Pays de la Loire.

8.Recipe

Buckwheat galettes

Ingredients for ten to fifteen galettes:
- 300 g of buckwheat flour
- 75cl of water
- 10g of salt
- 1 egg (optional)

Two hours before cooking, or even the day before, prepare the dough by mixing the ingredients. Pour a ladle of the preparation into a hot and oiled pan on a bilge. A rake can be useful to spread the dough. Cook on one or two sides, but not too long to prevent the galettes from being brittle. Keep the galettes covered, on a plate, while waiting for the filling. In Brittany, galettes are commonly filled with ham, cheese, egg or sausage. Mushrooms, leek, spinach, fit also well. Serve hot.

9.Literature cited

Kayashita J, Shimaoka I, et al. Consumption of buckwheat protein lowers plasma cholesterol and raises fecal neutral sterols in cholesterol-Fed rats because of its low digestibility. J Nutr 1997

Zielinski H, Kozlowska H. Antioxidant activity and total phenolics in selected cereal grains and their different morphological fractions. J Agric Food Chem 2000 June 48(6): 2008-16.

Préstamo G, Pedrazuela A, *et al*. Role of buckwheat diet on rats as prebiotic and healthy food. Nutrition Research 2003,23: 803-14.

Carrots – neglected genetic resources: an overview from Switzerland

Philipp Holzherr
ProSpecieRara PSR
Philipp Holzherr
Bereichsleiter Garten-, Acker- und Zierpflanzen
Unter Brüglingen 6
4052 Basel
philipp.holzherr@prospecierara.ch

Image references: If not otherwise referenced, all images ©ProSpecieRara

Schweizerische Stiftung
für die kulturhistorische
und genetische Vielfalt
von Pflanzen und Tieren

1. State of art of neglected genetic resources of carrots in Switzerland

In Switzerland the task of collecting and conserving neglected vegetables varieties is mainly done by the governmental Swiss Gene Bank of Agroscope[8] as well as by the NGO foundation ProSpecieRara. In total they currently conserve **35 old carrot varieties**. This number looks small in comparison to other crops, e.g. tomatoes with currently 184 varieties in conservation. Especially as carrots have a deep and long history of cultivation in Europe. We estimate the main reason for this being the laborious seed propagation of carrots.

As a biannual crop, carrots have to be cultivated an extra year for seed propagation. Moreover carrots are strictly reproduced by allogamy and are sensible to inbreeding, and therefore should be propagated with at least 60 individuals in each generation. This prevents private gardeners without a lot of resources (that is land area and time) from multiplying their own carrot seeds, or if not, varieties multiplied with less individuals often suffer from inbreeding over the years, which may end up in a total loss of seed fertility. A third difficulty rises by abundant wild carrots in Switzerland, which can cross with cultivated carrots and therefore necessitate pollination barriers. These reasons also make the crop hard for farmers to propagate on their own, as well as some reasons make maintaining a big diversity of varieties unappealing for a given seed company.

ProSpecieRara not only estimates that a lot of varieties have come and gone over the centuries without remaining at least in some places, but we also encountered over the last 30 years various examples of lost, mixed or inbred carrot varieties, or ones of a low growing quality.

Carrots are therefore a typical crop, where the current genetic diversity is strongly connected to the activities of seed commerce. (Other examples of hard-to-multiply-privately-vegetables being beets, celery and crops of the *Brassica* group like kale, turnip.) Not only used the carrot varieties in older times not to be multiplied by non-commercials because of the mentioned reasons, but nowadays they often couldn't be propagated even if organisations as ProSpecieRara or the Swiss Gene Bank could provide the necessary resources. The reason is mainly because of the modern breeding strategies that pursue hybrid varieties or other not-open-pollinated varieties.

A lot of the genetic diversity of carrots is therefore in the hands of the breeders and seed companies. Luckily there are still some breeders and seed traders providing open-pollinated varieties, mainly aiming at the organic market or at the use in house gardens. Still, the market is dominated by hybrid varieties. As of 1.5.2017 there are 535 entries of carrots on the EU database of registered plant varieties[9], and excluding synonym entries there are in total **472 different registered carrot varieties**. Of these **297 varieties are declared as hybrids.**

For the Swiss market there are no further officially registered carrot varieties, with exception of two so called niche varieties for a limited commercial volume. An overview of the effectively used carrots in Switzerland is best given by the promoted varieties by seed traders. For this literature overview the offers of the most important seed traders have been analysed, if catalogues or webshops were available. Generally the vegetable seed market consists of two different customers, professional

[8] https://www.bdn.ch/organisations/acw/

[9] http://ec.europa.eu/food/plant/plant_propagation_material/plant_variety_catalogues_databases/search/public/index.cfm

vegetable growers and hobby gardeners. Although both will profit up to a certain degree of all available varieties, the way of how seed shops make their offers available gives good clues about their target group. Given that, we estimate about **39 carrot varieties are used in vegetable production**, of which 31 varieties are declared as hybrids. **In total there are seeds of about 73 carrot varieties available with Swiss seed providers**, which means about 34 varieties are mainly used in hobby gardens. Of course nowadays the global seed market is always available, so the latter number has to be taken with a grain of salt. However we estimate the number of carrots used in vegetable production as realistic.

Near forty carrot varieties to be met in daily use sounds amazing. However the felt diversity is much smaller, as a lot of these carrots are of the same type, which could be described as orange, cylindrical and is often referred to as the «Nantes type». Other orange commercial varieties are of a more conical shape, where the root narrows to the tip («Flakkeer type», «Berlikumer type»), or they are of shorter length for selling in bunches («Amsterdam type»). Only with the latter type consumers could sense a certain diversity, if they are aware of the differences in length, as this type otherwise is rather similar to the «Nantes type». However carrots of the «Flakkeer-» and «Berlikumer type» will often come in processed form, that is cut and deep frozen, to consumers who therefore can't be aware of the carrot's different shapes and lengths.

It is difficult to estimate the share of production volume of these carrot types, but we think it's safe to say the «Nantes type» makes out over 80% of the Swiss carrot market, which is currently estimated with **60'400 t production volume** (fresh- and storage carrots). By the way carrots make out a big part of vegetables per head consumption compared with other species (carrots 8.5 kg, tomatoes round and cherry 10.47 kg, iceberg salad 4.65 kg, peppers 4.4 kg) [10].

There are other carrots of a more different shape and calibre, and of different colours. They are mainly sold via direct selling on market stalls or in farm shops. However one yellow carrot type («Pfälzer») is essentially known as always having been represented in some quantities in supermarkets or in retail. Since about 2002, and 2005 respectively two purple varieties can be found as niche products in supermarkets ('Purple Haze F1', 'Deep Purple F1' respectively). And since 2003 a white, strongly conic landrace carrot ('Küttiger') as well as a variety of the yellow «Pfälzer» type ('Jaune longue du Doubs') is sold in supermarkets with the aid of the ProSpecieRara label. **So it could be said, carrot diversity started to come back on people's mind since the mid 2000's.**

Interestingly another special carrot type has been used since decades, but comes not on people's mind if asked. The reason being the round, small shaped carrot of the «Paris type» is mainly used for tinned food production, and is seldom seen on fresh markets. But after all 1900 t of Swiss grown carrots are yearly processed for deep frozen and tinned products, so between the «Flakkeer» and the «Berlikumer type» this variety type could occur in some amount in daily use.

Still, diverse and in colour or shape from the «Nantes type» clearly differing carrots can be viewed as small niche products. Open-pollinated (non-hybrid) carrot varieties even make for a more rare case, e.g. the two ProSpecieRara-carrots in the supermarket Coop together make out an average production of 40t, which is < 0.1% of the Swiss carrot production volume.[11]

[10] http://www.gemuese.ch/Ressourcen/PDF/Politik/CHGemuesebau_BROSCHURE_LID.PDF

[11] At this point, we take the liberty to leave the question open, if an estimated quantity of more than thirty different varieties of one or two carrot types does count for a healthy abundance of diversity in a scientific

2. Description of the carrot types

The following types and varieties should represent the existing carrot varieties in Switzerland. Each type is presented by one example variety; in some cases it's the only existing of its type. For reference we present first the most common carrots before diving into the diversity of less often seen carrot types:

«Nantes type», common carrot
The common carrot type is of cylindrical shape and of orange colour from skin to heart. The root is growing in the soil in total, avoiding green heads. The leaf base is set on a concave head in order to allow the cut of leafs without leaving stem rests. At the end the root narrows rather fast from a cylinder to the blunt tip, from which the main root only goes on in a very small diameter and is visually neglectable. From quality requirements, the following numbers can be derived for the common varieties: The root is accepted with a weight of 40-200 g and a maximal length of 24 cm (size class 1), root calibre should be homogeneous at least in the same package[12]. The root grows in a straight way. Common varieties fulfil these commercial demands, and generate good and early yields.

Common commercial varieties have furthermore some important inner values, which can differ from variety to variety. In some varieties there can be found a high Brix-content of 12-15%, which correlates to a high degree (about 70%) with a sweet taste, but others wouldn't offer such. Generally breeding efforts on taste were scarce.[13] Crispness is probably more a by-product of good agronomic properties, although a well-received one with consumers, than an effective breeding goal. This trait is found in a lot of common carrots. It correlates strongly with a fast growing period and a low dry matter content.[14] Other properties are resistances to diseases and pests, as e.g. *Alternaria dauci*, although recommended varieties for non-organic production often wouldn't need to offer such, as disease and pest problems easily can be treated with pesticides.

Carrots of the «Nantes types» are widely used for fresh- and storage carrots in the daily use.

view. On one hand, modern (carrot) varieties for commercial use are naturally all very close, as intrinsically only upgraded-best-of-the-best-varieties compared to existing ones have a chance on the market, and as product specifications for production, trade and selling range on a high level. There is an importance in breeding slightly more resistant, more productive varieties on a top level, therefore such varieties should of course be respected as true achievements and in the view of producers and experts can be viewed as contribution to diversity even though ordinary consumers wouldn't see a difference between such varieties.
On the other hand, it might be assumed that the genetic difference between varieties of the same carrot type would be much smaller than between different types of visually different shape and colour. (Unfortunately we are not aware of studies on this topic.) Anyway, in our view a (carrot) diversity that cannot be sensed, doesn't make aware to the topic of diversity, and doesn't encourage to a diverse use of carrots in the kitchen.

[12] «Schweizerische Qualitätsnormen für Gemüse», by swisscofel & VSGP: http://www.qualiservice.ch/uploads/normen2017/de/Karotte.pdf
[13] personal message from Amadeus Zschunke, director of the breeding company Sativa Rheinau AG , 2017
[14] personal message from Amadeus Zschunke, director of the breeding company Sativa Rheinau AG , 2017

Example variety of the «Nantes type»: 'Bolero F1', commonly used in organic agriculture due to good tolerance against *Alternaria dauci.* Good taste. (Image: poetschke.de)

«Amsterdam type»

These carrots grow shorter roots than the «Nantes type» and they retain a pointy tip also when ripe. They can be harvested early. Optimal for carrots in bunches on fresh markets.

Example variety of the «Amsterdam type»: 'Mokum F1' (Image: aiko-samen.de)

«Berlikumer type»

This type brings out larger carrots than the «Nantes type». The carrots have a longer growing period (140-150 days) and all carrots of this type are grown for storage and industrial use.[15] They are of an intense colour and provide good taste properties in aroma and sweetness.

[15] personal message from Amadeus Zschunke, director of the breeding company Sativa Rheinau AG , 2017

Example variety of the «Berlikumer type»: 'Berlin F1' (Image: Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie[16])

«Flakkeer type»
Carrots of this type are mostly used for industrial use. They provide strong yields and a homogenously coloured flesh. They differ from the «Nantes type» in their slightly conical shape, which means a steadily narrowed long root.


Example variety of the «Flakkeer type»: 'Komarno F1', with an intense and homogenous colour, and high dry matter content. (Image: bejosamen.de)

«Chantenay type»
These carrots build short and conical roots with a large diameter at the head. There are variants of this orange variety, be it with a touch of red in the core, or on the skin. Sometimes the typical, strong conical shape is generally referenced to as «Chantenay type», what would make the varieties 'Küttiger' and 'Gniff' belonging to this type, but "off-colour".

[16] «Versuche im deutschen Gartenbau 2014», Gerald Lattauschke, Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie, Dresden, 2014, www.landwirtschaft.sachsen.de/landwirtschaft/download/Moehren_Krinkel_2014.pdf

Example variety of the «Chantenay type»: ‘Chantenay à Coeur rouge 2’ (Image: Sativa Rheinau AG)

«Pfälzer type»

To this type generally all yellow coloured varieties can be counted. Their shape is similar to the shape of the «Nantes-» and the «Flakkeer-type», respectively, the shape can also lie in-between these two. Breeding initiatives on this type were low, so a certain heterogeneity between varieties of this type, as well as in the varieties’ populations themself can be detected even visually. E.g. in the population of ‘Jaune longue du Doubs’ two slightly different shades of yellow can be found. Also the varieties show some weaknesses that commonly used carrots have bred away, like abundance of green heads, and susceptibility to diseases.

Example variety of the «Pfälzer type»: ‘Jaune longue du Doubs’, one of the first products with the ProSpecieRara-label, which could be found in the supermarket Coop back in 2003, up to the current days. The variety build roots similar to the «Flakkeer type», but with a rather high abundance of green heads, and of course the yellow colour. This landrace was collected by the Swiss Gene Bank and has been retrieved from there to revive its production. Sativa Rheinau has worked on several properties, and could e.g. enhance Brix-content from originally 9% to 10-11%.[17]

«Paris type»

[17] personal message from Amadeus Zschunke, director of the breeding company Sativa Rheinau AG, 2017

Small, round carrots, used for tin food, typically in combination with peas, sometimes also for fresh markets in bunches.

Example variety of the «Paris type»: 'Pariser Markt-Original', the original type defining variety. The seed producer «Zollinger Samen» is selling this variety under the additional name «Pariser Herzchen», which could be translated with «Little hearts of Paris». (Image: zollinger.bio)

«Purple type»

We propose this also as a type definition, as there exist several very similar varieties, which can be found steadily on the market since the promotion of some hybrid varieties for professional production in the early to mid 2000's by the Dutch breeder's company «Bejo Zaden». These carrots are of an orange base colour, and the flesh is covered with an intense purple from the skin through to the heart in some cases, and from the skin into the carrot halfway through in other cases. The shape ranges from similar to the «Nantes type», to closer to the «Flakkeer type» .

Example variety of the «Purple type»: 'Purple Haze F1', the most abundant purple carrot on fresh markets, in farm shops, in retail and in supermarkets. (Image: bio-baumann.ch)

'Küttiger' and 'Blanche des Vosges'

These yellow-white, conical carrots represent a very old type, which probably has been used since centuries, although in recent decades for the human diet as well as for animal fodder. The carrots can reach large sizes and were used traditionally conserved in pickled manner for the winter diet.

Example variety: 'Küttiger Rüebli', a traditional landrace that has been guarded by farmer's women of the village Küttigen since decades. Their association is called «Küttiger Landfrauen» and up to this day they are growing carrots and seeds of their variety yearly. Remaining carrots will be sold on the traditional market in the neighbouring city of Aarau, so called «Aarauer Rüeblimärt» (carrots market of Aarau) in mid October. The traditional cultivation would be sowing the carrots into the short-before-harvested barley fields for a late autumn harvest of carrots. Since 20 years seed producers as Sativa Rheinau AG have multiplied the carrot. Sativa was able to enhance Brix-content and agronomic qualities for professional vegetable production, although compared to some mainstream carrots of the «Nantes type» the 'Küttiger's' taste is still very «rustic», that is, an only moderate sweetness (Brix-content has been moved up to 10-11%, from the original value of 9%) and a strong earthy flavour of herbs[18]. The carrot 'Küttiger Rüebli' is one of the first products with the ProSpecieRara-label, which could be found in the supermarket Coop back in 2003, up to the current days. (Image: ProSpecieRara)

'Gniff'

The 'Gniff' carrot is in a lot of properties much different from the above mentioned «Purple type». It reminds of the 'Küttiger' variety, but the purple colour makes it really outstanding. Different from other purple varieties, 'Gniff' has a white base colour. The conical shape is of the «Chantenay type», carrots are rather short. Taste properties are reminiscent of low breeding efforts and typical for landraces, with low Brix-content (originally around 9%, selection efforts achieved up to 10-11% nowadays[19]) but a strong herbal flavour and a long growing period (130-140 days). 'Gniff' was abundant as a landrace in several places of the Swiss canton Tessin, south of the Alps. Up to the late 2000's it was only conserved by farmers and gardeners, and due to probably very high degrees of inbreeding all the accessions that ProSpecieRara found, were severely suffering from fertility and growing problems. One accession originating from the village Savosa could be saved by the work of the breeder firm Sativa Rheinau AG, and can be viewed as viable nowadays. Still, as the landrace seemed strongly endangered in the late 2000's, ProSpecieRara and Sativa started a breeding project in 2012 to cross in new genetic variability from carrots of the «Purple type», and to reselect resulting lines of the old variety type, aiming at the enhancement of agronomic qualities.

[18] personal message from Amadeus Zschunke, director of the breeding company Sativa Rheinau AG, 2017
[19] personal message from Amadeus Zschunke, director of the breeding company Sativa Rheinau AG, 2017

Image: Franca Pedrazzetti & Beat Brechbühl

'White Satin F1' and 'Blanche à collet vert'

These carrots remind of the «Pfälzer type» as a coloured variant of a rather pure white. The abundance of green heads can have some negative impacts of the carrot's appeal, as contrast green to white is more striking compared to contrast to other base colours. This carrot type can be found in some niche production for market stalls. But efforts for this (compared to Küttiger) possibly more advanced white carrot of a less conical shape were rather humble, as e.g. in ProSpecieRara assortments 'Küttiger Rüebli' is the chosen whitish carrot with an impressing story of origin.

Example variety: 'White Satin F1', another special coloured variety resulting from the breeding efforts of the Dutch company «Bejo Zaden». (Image: bio-baumann.ch)

Other carrot types

There are still other carrot types that can be found in the specialties seed assortments, but we assume these not of great importance for the Swiss production. Interestingly in other countries such varieties could be very important, as the example of the «Imperator type» shows, a very long, conical carrot. This carrot is of relevance, for example in the carrot production of northern Germany, but it is seldom used in Switzerland.[20]

The origin of carrots

[20] personal message from Martin Koller, FiBL , 2017

Wild carrots (*Daucus carota* ssp. *carota*) are abundant in whole Europe. The first time cultivation of the crop is not clear, as prehistoric excavation results of carrots are only proof for the usage of the plant, which could be very well originate in wild harvesting. In early records it is often not clear, if the mentioned root vegetables are carrots or parsnips. The first proof of carrot cultivation is given by Albertus Magnus in the 13th Century. He describes «daucus» explicitly by the typical carrot flower. However it is not clear from Magnus whether the carrot is used as a medicine or as food. In herbal books of the 16th and 17th Century there are more and more hints about the culinary use of carrots.
The wild carrots of Europe build white roots. The nowadays omnipresent orange carrot has probably been bred in the Netherlands. The first proof of orange carrots can be seen on Dutch paintings of the late 17th Century. From the Netherlands the orange carrots spread soon into other European countries, where they superseded old varieties.

Modern carrots of Europe originate mostly in the breeding efforts of French, Dutch and English breeders, which in the 20th Century developed intensely the carrot varieties that came on the market in the 19th Century. During the last decades the breeding efforts where entirely on orange coloured hybrid varieties. Only recently the awareness for other colours and for open pollinated varieties has risen again.[21]

In the following paragraphs from 3. to 7. we won't discuss the carrot's cultivation as a whole, but we'll try to find some aspects concerning older and less abundant varieties compared to modern carrots. Although each variety has its own merits as well as its problems, we try to summarize the discussion for all the less used varieties as a group and compare it to the «Nantes type» as the most common carrot. This group is referred to as **«carrot diversity»** and could be described as containing all the carrots of different shape, and/or of different colour, and/or of low breeding efforts. Sometimes these carrots would be typical landraces, often they would grow slower than modern carrots and/or deliver smaller yields.

2. Relationship between carrot diversity and the environment

Compared to the common carrot production, we don't expect many differing aspects concerning environmental impacts of older varieties. We are not aware of any existing research on this specific topic. We estimate, that the somewhat smaller yields, the longer growing period and a higher susceptibility to diseases, probably result in a somewhat inferior life cycle assessment (LCA). But as the emission effects (in kg CO2-eq/kg) of carrot's production[22] and consumption[23] generally figure on a moderate level, we assess the effects of variety selection to be of a rather sophisticated nature. Other factors should be more relevant for LCAs, as e.g. energy for transportation, storage and farm machinery use. By the way in the context of the DIVERSIFOOD project, if a LCA-discussion of different carrot varieties should be of interest, we want to point the fact out, that some LCA's include impact on local wild plant diversity, but it is never covered the long-time values of a high, or low cultivated crop diversity, respectively.

[21] «Das Lexikon alter Gemüsesorten», M. Serena, M. Suanjak, F. Pedrazzetti, B. Brechbühl, AT Verlag, Aarau und München, 2014
[22] http://wikifootprints.org/en/Vegetables
[23] «Ökobilanzierung Früchte- und Gemüseproduktion – eine Entscheidungsunterstützung für ökologisches Einkaufen», A. Zhiyenbek, C. Beretta, F. Stoessel, S. Hellweg, ETH Zürich Institut für Umweltingenieurwissenschaften, 2016, online available: https://assets.wwf.ch/downloads/2017_01_oekobilanz_fruechte_und_gemuese_d_1.pdf

3. Seed management of carrot diversity

The main difference of seed propagation originates in the breeding method. Whereas **hybrid-varieties (F1)** make out almost all of the professional carrot production for the main markets, a lot of varieties of the non-«Nantes-type»-carrots are propagated **open-pollinated**. As mentioned in paragraph 1) this leads to a total dependence on breeder companies concerning the availability and conservation of F1-varieties, and the current gene pool of the agronomical best varieties, respectively. However any seed propagator can maintain open pollinated varieties.

As open-pollinated carrots mainly are offered to hobby gardeners, there is no special **seed quality** available. Exceptions can be found for varieties that established in a niche vegetable production, which are sold in certain quantities. E.g. the seed company Sativa Rheinau AG offers the old varieties 'Küttiger Rüebli' and 'Jaune longue du Doubs' in form of calibrated precision seed, as these varieties are demanded by a certain amount of producers. Precision seed is offered in three calibration classes: 1.4 – 1.6 / 1.6 -1.8 / 1.8 – 2.0[24]

Only a few private gardeners generally do **variety conservation and seed propagation** of carrots. Actually the necessary know-how is not so difficult to acquire. As seed plant selection of the biannual crop is done before the flowering by choosing the best carrots, the genetic quality of the resulting seed can be well anticipated. However the needed resources of land, storage possibilities, cross protection facilities, and ideally some technical equipment to measure special qualities, are rather preventing private gardeners to maintain or to develop their own varieties. Farmers do often have more resources available, but the caring for the seed plants under an insect-proof net, releasing pollination insects, harvesting and cleaning seeds, etc. are such distinct works, compared to common vegetable production, that the task just doesn't fit well in the farmer's routine. In addition farmers prefer the use of calibrated precision seeds, and farmers as well as privates would be overwhelmed to reach this seed quality themselves.[25]

As mentioned in paragraph 1) these are probably the reasons why so few old varieties have been passed down to the present day. And it bodes that carrot diversity will only grow if breeders are interested in it, and if there are again more players on the seed market, respectively. Regrettably at the moment the latter is far from true. Compared to other crops, there exist not so many active carrot breeders, and all of them except organic breeders are working on hybrid varieties, which provide high yields. As long as carrots remain a mass product, that can reach as low prices as 7 cts/kg[26], this main breeding goal will continue.

5. Agronomy of carrot diversity

Depending on the variety type farmers have to make some adjustments of the crop production. Carrots of the «Chantenay type» and ones in similar shape (e.g. 'Küttiger Rüebli') need a wider **gap between plants** in order to develop their calibre. A certain calibre is responsible to reach higher yields within these types. But quality needs restrict maximal calibre also for these carrots, as they often tend to grow over proportionally in diameter, and carrots of too much width are more susceptible to other quality issues, as e.g. to crack along the root, and such carrots simply won't fit

[24] personal message from Amadeus Zschunke, director of the breeding company Sativa Rheinau AG, 2017
[25] personal message from Amadeus Zschunke, director of the breeding company Sativa Rheinau AG, 2017
[26] personal message from Amadeus Zschunke, director of the breeding company Sativa Rheinau AG, 2017

any more in wrappings. Seeding on final density is therefore highly recommended, and the abundance of precision seed is a real improvement for these varieties. Regrettably this seed quality is not often available in rare varieties.

The **susceptibility to green heads** is abundant in several varieties. To a certain degree this can be reduced by earthing the carrots up , but some varieties show such a strong enlargement of root heads out of the soil that the phenomenon cannot be completely prevented (e.g. 'Blanche à collet vert').

The **susceptibility to *Alternaria dauci*** is especially a problem in organic production. The fungus exist in two types[27] and it affects leaves during the growing period and in can harmfully reduce the healthy leaf surface, and photosynthesis, respectively, which results in yield losses. In varieties of a deep in-sunken leaf base (e.g. 'Gniff', ' Küttiger Rüebli') the fungus settles in on the leaf base, which cannot be removed clean during harvest, if the root itself shouldn't be harmed. During storage affected carrots may then take severe damage at the core by growing *Alternaria,* but this quality loss cannot be seen from the outside. Varieties of a low resistance should be enhanced by a combination of breeding selection efforts and the treatment of the seed, as *Alternaria dauci* often spreads through seeds. There are several successful seed treatments available, even according to organic guidelines. Sativa Rheinau AG applies the «Hot steam treatment» for their organic carrot seeds, which at least reduces primary infection of the seeds.[28]

Generally old varieties need a somewhat **longer growing time** from seed to harvest, but the **lower harvest yields** can be viewed as having an economically higher impact. Carrot yields are generated by the total root weight and are in strong correlation with the root length. Another important yield factor is the amount of crop loss due to selecting out bad carrots. This amount is clearly higher in open-pollinated varieties of fewer breeding efforts, as these show a much higher heterogeneity of roots.

7. Quality aspects of carrot diversity

An important quality aspect is the **heterogeneity** as mentioned in paragraph 5). Although trading companies, stores and farmers committing to special varieties would show willingness to relax commercial norms, there is only so much margin. It is generally recommended to pack carrots of similar size into a given package[29], which can help on this issue. Interestingly recent discussions on food waste led to have supermarkets offering discarded carrots due to quality issues for a lower price[30]. Although there can only be found carrots of the common varieties («Nantes type») in this product line, it contributes to more consumer awareness and it may benefit to the success of the more diverging varieties from the norm.

Storage capability is an important trait of a storage vegetable. Experiences with landraces and old varieties indicate not much difference in storage compared to hybrid varieties, that is, as long as the carrots are not infected with *Alternaria* sp.*, Sclerotina* sp., *Botrytis* sp. or other fungal or bacterial infections. In regard of the sometimes-higher susceptibility to such diseases, there can result

[27] personal message from Amadeus Zschunke, director of the breeding company Sativa Rheinau AG, 2017
[28] personal message from Amadeus Zschunke, director of the breeding company Sativa Rheinau AG, 2017
[29] «Schweizerische Qualitätsnormen für Gemüse», by swisscofel & VSGP: http://www.qualiservice.ch/uploads/normen2017/de/Karotte.pdf
[30] See «Ünique» label for discarded vegetables and fruits oft he supermarket Coop, http://www.coop.ch/de/labels/uenique.html

indirectly a reduced storage capability. Generally carrots of high dry matter content are better suited for storage.

Some differences between varieties can be found in different **taste** traits. An obvious trait is the crispness of carrots. It strongly correlates with a short growing period and a low dry matter content. However, old carrot varieties often have a long growing period, that result in a high dry matter content, and a lower crispness. But this correlates also to a more intense aroma and a good sweetness. Interestingly, consumers would often indicate «good taste» with the more crisp carrots, although they often have a lower aroma or lower Brix-content than the less crisp varieties, which can be detected with juice tasting instead of tasting the raw carrot.[31]

S**weetness intensity** correlates strongly with the Brix-content, (that is about 70%.) According to Amadeus Zschunke of Sativa Rheinau AG, there have never been done a lot of breeding efforts for carrots targeting flavour, the reason being, that good carrot taste and flavour wouldn't be rewarded by consumers through higher demands, at least not in the mainstream carrot marketing of supermarkets. On market stalls, in farm shops and in similar direct marketing forms, this could be different. But there, emotional factors could influence the sensed taste, reasoning that the effective taste traits of the carrots also there are only of medium importance.[32] So although breeding can level up Brix-content or maintain intense flavours, it's not necessarily been done for a given carrot variety. Very sweet and lesser sweet carrots therefore can be found among modern hybrid varieties as well as among older varieties. But we found landraces without certain breeding directions and a rather high heterogeneity generally with lower average Brix-contents (about 9%) than varieties with a certain degree of a breeding history (>10%).

On the other hand, as mentioned above, longer growing periods of carrots result in intense flavours, and old varieties and landraces would often need 130-140 days until harvest, whereas some modern varieties of similar calibre grow during 110-120 days or less. Tasting of some landrace varieties indeed proved the abundance of **diverse flavours** that cannot be found in modern varieties. These flavours open up some interesting potential in the kitchen, be it by use of aware consumers, or by use in the gastronomy, see paragraph 7).

Carrots are often referred to a high **content of carotenoid**, and more specific of**β**-carotin, which counts as a precursor that is transformed by the human body into A vitamin. There is a strong correlation of the orange colour to the carotenoid content. E.g. the**β**-carotin content of the white carrot 'Küttiger Rüebli' was found to be not more than 1.5% of the content of a carrot of the «Nantes type», the content of a yellow carrot of the «Pfälzer type» was about 10%.[33] The carotenoid content therefore is not a good reason for the promotion of white and yellow carrot variants.

Carrots of the «Purple type» as well as the 'Gniff' carrot offer another interesting ingredient. The purple colour is effected by **anthocyanins** for which in recent years some interesting studies on health benefits were done. If such effects would be of more public awareness, anthocyanine containing food could be of more interest and as such also these purple carrots.

8. Potential uses of the carrot diversity

[31] personal message from Amadeus Zschunke, director of the breeding company Sativa Rheinau AG, 2017
[32] personal message from Amadeus Zschunke, director of the breeding company Sativa Rheinau AG, 2017
[33] «Karotten: Anbau, Erntezeitpunkt und Lagerung», R. Wellinger, H. Buser, J. Krauss, R. Theiler, Agroscope, Wädenswil, in Agrarforschung 13 (10): 412-417, 2006, online available: http://www.agrarforschungschweiz.ch/artikel/2006_10_1212.pdf

As with many other rare varieties, the main argument for using various carrot varieties is the consumer's interest in special properties, which they wouldn't find in common carrots. The most obvious are **differing shapes and colours** that open the potential to surprising components in the kitchen. But once known by consumers, a variety could also find a rising demand if its **taste qualities** are outstanding, that is if it's differing sufficiently from the one of common carrots. This could even be a supposedly esteemed lesser quality, as with lower sweetness, as there are consumers who'd like their carrots for cooking with less sweetness but with intense other flavours. However until now, such demands are rarely known, and as stated in paragraph 6) consumer feedback on taste qualities is scarce, so breeders and producers don't feel a high demand on special flavour traits.

Since a few years there is a trend going on also in Switzerland called «Nordic kitchen», originating in the north of Europe and known famously by the gastronomy concept of Noma, Copenhagen (noma.dk). The philosophy appreciates the diversity of products in their individual nature, and tries to authentically conserve their natural flavours and properties during procession. In context of such trends the carrot diversity and their various flavours could be valued anew in the **gastronomy**. In the example of the 'Gniff' carrot, flavours were described among others as: intense, earthy, of artichoke, spicy, somewhat green, of celery, of kohlrabi, a faint hint of chestnut, malty, of sweetpotato, with a subtle sweetness, and firm to the bite.

If the often-needed higher price for rare carrots therefore is accepted in exchange of such special visual and taste properties, a niche market can open up for these carrots. On fresh markets this is clearly given, and indeed the biggest carrot diversity can be found on **fresh markets or in farm shops** of specialised vegetable producers.

As can be seen in the example of ProSpecieRara-carrots in the supermarket Coop, and in the case of purple varieties, as well as in the "Pfälzer type", there is a potential for a carrot diversity in some niche assortments even in **supermarkets**. Interestingly, in Switzerland we found the potential of a vegetable diversity in retailers, as organic grocery stores, by now rather restricted. We estimate the biggest problem there to be the very restricted space of such small stores to include a lot of niche products. Also in organic stores, customers would foremost need the common vegetable products for the everyday use, which doesn't allow shop owners to replace a common carrot with a carrot variant of a higher price, be it even of very attractive outstanding colour or shape, etc.

Cases of farmers that appreciate a carrot diversity because of agronomic or other non-visually obvious advantages are far and between. Lesser breeding efforts to resolve production and storage problems in rare varieties mean a higher production risk in such varieties. Still, farmers that are producing a diversity of carrots, from time to time will appreciate also varieties of lesser yields, if they perceive an outstanding property in their carrots. An example was given to ProSpecieRara in 2016 by a farmer who had some storage quality problems with most of his carrots, but not with the carrot 'Gniff' that maintained a good root quality for a long time after other varieties had to be finished.

9. List of References

[1] https://www.bdn.ch/organisations/acw/

[2] http://ec.europa.eu/food/plant/plant_propagation_material/plant_variety_catalogues_databases/search/public/index.cfm

[3] http://www.gemuese.ch/Ressourcen/PDF/Politik/CHGemuesebau_BROSCHURE_LID.PDF
[5] «Schweizerische Qualitätsnormen für Gemüse», by swisscofel & VSGP: http://www.qualiservice.ch/uploads/normen2017/de/Karotte.pdf
[6-8] personal message from Amadeus Zschunke, director of the breeding company Sativa Rheinau AG , 2017

[9] «Versuche im deutschen Gartenbau 2014», Gerald Lattauschke, Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie, Dresden, 2014, www.landwirtschaft.sachsen.de/landwirtschaft/download/Moehren_Krinkel_2014.pdf

[10] personal message from Amadeus Zschunke, director of the breeding company Sativa Rheinau AG , 2017

[11] personal message from Martin Koller, FiBL , 2017

[12] «Das Lexikon alter Gemüsesorten», M. Serena, M. Suanjak, F. Pedrazzetti, B. Brechbühl, AT Verlag, Aarau und München, 2014

[13] personal message from Martin Koller, FiBL , 2017

[14] «Das Lexikon alter Gemüsesorten», M. Serena, M. Suanjak, F. Pedrazzetti, B. Brechbühl, AT Verlag, Aarau und München, 2014

[15] http://wikifootprints.org/en/Vegetables

[16] «Ökobilanzierung Früchte- und Gemüseproduktion – eine Entscheidungsunterstützung für ökologisches Einkaufen», A. Zhiyenbek, C. Beretta, F. Stoessel, S. Hellweg, ETH Zürich Institut für Umweltingenieurwissenschaften, 2016, online available: https://assets.wwf.ch/downloads/2017_01_oekobilanz_fruechte_und_gemuese_d_1.pdf

[17-21] personal message from Amadeus Zschunke, director of the breeding company Sativa Rheinau AG, 2017

[22] «Schweizerische Qualitätsnormen für Gemüse», by swisscofel & VSGP: http://www.qualiservice.ch/uploads/normen2017/de/Karotte.pdf

[23] See «Ünique» label for discarded vegetables and fruits oft he supermarket Coop, http://www.coop.ch/de/labels/uenique.html

[24-25] personal message from Amadeus Zschunke, director of the breeding company Sativa Rheinau AG, 2017

[26] «Karotten: Anbau, Erntezeitpunkt und Lagerung», R. Wellinger, H. Buser, J. Krauss, R. Theiler, Agroscope, Wädenswil, in Agrarforschung 13 (10): 412-417, 2006, online available: http://www.agrarforschungschweiz.ch/artikel/2006_10_1212.pdf

Chestnut in France

1. Chestnut in France

In France, in 2016, 7800 tons of nuts have been produced on 8142 ha. This ranks France forth European producer – after Italy, Portugal and Spain – and tenth in the world – far behind China, in first place, that cumulates 70% of the 1 million tons produced worldwide. Europe – including Turkey – is the second main area of chestnut growing (109 700 ha) after Asia (178 600 ha). More than 500 varieties have been identified in the Old Continent.

Ardèche, Dordogne and Lozère are the three leading departments for French chestnut production, which is spread over two basins:

- The Rhone-Mediterranea basin in the South-East (Ardeche, Lozère, Gard, Languedoc-Roussillon, Var, Corse) where two thirds of the national production - often in mountain areas - is assured by more than 100 traditional varieties, with the predominance of 'Comballe' and 'Bouche Rouge'.
- The Southwest (Dordogne and neighboring departments) where the traditional grove has been strongly influenced by the introduction of hybrid varieties like 'Marigoule' and 'Bouche de Bétizac'.

Because of ancient commercial flows, Eastern populations influenced by Italy are more variable and differ from Western ones, influenced by Iberian Peninsula. At country scale, more than 90% of the trees are non-hybrid varieties. The certified organic production concerns 1300 ha which makes chestnut is the most extensively grown organic fruit.

Even if chestnut is still eaten fresh (100 g per person and per year), its main outlets are cannery and confectionery (a jam called 'chestnut cream', 'marron glacé'). French consumption is not covered by national production: in 2010, 45% was imported, from China (30%), from the rest of Europe or Chile. France is the 2nd largest importer after Japan. The country exports about 35% of its production, mainly in fresh form, to other European countries.

2. History of Chestnut in Europe

Analyses of pollen and coals revealed that chestnut's presence in Europe could precede Roman colonization. During last glacial age (between 120 000 and 10 000 years before present), chestnut found refuge in Turkey, Italy and possibly in Northern Spain. Its spreading North and West started 40 000 years ago and accelerated with planting and grafting of extensive chestnut forests during Greek and Roman eras.

Chestnut is a multipurpose tree valued for its nut, timber, tannins, as well as forestry landscape. Through its integration in a large set of uses, it played for centuries a central role in the life of the populations inhabiting the middle mountains of southern Europe.

Used for tools, furniture, stakes and firewood, chestnut hardwood is appreciated for its durability. The Romans associated chestnut with grapevines for the production of wooden barrels. Large plantation with dual purpose – fruit and timber – were established during medieval ages, with an apogee in the 16th and 17th centuries. Conserved dried or as flour, nuts were a valuable winter food source. When they were not burned to dry the chestnuts, leaves and bugs served as litter. The small wood was used for basketry.

However, chestnut is species of long-term investment where immediate returns are limited. The "civilization of the chestnut tree" came to an end in the 19th century, in a context of agricultural modernization and rural exodus, when production, thus far domestic and oriented toward self-consumption, was integrated into processing and marketing chains.

At that time in middle mountains, cereals and potatoes supplanted chestnut in the daily diet. In competition with more productive woody species as Pinus or with tannin industry, often requiring a costly manual harvesting, affected by pests and diseases, many plantations couldn't integrate the new socio-economical system, which led to a general decline of the crop.

In relation with issues of landscapes diversification, promotion of local identity and rural tourism, chestnut experiences since thirty years a renewed interest.

3. Breeding and seed management

Chestnut was first domesticated by selection of the best nut from surrounding populations. A second domestication began when growers fixed characters of interest thanks to the mastery of grafting brought in France by the Romans. They propagated cultivars producing large monoembryonic nuts, sweet and easy to peel.

Traditionally, growers used seedlings coming from seeds germinated under the grafted trees to establish the new orchards, obtaining rootstocks with good compatibility and rusticity.

Since 1726 in Spain and in 1838 in Portugal, ink disease (Phytophthora spp.) were reported in Europe. It started decimating French plantations since 1870. Between 1917 and 1940, researchers introduced exogenous species, *C. crenata* from Japan and *C. mollissima* from China, showing resistance to ink but also less vigour, lower quality of the nuts, bad affinity with the local cultivars and difficulty in adapting to European climates.

Between 1942 and 1958, first generations of hybrids were obtained using C. sativa as female progenitor, and *C. crenata* or *C. mollissima* as male. Clones of these hybrids were selected as rootstocks in order to combine climate adaptation, ink resistance, easy propagation, and good compatibility. Nevertheless, most didn't cumulate all traits and presented incompatibility with many cultivars from *C. sativa*.

In addition, with the introduction of the Asiatic species, another disease, Blight (*Chryphonectria parasitica*) was imported and added to the damages caused by insects like weevil, codling moth and gall wasp.

Since the beginning of the eighties, besides stooling, layering and cuttings, *in vitro* microculture completed the list of rootstock propagation techniques.

4. Agronomical practices

In Southern France, orchards are located between 600 and 700m. Chestnut trees thrive in sandy or loamy soil, pour in active calcium, with acid pH - from 4.6 to 5.2 – and high drainage, eventually on slopes.

Chestnut is a cold hardy tree but spring frosts can be a limiting factor due to early blooming – especially for hybrids. Summer shouldn't be too dry, minimum rainfall for chestnut is around 800 mm. Irrigation can be necessary during the first two summers of the tree. Sum of degree-days between flowering and harvest must reach 2000, that is to say around 100 days at 18-19°C. Relatively low temperatures enable the female flowers to be fecundated and to develop a normal kernel.
Cross-pollination is essential for production that is why a combination of various cultivars is recommended. Chestnuts pollen is carried by the wind in Mediterranean areas, but the contribution from pollinators increases with hygrometry. A proportion of male cultivars are sterile - astaminate and brachystaminate -, they are still preserved for their productivity - they allocate more energy to nut production.

Depending on the pruning and on eventual removing of trees, distance between trees varies from 5 to 12 m. Against animals, sun damage and early frost, young plants can be protected by with local shrubs like genista or whin.

Traditionally, grafting occurs after the 3rd or 4th year. New plantations are often made with grafted plants. Tree formation depend on the expected production: nuts, wood or both. Then, one third of the crown of the old trees are traditionally pruned each 8 to 10 years. Lifetime of *Castanea sativa* groves exceed two centuries, after which a regenerative pruning is still possible.

The harvest extends from the end of September to the middle of December. The historic pickup tools are the rake and the clamp, they were mainly replaced by nets or machines. Mechanisation reduces human labour but calls for investments, gentle slopes and a good preparation of the ground. Vacuums and brushes mix nuts with soil and collect a big quantity of burs, leaves and pebbles collected that must be discarded later. After harvest, the chestnuts are sorted by soaking. Next come drying, husking and sieving.

Chestnut orchards can also provide pasture, it is the most common strategy of ground management in humid areas. In drier areas, to limit weeds and incorporating organic matter, some farmers grow wheat or rye during spring. But ploughing can provoke a strong erosion, especially on significant slopes. Herbicides are used by some growers. Another choice is to leave a spontaneous grass cover, mowed twice a year to avoid fires and facilitate the harvest.

5. Quality aspects and uses

In the past, chestnut could be people's main staple food: dried chestnuts were eaten off season, after boiling, whole, mashed or in soups. Flour can be used to make a bread than became typical in Corsica. As a celebration of the harvest, nuts were directly roasted in the fire.

Today, far exceeding local use, the principal market for chestnuts is for consumption by city dwellers as delicacies and in festive dishes. That way, the nut is used as filling accompaniment for the roast meat, transformed into jam or into a candy called 'marron glacé'.

6. Peasant points of view and perspectives

Rénova is an association based in Ardèche which employs five people. Created in 1997, it federates local associations safeguarding and upgrading the fruit heritage.

In 2000, impressed by the diversity and richness of centenarian chestnut trees, the association began to renovate old orchards by pruning and multiplication. Obtaining poor results with hybrids, it started grafting stools with a crown method and keeps testing several methods. Technical data sheets about grafting are about to be edited. Experiments aim to rediscover multiplication by seedlings and allow, in this perspective, to study the influence of early breeding in nurseries compared to on-farm seeding.

Since 2011, Renova undertakes a rigorous *in situ* prospection of the varietal heritage present in the territory. For this purpose, an evaluation is being carried on 160 trees for parameters regarding agronomy, process and taste. Sixty varieties have been identified while the rest still belongs to an unknown legacy.

Measures such as precocity – and therefore sensitivity to frost - or pollinating ability – and therefore varietal compatibility - lead to recommendations on variety choices and combinations. Precocity of the fruit fall is of particular interest for some professionals, often in search of very early or very late varieties. The ability of the nut to stay in its bug is studied as a possible determinant of the conservation potential. Characterization protocols include sensitivity to the gall wasp (in French: cynips), given that this insect native to China strongly disrupts the fruiting process. Varietal tests also include measures of chestnut size, ease of peeling, organoleptic quality, resistance to cooking, and sanitary state. They are completed by processing tests - to evaluate different conditions of harvesting, draining and preserving – and for the next season by cooking and nutrition tests.
On the basis of these data, Renova networks different actors of the food chain and encourages a collaborative organization of production, processing and sale of chestnuts originating from renovated orchards or from the participatory breeding process.

In addition to a mobile workshop intended for apple juice producers, a stationary one including a chestnut peeler gathers some 150 users. Training days are organized (30-40 each year?) (about chestnut production, processing?) (5-10 participants each). Renova gathers group (30 people) orders for rootstock and trees. The association offers hundreds of trees and 2000 rootstocks for sale.
Rénova collaborates with the regional conservatory of chestnut in Aveyron and with the association for chestnut renewal in Hautes pyrénées. It receves fundings from the region (Auvergne-Rhône-Alpes).

Going forward, the installation of a conservation orchard would ensure the protection of varieties, the spread of "certified" grafts and the ex situ prosecution of varietal observations.

7. Recipe

Pulenda, Corsican chestnut bread

- 1 kg of flour

- 2 liters of water
- a few pinches of salt.
Cook the mixture in a pot, stirring
After, the 40 to 50 minutes, the pulanda sticks the stirring stick
Flip the cooked dough over a cloth sprinkled with chestnut flour
Cut slices with a wire.
Eat hot or cold, plain or with milk, cheese, eggs, porkribs, ...

8.References

Dris, R., Shri Mohan, J., 2004, Production Practices and Quality Assessment of Food Crops, Vol. 1

Krebs, P., Conedera, M., Pradella, M. et al., 2004, Quaternary refugia of the sweet chestnut (Castanea sativa Mill.) : an extended palynological approach, Veget Hist Archaeobot 13: 145. https://doi.org/10.1007/s00334-004-0041-z

Aumeeruddy-Thomas, Y., Therville, C., Lemarchand, C., Lauriac, A., Richard, F., 2012, Resilience of sweet chestnut and truffle holm-oak rural forests in Languedoc-Roussillon, France : roles of social-ecological legacies, domestication, and innovations. Ecology and Society 17(2): 12. http://dx.doi.org/10.5751/ES-04750-170212

Einkorn

Reintroduction of an ancient grain into organic markets

Zoltán Dezsény, Christy den Hertog, Dr. Dóra Drexler

Hungarian Research Institute of Organic Agriculture (ÖMKi)
Zoltán Dezsény, research associate,
zoltan.dezseny@biokutatas.hu

ÖMKi
Ökológiai Mezőgazdasági Kutatóintézet
Research Institute of Organic Agriculture | Forschungsinstitut für biologischen Landbau
PARTNER OF FIBL SWITZERLAND

1. State of art of einkorn in Hungary

In Hungary, the Total Agricultural Area was 5,38 million ha in 2014. 68% of the area was used for grain production, in which over 1,1 million was wheat (CSO 2013). To date, there is no official data collected on the cropping area of einkorn in Hungary by the Central Statistical Office. The crop is categorized as “other grains”. Data available is derived from the two organic certifying bodies in the country. The total area of einkorn consisted approximately 200 ha. In 2016, the production was expected to double. According to the available data collected through interviews, the total turnover of economic activities related with einkorn and emmer production and processing is estimated around one million Euro (ÖMKi 2016).

There is no international statistics available on the production of einkorn in Europe. Apart from Hungary einkorn production is only found in small isolated regions in France, India, Italy (Apulia region and mountainous areas of Daunian Apenine), Turkey, former Yugoslavia and Romania.

2. Description of the crop

Einkorn wheat is recognized among the forms of wheat that were first cultivated by humans. Grains of the wild form were traced back to tens of thousands of years ago, and the first domestication of wild einkorn was recorded approximately around 7500 BC. It is believed to originate from the fertile areas of the Tigris-Euphrates region. The wheat is believed to originate from the natural crossing of Triticum speltoides (wheat grass) and Triticum monococcum (domesticated wheat).

DNA finger-printing has shown evidence to suggest the domestication of einkorn wheat was carried out close to the mountains of Kacara Dag, located in the south-eastern parts of Turkey. However, the Bronze Age saw a decrease in the cultivation of the grain.

The crop can be found in mountainous regions of Morocco, France, Turkey, and parts of the former Soviet Union. It survives and thrives on soils where most other forms of wheat do not flourish. Einkorn was among the first cereals that were cultivated, following its wide distribution around Transcaucasia, the Middle East, south-western Europe, the Balkans and the Mediterranean areas (http://alkobeerprojekt.hu).

Thanks to their vigour and adaptability to harsher climates, glume wheats survived in cultivation in the sub- and mountainous areas of Europe, until the beginning of 20th century. A common feature of einkorn and emmer is that their cultivation was largely abandoned and is currently underutilized. However, they were able to survive for centuries in the subsistence farming systems of Europe and the Middle East (Hajnalová – Dreslerová 2009).

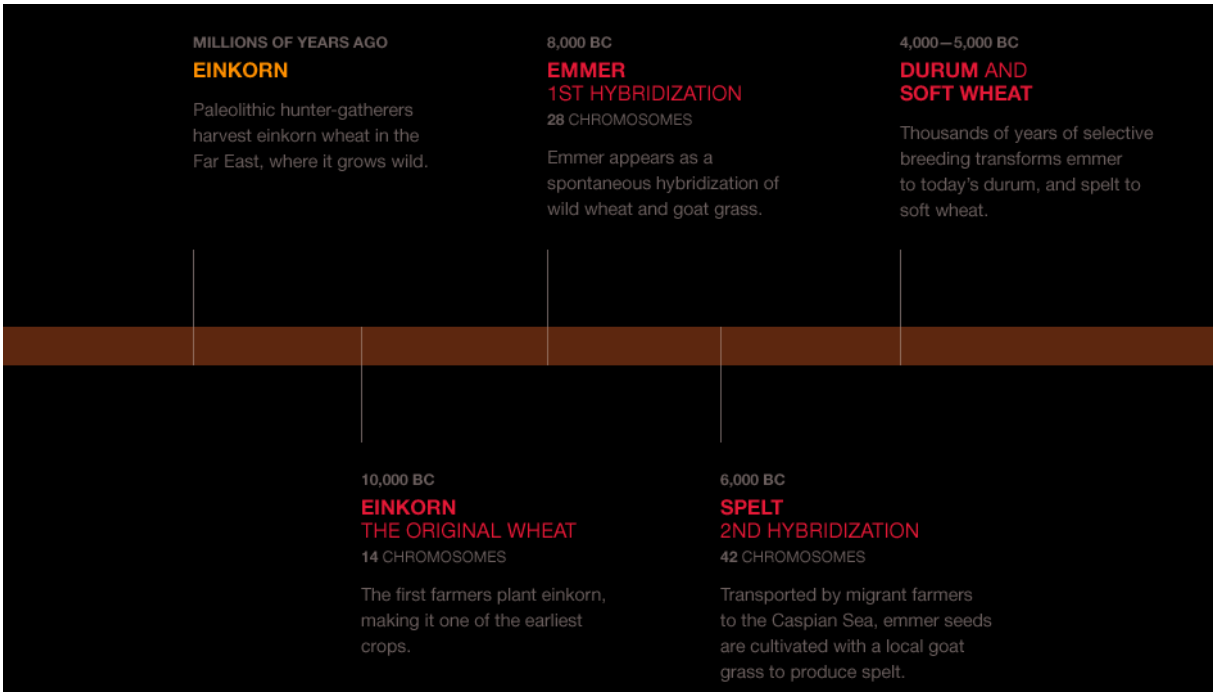


Fig. 1 Evolution of wheat
Source: https://jovialfoods.com/einkorn/

3. Relationship between the crop and the environment

Einkorn, emmer, as well as spelt (Triticum spelta) are hulled (syn. glume) wheats where robust glumes surround the grain. To separate the grain from the glumes, additional steps in processing are necessary: parching by fire, pounding in mortars, repetitive winnowing and sieving. In contrast, ("modern") bread and macaroni wheats are free-threshing, which means that their grain falls out of glumes already at threshing. The advantage of hulled wheats is that robust glumes protect the grain more efficiently against pests in the fields (birds and rodents), safeguard it against insects and fungal attacks during storage, thus making them more vigorous than free-threshing wheats (Nesbitt — Samuel 1996).

Einkorn adapts well to poor soil conditions, it can be successfully grown in areas where winter wheat or durum wheat are not possible to produce. It is able to adopt harsh environmental conditions, too. Some traits are resistant to serious frosts, water lodging or heavy snow cover during winter months. Also, the species is a known source of disease and pest resistance traits (common bunt, stem rust, leaf rust, powdery mildew etc.), however scientific data is fragmented, more research is needed in this topic.

The increasing demand by consumers for traditional products, the request for species suitable for growing in marginal areas and the need to preserve genetic diversity have renewed the attention towards these ancient species, rediscovering the better performance under marginal conditions of hulled wheats like einkorn as compared to modern cultivars.

4. Breeding and seed management

4.1 Available varieties in Hungary

The available einkorn varieties in Hungary were bred through two projects: 1) MV Alkor was bred within the project GAK Alakor05 and 2) MV Menket was bred within the Alkobeer (2009-2014) project. Within the project in the Centre of Agricultural Research of Hungarian Academy of Sciences the first bred einkorn wheat variety was state registered in 2011 as Mv Menket. This is the first intensive semi-dwarf einkorn wheat variety that due to its shorter stems is more in line with the modern cultivation preferences.

Besides these projects there is no current data available on agronomic features and crop-environment relationships. Therefore we cite here the descriptions of the cultivars which were bred within the above mentioned projects. This information is relevant characterizing not only these cultivars, but einkorn as a marginal crop as well.

4.2 List of state-registered varieties in Hungary

Mv Alkor

Mv Alkor is the first diploid einkorn wheat variety produced in Hungary from an organic breeding programme. Under organic cultivation conditions it is capable of a yield of 2.5–3.5 t/ha. The plants are 120–130 cm in height and the stems are thin, but strong and flexible.

Its excellent tillering and weed suppression ability make it ideal for use in organic farming and under low input growing conditions. It has excellent winter-hardiness and good tolerance of drought. It has little tolerance of high soil nutrient levels. The soft grains have high wet gluten and crude protein content, but the gluten is soft. The flour is rich in carotene, being yellow in colour. Due to its high biological value, good digestibility and high content of bioactive components, it can be used to produce functional foodstuffs. It is recommended primarily for organic farming and for the production of bioproducts.

Mv Menket

The Mv Menket is the first intensive semi-dwarf einkorn wheat variety. The plant is only 80-90 cm in height at maturing, while its production is 20 % higher than production of Mv Alkor, partly because it produces two rounded kernels on its rachis nodes. About 20 % of the kernels are free from chaff, naked when coming out of the combine harvester.

It tolerates more intensive cultivation conditions well, but it is especially sensitive to herbicides, however, these are not necessary due to its excellent tillering and weed suppression ability. Due to its shorter stems it can be sown with seed rate of 4,5-5 million seeds/ha without the risk of lodging after elongation. It has excellent winter-hardiness, standing ability and resistance to fungal diseases. It is a late maturing variety and its soft grains have excessively high crude protein and fiber content. The flour is rich in carotene, being yellow in colour. It can be used also for making bakery products.

Due to its high biological value, good digestibility, high content of bioactive components and ideal tocotrienol/tocol ratio (T3/T, vitamin E) it can be used to produce functional foodstuffs as well. It is recommended primarily for organic farming and for making organic products.

MvA6-13 (candidate variety)
Mv A6-13 is a traditional type organic bred einkorn wheat variety. It tillers well, the recommended seed rate is 3,5 million seeds/ha. It is 125-135 cm in height and the stems are thin but strong and flexible. The ears are light red in color.**[2]**

Higher density and taller crop growing on N-rich soils is susceptible to lodging when overripe, it is recommended primarily for organic farming. Although it is a facultative type, it tolerates hard winter conditions well. It has a good tolerance of drought and excellent weed suppression ability and it is resistant to the main fungal diseases. It is a later maturing variety compared to the other einkorn wheat varieties already being in production but it has higher productivity. Yield is similar to the moderately productive wheat varieties (3 t/ha). The soft grains have lower crude protein content than the previously bred einkorn wheat varieties, so it is more in line with brewing industry preferences. The carotene-rich, yellow flour is suitable to make bakery products or pasta. Due to its high biological value, high content of bioactive components and fibers, it can be used to produce functional foodstuffs. **[2]**

5. Agronomy

Einkorn is suitable for low input systems - organic farming - because of its better adaptability in marginal areas (in comparison with other crops). It has a good ability to compete with weed. Due to lack of experience there is very limited reliable data available on agronomic details of einkorn production.

6. Climatic requirements

Einkorn has similar climatic requirements to winter wheat, however it strongly depends on the origin of traits, since the species has huge genetic diversity.

Field preparation Fields for growing einkorn are prepared similarly to common wheat depending on agro-ecological conditions, variety and available infrastructure.

Fertilization In studies related with fertilization requirements of einkorn, the differences in yield after the various fertilization rates were insignificant. In fact, fertilization can have adverse effects since there is a pobability of greater lodging when there is too much nitrogen available in the soil. It prefers organic forms of nitrogen, in most cases there is no need for mineral fertilization. Einkorn effectively utilizes the available soil nutrients since it has a very extensive, robust root system.

Seeding There are contradictory data in scientific literature on optimal seeding rate of einkorn. According to certain studies (Troccoli – Codianni 2005), it needs more space among plants to give a good grain yield, while significant yield losses may occur as a consequence of the competition among plants when high seed density is used. For this reason, the best performance of einkorn was obtained with a seeding rate of 100 seeds and 360 spikes per square meter. In other studies (Codianni et al.

1993) it was found that under the same experimental conditions, the highest grain yield with high plant density. Further supplemental investigations are needed for einkorn in this respect.

Einkorn can be sown in fall or spring, depending on the agro-ecological conditions and used variety. Sowing should be carried out into the well-firmed seedbed 3 or 4 cm deep. Grower should be careful with nitrogen dressing, which can cause excessive shooting and increase lodging of the crop.

Plant protection
Most experienced with einkorn emphasized that many traits of resistance to fungal diseases have been identified in einkorn. Depending on the weather conditions it mainly does not need plant protection interventions during the growing period.

Harvest
It is necessary to adjust combine-harvester in order to catch released smaller grains of einkorn and one-seed spikelets too. Harvested grain (spikelets) should be separated from impurities. Spikelets if not used as a seed are dehusked. The most common method of removing the husk is abrading by abrasive wheels. There is some risk of damage of outer layer of the seed.

7. Quality aspects

Nutritional benefits of einkorn grain are attractive. It contains high levels of protein, essential fatty acids, phosphorous, potassium, pyridoxine (B6), lutein and beta-carotene (lutein) compared to other grains. The latter are natural red, yellow or orange pigments that are found in many vegetables and fruits, and in a few grains. They are important for eyes and nervous systems.

The einkorn flour is characterized by high protein (fig. 2), high ash, a very high carotene content, and small flour particle size when compared to the modern bread wheats. Einkorn grain has higher concentration in soluble sugars and minerals, and less in total and insoluble dietary fiber than other cultivated grains.

In terms of taste, it is superior to winter wheat. “Einkorn has fuller aroma profile than bread wheat - slightly nutty, fine tasting, most often coupled with a fresher feeling in the breads. In beer, spelt, emmer and einkorn deliver a sounder and deeper aroma”.

Einkorn is not gluten free, but it has lower gluten content than winter wheat. According the empirical experience many people with gluten sensitivity can eat einkorn without digestive difficulties. Academic studies are lacking in this field, more research is needed to figure out exact nutritious benefits.

Listed benefits

1) Einkorn contains 3 to 4 times more beta-carotene than modern wheats (Boosts immunity, helps prevent cancer and heart disease);
2) Einkorn contains 35 times more Vitamin A than modern wheats (Healthy eyes, reproductive organs and prevention of many cancers);
3) Einkorn contains 3 to 4 times more lutein than modern wheats (Prevention of macular degeneration and cataracts);
4) Einkorn contains 4-5 times more riboflavin than modern wheats (Used by the body to create energy and is an antioxidant that slows aging).

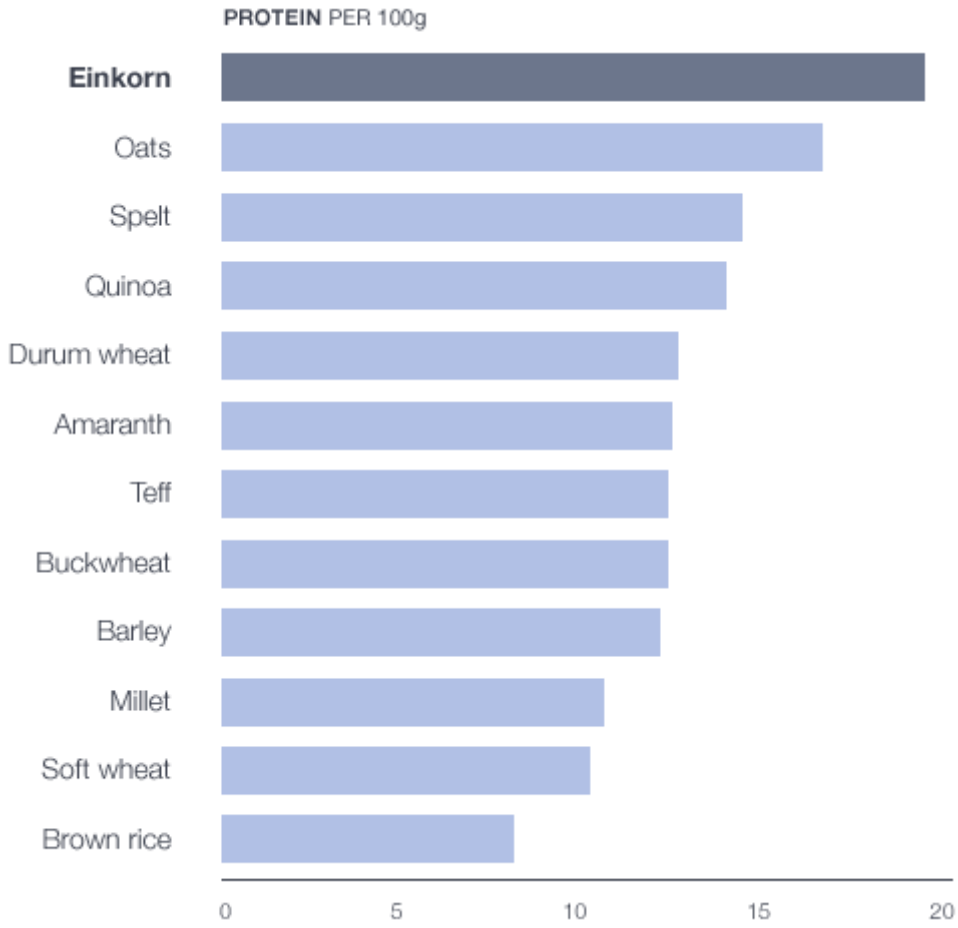


Fig. 2 Protein per 100 gr
Source: https://jovialfoods.com/einkorn/

8. Potential uses

First and foremost, einkorn can be the main ingredient for many specialty processed products in the organic market in Europe for human consumption. There is every reason for renewed interest in ancient grains as functional or special food products due to their exceptional dietary value, high content of protein, minerals and vitamins.

Also, einkorn can be fed to monogastric animals as animal feed. The straw could be used in basketry and for making gifts and souvenirs.

The currently available processed products within the einkorn value chain in Hungary are hulled grains, pastas, bakery products and snacks. There is only a couple of market player distribute einkorn based products. There is an einkorn beer on the market developed within the Alkobeer project which focused on organic bred einkorn wheat and to produce a health promoting einkorn wheat-based beer with high biological value. Some organic and/or artisan bakery produce einkorn bread.

Figure 3. Einkorn beer Source: www.alakorsor.com

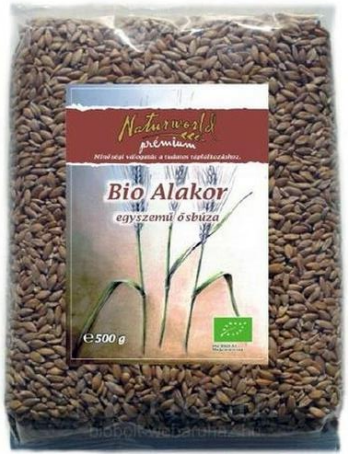


Figure 4. Einkorn hulled grain. Source: http://gomortorna.hu/gt-webaruhaz/category/12-naturgold-hungaria-kft

PIPACS
~ PÉKSÉG ~

Figure 5. Einkorn bread at Pipacs Bakery. Source: http://pipacspekseg.hu/project/kenyereink-alakor-kenyer/

9. Literature cited and useful links

Central Statistical Office (2013): Agriculture 2012, Budapest, Hungary

Hajnalová-Dreslerová (2010): Ethnobotany of einkorn and emmer in Romania and Slovakia: towards interpretation of archaeological evidence. Pamatky Archeologicke. 169-202.

Maneva et al. (2015): Influence of sowing and fertilization rates on the yield and plant health of einkorn wheat (Triticum Monococcum L.). AGRICULTURAL SCIENCE AND TECHNOLOGY, VOL. 7, No 4, pp 460 - 463, 2015

Nesbitt-Samuel (1996): From Staple crop to extinction? The archaeology and history of the hulled wheats. In: Padulosi, S. — Hammer, K. — Heller, J. (Eds.): Hulled Wheats. Promoting the Conservation and Use of Underutilized and Neglected Crops. Rome: IPGRI, 41–100.

ÖMKi (2016): Case study report to describe key processes that affect the minor cereal market development in HUNGARY. Draft. Hungarian Research Institute of Organic Agriculture. in WP 8 Healthy Minor Cereals FP7 Project

Troccoli - Codianni (2005). Appropriate seeding rate for einkorn, emmer, and spelt grown under rainfed condition in Southern Italy. European Journal of Agronomy - EUR J AGRON. 22. 293-300. 10.1016/j.eja.2004.04.003.

Zaharieva – Monneveux (2014): Cultivated einkorn wheat (Triticum monococcum L. subsp. monococcum): the long life of a founder crop of agriculture. Genetic Resources and Crop Evolution 61(3):677-706

Online resources:

http://alkobeerprojekt.hu/cms/english/organicbreeding/
http://www.einkorn.com/einkorn-history/
https://jovialfoods.com/einkorn/
http://www.vurv.cz/altercrop/einkorn.html
http://www.einkorn.com/einkorn-nutritional-facts/
http://www.einkorn.com/tag/wheat/
https://www.agronomy.org/science-news/ancient-going-nouveau
http://www.einkorn-bg.eu/about-eikorn/

Emmer : Rediscovering ancient grains

Zoltán Dezsény, Christy den Hertog, Dr. Dóra Drexler
Contact:
Hungarian Research Institute of Organic Agriculture (ÖMKi)
Zoltán Dezsény, research associate, zoltan.dezseny@biokutatas.h

ÖMKi
Ökológiai Mezőgazdasági Kutatóintézet
Research Institute of Organic Agriculture | Forschungsinstitut für biologischen Landbau
PARTNER OF FIBL SWITZERLAND

u

1. Emmer production in Hungary and worldwide

In Hungary in 2015 the total area of emmer was under 100 ha. In 2016 the production was expected to double. According to the available data collected through interviews, the total turnover of economic activities related with einkorn and emmer production and processing altogether is estimated around one million Euro in the country.

Apart from Hungary according to the literature emmer is currently grown in Morocco, Spain, the Carpathian Mountains on the border of the Czech and Slovak Republics, Albania, Turkey, Switzerland and Italy. It remained an important crop in Ethiopia. Also it received attention during the recent past in the U.S. as well.

2. Description of the crop

Emmer wheat (Triticum dicoccoides or T. turgidum ssp. dicoccoides) is the wild form of nearly all the domesticated wheat in the world. It is one of the traditional eight founder crops of the origins of agriculture.

The earliest evidence of the use of emmer wheat is from the site of Ohalo II, where hunter-gatherers collected wild emmer about 23,000 years ago, on the shore of the sea of Galilee in what is today Israel. Based on the recovery of charred grains, Ohalo's residents processed the wheat into flour and baked it. Current understandings are that hunter-gatherers began cultivating wild emmer about 11,300 years ago and within 2,000 years had created a cultivated emmer (T. dicoccum).

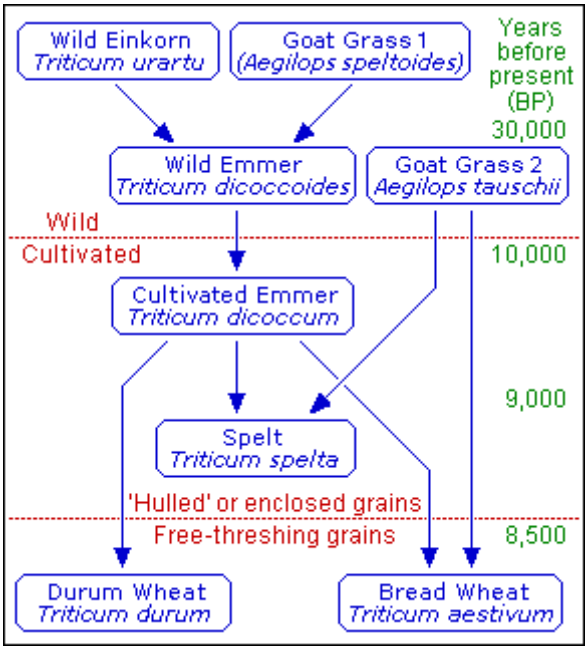


Figure 1. Evolution of emmer
Source: http://www.newhallmill.org.uk/wht-evol.htm

Several studies confirmed a decline of their cultivation (Nesbitt and Samuel, 1996; Heun et al., 1997) which is attributed to dietary and economic changes and the introduction of bread and durum wheat, which are both higher yielding and threshable (Nesbitt and Samuel, 1996).

3. Relationship between emmer and the environment

Emmer is well adaptable to most growing conditions. It grows well on nutritionally poor and podsol soils and does not require special temperature conditions. Its deeper root system makes this plant more resistant to drought compared with other cereals.

Its value lies in its ability to give good yields on poor soils, and its resistance to fungal diseases such as stem rust that are prevalent in wet areas.

Wild emmer wheat is the immediate progenitor of tetraploid and hexaploid cultivated wheats. It is recognized as a source of genes for agronomically important traits. These include genes for large spike and grain size, high grain and protein yield, desirable composition of storage proteins, photosynthetic yield, herbicide response, salt tolerance, disease resistance, profuse tillering, drought tolerance, and presumably genes for other quantitative traits. With the advent ofand easy accesses to, molecular genetics and breeding tools, wild emmer wheat is expected to contribute the full range of its diversity, in qualitative and quantitative traits, for a more sustainable wheat production, especially in the developing world. It is also valuable for its contribution in the safeguard of biodiversity.

4. Breeding

Emmer is an annual, predominantly self-pollinated plant with large oval grains and brittle ears. Tetraploid (2n=28) hulled wheat. Spike is almost always with awns and breaks into double seed spikelets during thrashing. Its height is up to 75-120 cm.

It is a serious potential source of hybridization - it contains several attractive characteristics that could be used by other plants.

Up to date there is limited written evidence available on the characteristics of different emmer cultivars. Seed evaluation and increase of adapted lines along with cultivar development needed for future crop expansion.

In Germany a long-term breeding program is ongoing at the University of Hohenheim by the State Plant Breeding Institute. The main emphasis is to improve susceptibility against lodging and to improve winter hardiness. The Wheat Research Group performs each year about 20 crosses for einkorn and emmer. In a classical pedigree scheme, they select in multiple years for improved traits and perform field testing across whole Germany under conventional and organic farming. Best breeding lines are offered to breeders. The recent varieties in emmer are Ramses, Heuholzer Kolben and Späth's Albjuwel.

In Italy in the last few years, the renewed interest for emmer wheat has stimulated breeding programs releasing improved genotypes obtained not only by selection from landraces but even by crosses with durum wheat varieties.

In Hungary currently only one emmer variety is listed in the National Variety Catalogue: MV Hegyes (2008). It is a result of an organic bredding program by a state organization, the Agricultural Institute, Centre for Agricultural Research at Martonvasar (***MTA ATK Martonvásár*** - branch of the Hungarian Academy of Sciences).

5. Agronomy of the crop

Due to lack of experience there is very limited reliable data available on agronomic details of einkorn production. In the future management practices need to be refined and knowledge transfer on the growing practices of the crop needs to be enhanced in order to broaden the scope of production.

General characteristics of emmer
The cold resistance and the drought resistance of einkorn and emmer are excellent, and both plants can be produced on sandy soils too. In addition, they are resistant to most of the pests and diseases.

Sowing
Cultivation of soil before sowing is very similar to common wheat. High level of nitrogen is avoidable since it increases the risk of lodging. Emmer is sown in well-firmed seedbed in fall/spring, depending on the cultivar and given climate. It is best to sown in spikelets (two seeds) because hulls can protect the germ from soil pathogens. The amount of seed is 3-3.5 million seeds per hectare under 100 % germinating ability. The most suitable depth is 3-5 cm.

Crop Management
This crop is managed during growing season the same way as common wheat.

Fertilization
Emmer can excavate and utilize nutrients very efficiently, therefore it is not advised to fertilize the field even in the case of poor quality soils. On soils that are rich in nitrogen they are susceptible to lodging in rainy years. In the case of poor quality soils, it is advised to perform fertilization with organic manure two years before the production of emmer.

Harvest
To avoid excessive losses of grain during harvesting the combine harvester adjustment is necessary. According to a Hungarian experiment using the same harvester adjustments as during the harvest of rye, but setting a larger vent hole the harvest of emmer did not cause any problems. However, a small proportion of the spiculas (about 15%) was thrashed out, and these cases we found some broken seeds as well (Emődi et el. 2014).

Once harvested grain (spikelets) should be separated from foreign material and other impurities. Spikelets if not used and stored as seed are dehusked. The most common method of the husk removing is abrading by abrasive wheels. There is some risk of damage on outer layer of the seed.

6. Quality aspects of emmer

Emmer wheat, *Triticum dicoccum*, has been traditionally grown and used as a part of the human diet. As requirements for the diversity and quality of food products becoming more demanding, interest in this wheat species is increasing. Emmer has high nutritional value and good quality of grain. The grains contain more crude protein than the grains of modern varieties; protein content varies from 15 to 24 %. Whole meal flour is a valuable source of dietary fiber, in its insoluble forms, cellulose and hemicellulose. Emmer has higher content of vitamins (thiamine, riboflavin, niacin) and it contains high quantities of Ca, P, Zn, Cu, K, Mg and Mn. Lysine and treonin are limiting amino acids. This cereal is easily digestible with no anti-nutrition compounds. Also, it has the lowest glycemic index of all cereal grains.

6. Potential uses of emmer

According to the result of on-farm trial experience in Hungary using the available variety MV Hegyes emmer can be easily integrated into organic farming systems even in areas with poorer production conditions.

Aromatic and highly nutritious porridge can be prepared from emmer. Groats (sausages, soups), flat bread in Italy known as a "focaccia", bakery and confectionary products, and pasta belong among the most common products. Emmer is regarded in Italy as producing the finest quality pasta.

It is extremely versatile for cooking; many uses such pasta, flour, mixes for pancakes, waffles, biscuits, muffins, cookies, crackers; cracked, bulgur, flaked, cereal, etc. Emmer flour can be used as a substitute for wheat flour in most recipes. Also used in deserts, soups and salads. Emmer dishes are now often featured in high-profile restaurants, especially in Europe and on the U.S. East and West coasts.

In Italy, whole emmer grains can be easily found in most supermarkets and groceries, emmer bread (pane di farro) can be found in bakeries in some areas, and emmer has traditionally been consumed in Tuscany as whole grain in soup. Higher in fiber than common wheat, emmer's use for making pasta is a recent response to the health food market.

There is huge market potential for emmer products, but a definite need for education, promotion and product development.

Figure 2: Organic emmer pastas available in Germany, Italy and Hungary

8. Literature cited and useful links

Emődi et al. (2014): Two ancient wheat species, possibilities for the production of einkorn and emmer in organic farming. ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering. Tome XII, Fascicule 2.

Nesbitt - Samuel (1996): From staple crop to extinction? The archaeology and history of the hulled wheats. In: Padulosi, S., Hammer, K., Heller, J. (Eds.), Hulled Wheats, Proceedings of the First International Workshop on Hulled Wheats. Castelvecchio Pascoli, Tuscany, Italy, 21–22 July 1995. International Plant Genetic Resources Institute (IPGRI), Rome, Italy, pp. 41–100.

ÖMKi (2016): Case study report to describe key processes that affect the minor cereal market development in HUNGARY. Draft. Hungarian Research Institute of Organic Agriculture. in WP 8 Healthy Minor Cereals FP7 Project

Troccoli - Codianni (2005). Appropriate seeding rate for einkorn, emmer, and spelt grown under rainfed condition in Southern Italy. European Journal of Agronomy - EUR J AGRON. 22. 293-300. 10.1016/j.eja.2004.04.003.

http://www.naturesorganicgrist.com/new-page-4/
http://archaeology.about.com/od/eterms/qt/Emmer-Wheat.htm
http://www.newhallmill.org.uk/wht-evol.htm
http://www.vurv.cz/altercrop/emmer.html
http://ucanr.edu/sites/Grown_in_Marin/files/131333.pdf
http://eorganic.info/sites/eorganic.info/files/u461/Grain%20quality%20webinar%20final%5B2%5D.pdf
http://orgprints.org/20757/1/InTech-Wheat_growing_and_quality_in_organic_farming.pdf
https://lsa-weizen.uni-hohenheim.de/en/111433

The lupine story in The Netherlands

Boki Luske
Onderzoeker agrobiodiversiteit
Louis Bolk Instituut| Hoofdstraat 24 | 3972 LA Driebergen | 0343-534860 | 06-13041420
b.luske@louisbolk.nl

1. Crop production in The Netherlands

The Netherlands is a relatively small country. Most of the agricultural area (1,8 million hectares) is in use as grassland for dairy production. The area in use for arable cropping is around 710.000 hectares. Mais silage for dairy production is the main crop, followed by cereals, potato and sugarbeet production (Figure 1). The acreage cultivated with legumes which are harvested dry decreased from 47.000 ha in the 1950's until 2.820 ha in 2015. This is around 0,4% of the land which is in use for arable cropping.

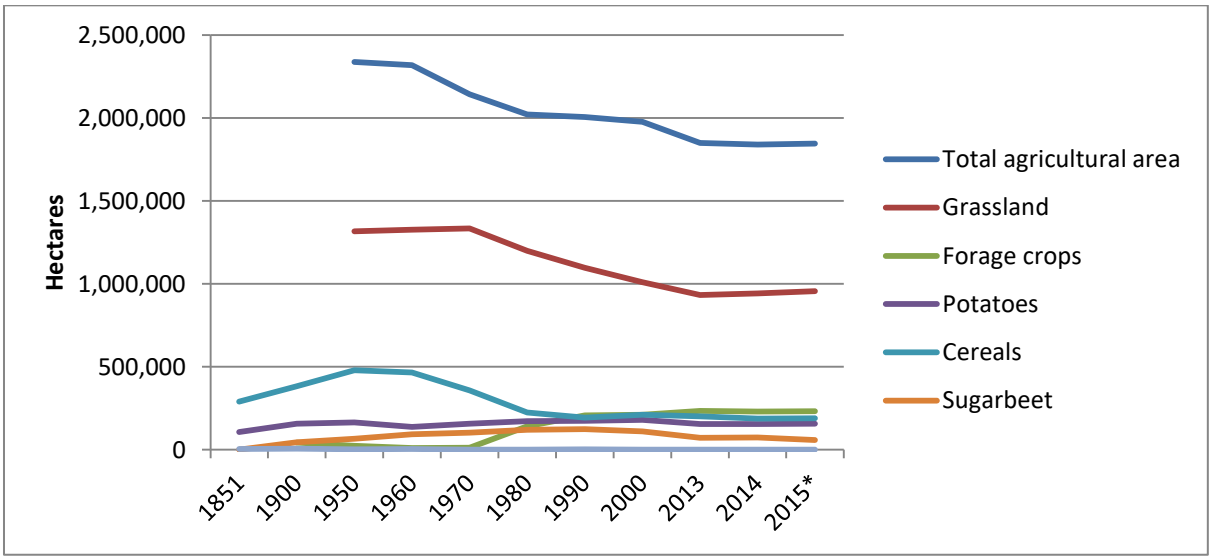


Figure 3. Acreage of the main crops in The Netherlands (CBS, 2017)

At the moment several types of legumes are cultivated in the Netherlands. Freshly harvested legume in the Netherlands is mostly pea (3490 ha) and fresh bean (3280 ha) (Figure 2)

The most important legumes harvested as a dried crop is brown bean (1570 ha), field bean (360 ha), capuchin and grey pea (340 ha), feed pea (270 ha) and pea (200 ha). Sweet lupines is the crop with the smallest acreage of all dried legumes in The Netherlands (80 ha in 2015).

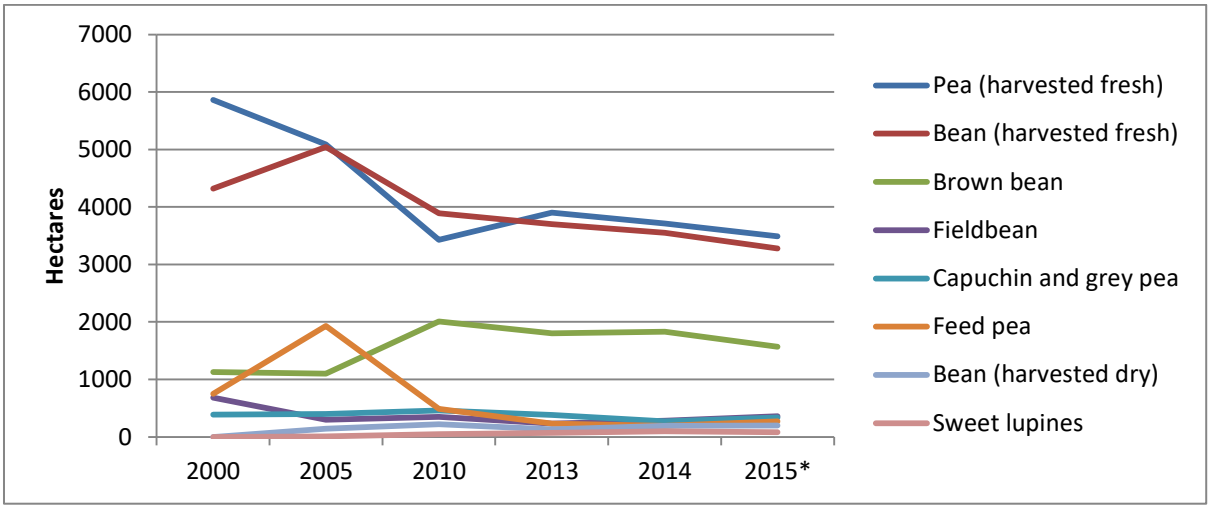


Figure 4. Acreage of different types of legumes in The Netherlands (CBS, 2017)

2. Background of the lupine

Since the beginning of the calender era, lupinee was commonly cultivated in the Mediterranian area. But in the northern region of Europe – including The Netherlands, it is a novel crop, introduced around the start of the 20th century. In this period, yellow lupinee was introduced as a green manure for soil restoration of old heathlands.

Yellow lupines are rather bitter, but during the 20th century, some sweet mutants were discovered. These sweet varieties were interesting, as they simplified the use of lupinee for fodder purposes. Other varieties needed to be soaked and rinsed first, as the presence of secondairy compounds made the seeds unfit for direct consumption by animals. It was in this period that the selection and development of mostly white lupines for the north of Europe began. Due to an outbreak of the disease anthracnose (caused by the fungus *Colletotrichum lupinei*) this development suddenly came to an halt and the interest shifted towards blue lupinee varieties that were less susceptiple for anthracnose.

The Blairhouse agreement was a trade agreement in 1992 between the USA and Europe, which protected the unlimited export of wheat in Europe and unlimited import of legumes from the US. This caused a steep increase of -relatively cheap- soy import from latin america, and a marginalisation of the cultivation of legumes in (Northern) Europe. Only some niche markets of legumes survived like the cultivation of brown beans in the south of The Netherlands. Also the earlier introduction of artificial fertilizers diminished the role of legumes in the crop rotation as a natural fertilizer. All these developments together slowed down the process for the introduction of lupinee as a crop and the required selection and breeding of suitable varieties.

Recently this situation changed. New economies in China and Brazil have an increasing demand for soy. Worldwide the prices for protein feeds for livestock are increasing. In Europe there are raising

concerns for insufficient protein supply for the animal production. At the same time the transition from animal protein (in meat) towards more vegetable proteins in the human diet is promoted, for environmental and health reasons. Therefore there is a growing attention for the production of vegetable protein in Europe itself.

3. Lupines and the environment

As for most legiminous species, lupinee can live in symbiosis with nitrogen binding bacteria in root nodules. The plant can therefore live on nitrogen poor soils. Due to the excretion of root exudates, it also mobilizes phophates from the soil for plant uptake.

Before lupinee developes its protein rich seeds, it blooms and in this period of time it can be visited by bees, bumblebees, butterflies and hoverflies. However this effect is rather small, as the blooming period of lupinee is short.

4. Breeding and seed management

Lupineus is a genus belonging to the legume family (Fabaceae). At this moment there are three lupinee species that are grown as a crop in The Netherlands.

- Blue lupinee or narrow-leaved lupinee (*Lupineus angustifolius*)
- White lupinee or field lupinee (*Lupineus albus*)
- Yellow lupinee (*Lupineus luteus*)

Within every species there are several varieties that are cultivated at the moment. At the moment the white lupinee varieties Boros and Dieta are mostly used and for the blue lupine this is Iris. The search for the best suitable varieties for The Netherlands is still in progress. Small scale projects with on farm field trials are used for further selection and breeding of potential vareities. As not all soils contain the specific nitrogen binding bacteria that lupinee needs, it may be necessary to inoculate lupinee seeds before sowing (Prins 2015).

5. Agronomy

Lupinee requires specific soil conditions. Water drainage and a good soil structure are needed in the first place. But also soil pH is very important. The optimal growing conditions are with an pH in between 4.6 and 6.5, but this differs between the different lupinee species and varieties.

The nitrogen binding capacity and the mobilization of phosphate makes lupinee very suitable in crop rotations and crop mixtures (Jensen et al. 2003). For the Netherlands the search for the

right crop mixture is still ungoing, as it is difficult to find the right varieties of lupinee and for instance cereals or crucifers that have the same timing of ripening.

The last couple of years yields in the Netherlands varied between 1,1 and 3,7 t/ha (15% moisture) for different variaties of white and blue lupinee (Prins et al. 2017).

Seed emergence of lupinee goes slow and therefore the crop has a low level of weed suppression. Lupinee has one deep growing root with lateral roots. Compared to cereals, the root system is less intense, as the plant brings his own nitrogen.

Lupinee is susceptible for various diseases. Anthracnose is the most important one. One should take into account that anthracnose can be transmitted through infected seeds. Other diseases are brown spot disease (Pleiochaeta setosa), botrytis (Boytrytis cinerea) and fusarium (Fusarium oxysporum). The crop rotation should be at least 1:4 to limit the development of diseases (Leijsen 2011). The crop is susceptiple for insect damage from larvae of coleoptera (*Agriotes lineatus*), flies (*Oscinella frit*) and musquitos (*Tipulidae*).

6. Composition and quality factors

Lupinee seeds contain high levels of protein and complex carbohydrates (fibres). The crop matches very well with human dietery needs. However, the seeds also contain certain levels of anti-nutritional factors (secondary compounds) like alkaloides, which differs significantly between lupinee species and existing varieties.

7. Uses

The different lupinee varieties can be used for different purposes:

- For human consumption (Prins et al 2017)
    - Lupinee meal is used in baking products and bread as a substitute for soy meal.
    - After processing, protein concentrates from the lupinee beans are used in for instance snacks, as it improves the 'bite', structure and preservability.
    - In The Netherlands, lupinee is used for a scala of food innovations, where the proteinrich bean is used for the development of meat substitutes (Meatless http://www.meatless.nl/en/ , Vivera http://www.vivera.com/en/)
    - The crop has the potential to be used in the development of nichemarkets for healthy and environmently friendly protein products

    Recipe to be included: http://powerpeul.nl/en/krokantelupineeburgers.html

- For animal consumption

- Lupinee is a potential protein rich animal feed (substitute for soy). At this moment however, yields need to be increased and more suitable varieties for different soil types are needed

- As a green manure in the crop rotation

8. Interview with André Jurrius, Ekoboerderij de Lingehof, Hemmen, NL 19 of April 2017

How and when did you came across lupinee as a crop?

In 2008 the Vegetarian Butcher in Amsterdam contacted me for the cultivation of lupinee. He wanted to have organic lupinee from the Netherlands fort he production of new meat substitutes. The first year I cultivated only 6 hectares of blue lupinee. Over the years the acreage with lupinee on my farm grew. Besides blue lupinee, I also cultivate white lupinee, which mostly goes to Powerpeul. Powerpeul is a start-up that promotes lupinee as a food crop among citizens. At markets, trade-shows and events, lupinee is sold in small bags. At the same time the consumers are informed about possible uses, recepies and the advantages of lupinee for the environment and human health.

Why would you recommend the cultivation of lupinee to other farmers?

The cultivations of lupinee is relatively simple. The crop fits very well in a crop rotation, because it is a leguminous species. Lupinee can be sowed quite early in spring, which makes it be easily combined with other on-farm activities. As lupinee blooms abundantly, the crop has a huge impact on people that pass by: the crop is a colourfull showpiece for the farm. Apart from all this, as a farmer it is very interesting to be part of the development of new crops. On the other hand, the economic yield of a hectare of organic lupinee is around the same as for organic wheat. That is not a lot, but the advantage of lupinee is that is also deliveres nitrogen to the following crop.

Which challenges are there for the cultivation and further selection of lupinee?

There are still a number of aspects of lupinee which could be improved. In the first place, selection for plants that have a shorter growing season, so the seeds ripen earlier. That would be advantagious regarding the Dutch climatic conditions. Secondly, the yield per hectare could be improved. Thirdly, a fast early plant stage development is important, which will enhance weed suppression.

Which developments are needed in the production chain to increase the demand for lupinee?

Untill now, large scale projects with lupinee never took place. Therefore the production and demand remains in the pioneering phase. With a large scale project, bigger steps can be taken in further selection and production chain development. In that case it might also be possible to further develop lupinee as a feed stock.

9. Reference and links

Nirenberg HI, Feiler U, Hagedorn G (2002). Description of Colletotrichum lupinei comb. nov. in modern terms. Mycologia 94(2): 307–320.

Prins, U. (2015) Lupinee voor menselijke consumptie; Teelthandleiding. Louis Bolk Institute, Driebergen The Netherlands. http://www.louisbolk.org/nl/publicaties/publicatie/?pubID=3066

Prins, U, van de Vijver, L & P Voshol (2017). Lupinee; Een gezond alternatief voor boer en burger. Louis Bolk Institute, Driebergen The Netherlands.

Jensen CR, Joernsgaard B, Andersen MN, Christiansen JL, Mogensen VO, Friis P & CT Petersen (2003). The effect of lupines as compared with peas and oats on the yield of the subsequent winter barley crop. European Journal of Agronomy (..): 1-14

Leijsen A van (2011). Teelthandleiding Lupinee. DLV Rundvee advies.

Lopez-Bellido L & M Fuentes (1986) Lupine crop as an alternative source of protein. Advances in Agronomy 40: 239-293.

http://powerpeul.nl/en/

https://www.thevegetarianbutcher.com/

https://www.cbs.nl/en-gb

Figure 1. Anthracnosis in White lupin. (Foto Udo Prins, Louis Bolk Institute)

Figure 2. Field with white lupin Boros (Foto Udo Prins, Louis Bolk Institute)

Figure 3. Blue lupin with white flowers. (Foto Udo Prins, Louis Bolk Institute)

Lupins in Switzerland

Christine Arncken
Monika Messmer
Forschungsinstitut für biologischen Landbau FiBL | Ackerstrasse 113 | Postfach 219
5070 Frick | Schweiz | Tel +41 62 865 72 72
| christine.arncken@fibl.org | www.fibl.org

1. Major and minor crops in Switzerland

1.1 Agriculture and major crops in Switzerland

Switzerland has a size of 41'285 square kilometres of which 36 % are farmland. As a large proportion of the farmland lies on the slopes of the Swiss Alps and Swiss Jurassic mountains, grassland and dairy production play a dominant role in Swiss agriculture. The agricultural area (seasonal pastures in the higher mountains excluded) is about 1 million hectares, 58 % of which is permanent grassland, only 38 % are arable, mainly concentrated in the Swiss plateau region between the Jura Mountains and the Alps (Agristat 2017).

Labour and machinery are expensive in Switzerland and much above EU levels, leading to high prices for agricultural crops and a high proportion of import. However, direct state payments and demand for high-protein, Swiss varieties allow for bread wheat production on 80'000 ha, rendering 315 000 to 400 000 tons per year, which is about 70 to 85% of the country's demand. Due to the strong role of dairy production and animal husbandry, much of the arable land is cultivated for growing feed: grass-clover mixtures, maize for silage or grains, and feed cereals (mainly barley and triticale). Table 1 gives an overview over the area covered by the main arable crops.

About 14 % of the farmland are cultivated organically. Management differences between organic and conventional farming are smaller in the mountain areas than they are in the lowland, but price

differences are significant. Consequently, many mountain farms have been converted to organic, leading to an even higher proportion of grassland within the organic sector.

Table 1: Overview over arable land and area under organic regime in Switzerland (simplified figures from BFS 2017a,b and Willer 2017)

	Hectares	% of whole country	Organic (ha)	% of total
Switzerland size	4 100 000	100,00		
Switzerland farm land	1 500 000	35,40		
Pastures in the Alps and Jurassic mountains	430 000	10,50		
Utilized agricultural area (without mountain pastures)	1 050 000	25,40	140 000	13,5
Permanent (natural) green land (lowland)	600 000	15,00	110'000	18,0
Arable land	400 000	9,6	28'000	7,1

Within the organic sector with its arable acreage of 28'000 ha (in 2016), the four main crops covering areas over 1'000 ha are grass-clover mixtures, bread wheat, spelt, and maize for silage. Vegetables are grown on 2'000 ha. Crops covering areas between 500 and 1'000 hectares are barley, maize for grains, wine and potatoes. Fruits, peas and triticale cover 450, 400 and 400 ha, respectively. Less important crops covering an acreage between 200 and 300 ha are rye, soybeans, sunflowers, and rapeseed. This overview over the main crops only reflects the acreage but not the financial output. In terms of financial production, vegetables, potatoes, fruits and wine play the most important role.

Table 2: Main crops and less important crops according to acreage in Switzerland, under conventional and organic regime 2015, 2016 (simplified figures according to: Schweizer Bauernverband 2017, Willer 2017, Clerc et al. 2015).

Category	**Crop**	**Acreage (ha)**	**Organic (ha)**
Feed	Ley (grass-clover mixtures)	126 000	12 000
	Maize for silage	46 000	1'600
	Barley (for feed)	28 000	1 000
	Maize for grains	15 000	600
	Triticale	8 000	400
	Wheat (for feed)	6 000	170
	Peas	4 400	400
	Faba beans	560	180[1]

Bread cereals	Bread wheat (winter and summer)	76 000	4 000
	Spelt and other bread cereals (Emmer, Einkorn…)	6 000	1 300
	Rye	2 000	300
Special	Fruits	31 000	450
	Rapeseed	23 000	200
	Wine	16 000	800
	Potatoes	11 000	600
	Vegetables	11 000	2 200
	Sunflower	4 600	280
	Soybean for human consumption	1 800	300

[1]: in 2014

1.2 Minor crops in Switzerland

For many farms in Switzerland, direct marketing of products is an important part of their economic strategy, and finding market niches helps to realize this. This is especially true in organic farming, the regime under which most of the minor crops are grown. Biofarm Genossenschaft, a committed trade organisation, tries to encourage farmers to grow minor crops for human consumption and is engaged in advice and trade of e.g. Swiss grown millet, oat flakes, rapeseed, sunflower oil etc. This helps to diversify the agrarian landscape and to reduce imports. – Table 3 gives an overview over the acreage of minor crops in Switzerland.

Table 3: Acreage and production amount of minor crops (conventional and organic) in Switzerland (2015) (according to Schweizer Bauernverband 2017, Erdin 2017, and Swissgranum 2017).

Crop	Acreage (ha)	Production (t)	Organic (ha)	Production (t)
Linseed	121	297	60	n.i.
Millet	63	172	30	n.i.
Emmer, Einkorn	67	500[1]	23	n.i.
Faba beans	556	2 000[1]	n.i.	n.i.
Lupins	105	311	13	n.i.
Lentils	70	n.i.	n.i.	n.i.

[1] Estimation by Swissgranum for 2017; n.i.= no information

2. The lupin story

2.1 Origin and history of lupins

The big, flat White Lupin (*Lupinus albus*) seeds have been eaten in the Mediterranean area since the time of the Egyptian pharaohs. Traditionally, they are eaten as whole kernels, washed, cooked and conserved in salt brine, similarly to olives, as a snack to accompany beer (ital. Lupini, span.

Altramuces, port. Tremoco, egypt. Termiz). Through the procedure of soaking and washing lupins in brine over several days and subsequent cooking, the bitter and poisonous alkaloids in the seeds are removed.

Fig.1: Lupini sottovuoto (Source: www.agraria.org)

Fig.2: Altramuces sold on the market (Quelle: commons.wikimedia.org)

In ancient Rome, authors already mentioned the fertilizing and soil improving effect of lupins. In the 18th century, King Frederick the Great of Prussia (Germany) tried to introduce lupins in Prussia in order to improve the poor, sandy soils, but the bitter green manure crops were never grown extensively north of the Alps. With the rise of modern plant breeding in the first third of the 20th century, German breeders started to screen thousands of single plants systematically for low alkaloid content. The success was a breakthrough and the beginning of Sweet Lupin breeding. It started with White Lupin, but later, also the more delicate wild plants Blue Lupin (*Lupinus angustifolius*) and Yellow Lupin (*Lupinus luteus*) were bred for low alkaloid content. Today, all three varieties are cultivated for feed and, to a lower proportion, for food and food ingredients such as protein isolates.

Fig.3: White lupin (*Lupinus albus*)

Fig. 3: Blue lupin (*Lupins angustifolius*) (here,a white-flowering cultivar)

Fig.4: Yellow lupin (*Lupinus luteus*)

After the Second World War, when cultivation of pulses became more and more unprofitable for farmers and imports of soybeans increased, lupin breeding played only a marginal role in the breeding companies. At present, new awareness of the importance of pulses, and especially home grown pulses, rises in Europe and all over the world. Pulses can contribute to a healthy diet as well as to a diversified landscape and crop rotation. Many projects started in the last decade in order to

revive and support pulse growing. The 68th UN General Assembly declared 2016 the International Year of Pulses in order to heighten public awareness of the nutritional and ecological benefits of pulses for food security and nutrition.

Sweet lupins can render high quality protein with an amino acid composition more valuable for animal or human nutrition than that of peas and faba beans. For this reason, and due to their lower need for warm spring temperatures, lupins are sometimes called the “soybeans of the North”, and related to the massive rise of Russian lupin production in recent years, one could even better call them the “soybeans of eastern Europe”. However, it is important in lupin breeding and cultivation that alkaloid levels are always controlled and kept at a minimum level.

Lupin growing experienced a great drawback when anthracnose, a disease caused by the fungal agent *Colletotrichum lupini*, appeared in the 1990s. This has led to a shift from white to blue lupin in Germany and Poland because blue lupin is less susceptible and renders better yields at the moment despite its lower overall yield potential. Yellow lupin, the most susceptible of the three Old World lupins, more les completely vanished from European fields except from some regions in Poland. Efforts in resistance breeding started, but until now, no truly resistant cultivars are on the market.

2.2 Lupins in Switzerland

To our knowledge, lupins have no tradition in Switzerland, neither have they been introduced to the country from the northern neighbour Germany, the western neighbour France nor from the southern neighbour Italy, where since Roman times lupins have been cultivated for human consumption.

In the late 1980s, several authors conducted trials with lupins and discussed the possibility of introducing them to Switzerland (Reinhard and Gehriger 1988, Perler 1991). Lupins turned out not to be able to compete with other crops under the given circumstances. When concern about the amounts of imported protein crops into Switzerland and about GMOs arose in the public awareness, lupins and soybeans were again tested in Switzerland within a European INTERREG trinational project (DE, FR, CH). Field trials with white lupin (Lupinus albus) and blue lupin (L. angustifolius) were performed and seed treatments against anthracnose, the presently most important fungal disease of lupins, were tested (Nawrath and Vetter 2001). One of the lupin pioneers in Switzerland was the organic farm bioböhler in Mellikon AG who produced a coffee substitute from white lupins in 1990 but had a devastating experience with anthracnose the following year. The farmer also run a lupin trial on his farm for his diploma thesis (Böhler 1998). After the experiences of the late 1908s, advisors no more recommended white lupin for cultivation in Switzerland. Another barrier for growing white lupins is the long ripening period in late summer when sometimes rainfalls stop the harvest season before ripening is finished.

Blue lupin, however, proved to have a much earlier ripening time and better resistance to anthracnose. FiBL produced a first technical leaflet on organic lupin growing in 2002
(Dierauer and Böhler 2002). Thus, blue lupin growing was recommended by advisors and feed mills, but without much success. Lupins were only grown on 50-100 ha in Switzerland in the past ten years (FAOSTAT 2017), and among the few farmers who know lupins it is a widespread opinion that lupins “don’t grow properly” and cannot compete with weeds.

After the organic grain legume acreage in Switzerland had decreased to nearly zero in the 1990s (Dierauer et al., 2017), awareness of this loss in diversity and knowledge arose in the first years of the 21st century. Like in many European countries, interest in and engagement for domestic protein feed

grew again (Lehmann 2014) and public support for grain legumes was implemented (Bundesamt für Landwirtschaft, 2017). Research on grain legumes became also supported by private companies. Supported by the biggest retailer in Switzerland, Migros, and several feed mills, the FiBL extension service started the project “protein made in Switzerland” (FiBL, 2016) and set up on-farm field trials in 2008/09. It was the main goal of the trials to improve organic pea and faba bean production. Mixed cropping of peas and barley proved to be a successful strategy for organic production to overcome weed problems, but in the first years it was difficult to sell the harvest of the pea-barley mixture. This changed when two organic feed mills decided to invest in machinery for separation of the harvest mixtures. When they signalled that they were ready to buy harvest mixtures of grain legumes and cereals, the organic mixed cropping area started to grow again – up to over 500 ha in 2014 (Dierauer et al., 2017). Another factor for this success was the direct federal payment of 1000 Swiss francs per hectare not only for pure stands of grain legumes but also for mixed cropping, as long as the share of legumes in the mixture was higher than 30 percent (since 2014. Before, the minimum share had been 50 percent which very often could not be achieved).

In 2012, trials with mixtures of blue lupins and oats were added. Lupin growing was reconsidered given the fact that lupins were the third European domestic grain legume after peas and faba beans. Lupin is an interesting supplement to the range of grain legumes due to its high protein content and due to it being doubtlessly free from genetic engineering. The FiBL crop science department took up the lupin subject in 2014 and started a small-plot trial with lupins in order to test cultivars and cropping partners of blue and white lupins and to start anthracnose resistance pre-breeding of white lupin.

Through field days, newspaper articles and other dissemination activities, FiBL tried to make lupins known better in Switzerland.

At present (2015), only 105 ha of lupins are grown in Switzerland (BLW 2016). FiBL hopes to be able to promote lupin growing in Switzerland. Through field trials and media activities lupins are made better known, cultivars are tested and mixed cropping regimes are tried in order to suppress weeds.

3. Lupins and environment

3.1 Soil

The beneficial effect of lupins on soil fertility has been observed since the Roman times and was the main reason for the Prussian King Frederic the Great of Prussia to prescribe lupin growing in the 18th century in the northeastern parts of Germany. The ability of the lupin roots to fix nitrogen with the aid of the symbiotic bacteria Bradyrhizobium lupini and to mobilize phosphorous from deeper soil layers has often been described (Lucas et al. 2015, Dissanayaka 2016, Howieson et al. 1998). Through these traits, lupins are interesting crops for poor soils or low nitrogen input conditions. Organic farming always has to manage limited nitrogen supply, which makes legume growing essential. Diversity in legume crops helps to minimize pest and disease risks.

Lupins are sensitive to alkaline soils and can only be grown at a pH lower than 7. Free calcium in the soil interfers with the nitrogen fixing metabolism of the root nodule rhizobacteria and leads to chlorosis and iron deficiency. White lupin is more tolerant in this trait than blue lupin.

Despite their ability to ameliorate soils with their deep and active roots, lupins, especially blue lupins, cannot be grown on compacted soils, their roots being dependent on the oxidative process in the nodules.

3.2 Climate, Pests and Diseases

Being the protein crop with the best protein quality after soybeans, lupin can be sown much earlier in spring than soybean due to its higher cold tolerance, i.e. in March, and it can be grown up to an altitude of ca. 600m, whereas soybeans can only be grown in the warmer lowland regions. In France, a shift from spring-sown to autumn-sown white lupins can be observed currently (Moquet 2014), but in Switzerland, winter forms are not sown at present due to bad overwintering of the French cultivar Lumen in a field experiment in the winter 2012/2013 (Dierauer et al. 2013). However, spring-sown varieties have a good frost tolerance, and especially for white lupin, cold spring conditions help to stimulate generative development.

For white lupins having a vegetation period that is about six weeks longer than that of blue lupins, early maturity is a crucial trait because rainfall and moisture can lead to delayed harvest in autumn, enhancing the risk of crop destruction through anthracnose, which at present is the most important fungal disease in lupins. Another problem associated with the late maturity of white lupins is the risk of infestation with late, unwanted weeds, a problem that FiBL tries to address with mixed cropping trials for weed suppression.
Blue lupins can usually be harvested in late July or early August, which allows mixed cropping with cereals like oats or triticale if suitable cultivars are chosen.

Regarding the fact that the climate in Switzerland is currently changing faster than in other parts of Europe and that summer droughts have occurred regularly during the last decades (Bundesamt für Meteorologie, 2014), the ability of lupins to cope with dry conditions makes them a putatively interesting crop for the future.

Currently, anthracnose is the main problem in lupin growing, but as the cultivated area increases, other fungal diseases, viruses and pests like lice and lupin weevil (*Sitonia*) may arise.

3.3 Aesthetical and Ecological role for the landscape

Lupins have beautiful flowers enriching the green, maize-dominated aspect of the Swiss lowland landscapes. In the Swiss national agricultural policy 2014-2017, canton-based payments for crops that improve the aesthetical and ecological quality of the landscape have been introduced (Bundesamt für Landwirtschaft 2017b). In most cantons, such payments can be obtained for lupin growing. Many different insects can be observed in a flowering lupin field, especially bumblebees and other wild bee species, but also honey bees, several beetles and flies. Honey bees seem to profit more from lupin pollen than from nectar (Klein 2017).

Fig. 5: besides bumblebees, honey bees regularly visit lupin fields, loaded with pollen pellets.

4. Breeding and seed management

When modern sense lupin breeding started about one century ago, a narrow genetic bottleneck was created through the search for low alkaloid ("sweet") lupins. All breeding material was crossed with the same few "sweet" breeding lines and afterwards selected for soft white seed and low pod-shattering, enhanced yield and reduced flowering time and branching architecture. All these traits remaining important breeding goals, current breeding in white lupin is especially focused on anthracnose resistance (Wolko et al., 2011).

Breeding of white lupins is performed in Australia and has led to the release of cultivars with an improved anthracnose resistance there. In the Old World, white lupins are bred in France (Jouffrai-Drillaud), in Poland (Hodowla Roslin), in the Ukraine, in the Czech republic (Oseva), and in Germany (Saatzucht Triesdorf). Yellow lupin is bred in Poland (Hodowla Roslin) and some pre-breeding is done in Germany (Julius-Kühn-Institut). Blue lupin is bred in Poland (Hodowla Roslin), and in Germany (Saatzucht Steinach). The Chilean breeding company Semillas Baer also introduces its cultivars of blue and white lupin into the German registration system. Newly started, organically oriented breeding projects for white lupin exist in the Netherlands (Louis Bolk Institute) and Switzerland (FiBL).

Lupins being predominantly self-pollinating, breeding has normally been performed through pedigree selection of pure lines, but suffers from relatively high outcrossing rates of 8-10 % (Wolko 2011, Australian Government 2013, Green et al., 1980) which make isolation of flowering plants through insect and pollen proof material necessary. In seed production, good practice minimum distances between different cultivars are 100-200m (McNaughton 2017, Heinz 2016). This is important because cross-pollination may lead to increased alkaloid levels in the seed even if it takes place between two low-alkaloid cultivars.

One of the main constraints in lupin seed production is the fact that anthracnose is transmitted via seeds. An agar-based method for detection of seed infestation was established at the beginning of the century (Feiler and Nirenberg 1998), but the test takes three weeks and did not always render reliable results in practice. For white lupin, it is at present not possible to produce healthy seed organically as long as a fast, reliable seed testing method is lacking. Organic White lupin growers in Germany have to use conventional, untreated seed. (No white lupin is grown in Switzerland at present). For this reason, FiBL started to investigate in a qPCR-based method for seed analysis in 2016 (Szuszkievicz 2016), a work that is currently continued in the scope of a phd thesis.

5. Agronomy

Cultivation instructions for lupins can be read in many publications – printed or published in the internet (Böhler and Dierauer 2011, Gesellschaft zur Förderung der Lupine 2017, Schachler et al. 2016, Ökolandbau.de 2015, Spiegel et al. 2014, White et al. 2008). Therefore, these are not repeated here. As most instructions that can be used in Switzerland have been published in Germany, our main questions refer to differences between the two countries and can be posed as follows:

- Can lupins be grown on Swiss soils at pH 6,5 to pH 7 or are these too alkaloid?
- Which cultivars are suitable?
- Can lupins cope with the high Swiss rainfalls of 1000-1300 mm/year?
- How early can lupins be sown?
- Can mixed cropping help to defend lupins against weeds – and if yes: what partners can be recommended (species, cultivar) at what sowing densities?
- How does anthracnose develop under Swiss conditions?
- Do alkaloid levels stay below the thresholds of 0.02 % for human consumption or 0.05 % for feed under Swiss conditions?

These questions are subject of our lupin trials. As no extensive lupin trials have been run before in Switzerland, we will have to refer to our own results once we can rely on several years' experience. This will be done in the final report of the DIVERSIFOOD project.

Fig. 6: a ripe field trial with white lupins in 2015

Fig.7: harvesting the white lupins in 2015: how much weeds can be seen?

6. Quality aspects

In ancient and historical times, lupins were mainly grown for human consumption. The traditional, snack-like preparation of lupins as whole seeds illustrates their special taste and nutty consistence, which is quite different from the rather mealy consistence of other cooked pulses like peas, chickpeas, red beans, and lentils. This consistence is due to the high protein and relatively high oil content and virtual absence of starch in the seeds. Table 4 gives a comparison of the main nutrients of blue and white lupins with soybeans and the domestic pulses faba beans and field peas.

Table 4: nutrients of grain legumes compared to soybean meal. Reference values from feeding tables (Source for pea, faba bean, soybean, and blue lupin: Weber et al. 2016; for white lupin: Roth-Maier et al. 2004; for soybean meal: Bellof et al 2016) and field samples taken in Germany in 2015 (in brackets (Weber 2016)).
Units in g/kg original substance, related to a dry matter content of 88%.

	Dry matter	Crude protein	Crude fat	Crude fibre	Starch	Lysin	Methionin
Blue Lupin	880	295 (289)	48 (56)	143	49 (40)	14,7 (14,4)	1,8 (1,9)
White Lupin		328	77	114	74		
Soybean meal (post oil extraction)		449	13	59	69	27,3	5,9
Soybeans	880	356 (324)	181 (196)	55 (66)	52 (62)	21,8 (21,1)	4,8 (4,8)
Faba bean	880	260	14	86	390	16,3	1,8
Pea	880	200	13	57	430	15	1,9

An important quality trait of modern “sweet” lupin varieties is their low content of the bitter, toxic alkaloids. Cultivars containing less than 0,05% of alkaloids in the dry matter are called “low alkaloid” in breeders’ terminology; cultivars containing less than 0,02 % are called “alkaloid free”. These values are regarded as the thresholds under which lupin intake is harmless, and they are required for feed (0,05 %) and food (0,02 %). Since alkaloid levels may vary with year, cultivar and soil conditions, they have to be always controlled. Even the low threshold levels of alkaloids can be detected sensorically (Bundesinstitut für Risikobewertung 2017). Therefore, the preparation method of lupins is important in food factories as well as in private kitchens for the acceptance of the products.

Another critical issue of lupins is their allergenic potential. Especially persons allergic to peanuts or soybeans have to be careful when trying lupins. Therefore, lupin ingredients must always be declared in food.

Lupin protein is of high quality and rich in lysine and arginine, but, like all legumes, has a low level of sulphur containing amino acids such as methionine and cysteine. Thus, lupins become more valuable if combined with methionine rich foods like sesame seed, nuts, or cereals. Lupin oil is rich in unsaturated fatty acids, especially oleic acid and linoleic acid. Lupins are also rich in insoluble fibre, predominantly non-starch polysaccharides that have a less flatulent effect than those of other pulses. Recently, several studies have shown beneficial health effects of lupins in human nutrition (Bähr et al. 2014, Jahreis et al. 2016). Bread enriched in protein and fibre derived from lupin kernel flour resulted in significantly higher self-reported satiety of test persons, and in lower carbohydrate intake at the following meal. Systolic blood pressure and pulse pressure were significantly reduced in overweight test persons when lupin bread was consumed compared to white bread (Lee 2006). Further health related advantages are cited in Gesellschaft zur Förderung der Lupine 2017.

7. Uses of lupins

7.1 Green manure

One of the traditional uses of lupins is green manure. Due to their environmental properties, Lupins can help prepare uncultivated or disturbed soil for cultivation. For this purpose, bitter lupins are grown due to their greater vigour in growth. Mostly, they form one component of a rapidly establishing and deep rooting mixture. Thus, farmers growing sweet lupins should make sure that no bitter lupins are grown near their fields. In France, bitter lupin growing is forbidden (Harzic, 2017).

7.2 Feed for pigs, poultry, cattle, and fish

Lupin seeds are the second richest legumes in protein after soybeans and thus valuable for feed, but if compared to soybean meal (post oil extraction) which at present is regarded the ideal main protein ingredient of feed mixtures for all animal groups, there are some typical differences (Table 4).

In monogastric animal feeding (pigs and poultry) it is important to keep in mind the low level of sulphurous amino acids, especially methionine, because it is essential for them and cannot be synthesized by the organism. Thus it is recommended to supplement methionine in feed mixtures or, as in organic farming where no isolated amino acids are allowed, to supplement methionine through food mixtures containing extraction cakes from rapeseed, sunflower, linseed, sesame etc. (Verbund ökologische Praxisforschung 2014). As pigs and poultry are sensitive to alkaloids, it is also important to keep the lupin seeds below the threshold of 0.05 % alklaloid content. Given the modern blue lupin cultivars currently available on the European market, this is not a problem if certified seed is sown.

For cattle feeding, lupins can replace soybeans completely if the composition of the feed mixture is adequately adapted. The higher fat content compared to soybean meal has to be kept in mind. However, many organic actors try to encourage farmers to make a shift in cattle feeding from high energy and high protein diets towards diets consisting exclusively of roughage like grass, hay and silage.

In Switzerland, little experience with feeding lupins to lifestock exists. However, since the cultivation of peas, faba beans and lupins has increased during the past years in Germany due to the new EU Common Agricultural Policy (CAP), several new feeding recommendation booklets have been elaborated there (Weber et al. 2016, Bellof et al. 2016, Gesellschaft zur Förderung der Lupine 2017, Losand 2016).

Lupins are also suitable as fish food in aquaculture. In Germany, a project started in 2015 to investigate and improve lupins as fish food at the Alfred Wegener Institute (Helmholtz centre for polar and marine research) (Weiss and Fitzel, 2015). In Chile, a large proportion of the lupins grown there are used in aquaculture as feed for salmon (von Baer, 2014).

7.3 Food

In the vegetarian/vegan food sector, which currently evolves with double-digit growth rates, more and more lupin products can be found in wholefood/organic shops and in specialized webshops, whereas in the bigger retailers lupin products can hardly be found to date. To date, all lupin products that can be bought in Switzerland are imported, most of them from Germany. There exists no lupin processing in Switzerland yet, but some businesses are considering to try out lupin recipes. (Bio Partner, 2016)

All foodstuffs that can be made out of soybeans, like tofu, tempeh, “soy sauce”, vegan milk and meat substitutes, can also be produced from lupins. Due to the lower protein content compared to

soybeans, the protein concentration process during tofu production generates a large amount of unwanted by-product (Okara, or lupin fibres, lupin seedcoats and lupin oil). In addition, the consistency of lupin tofu cannot compete with soy tofu to date, so isolated lupin protein is rather used for milk substitutes, as an excellent emulsifier, and as an ingredient in many protein rich functional foods especially for athlete nutrition.

In the organic sector, products containing the whole seeds rather than only the lupin proteins prevail. These are e.g. spicy bread spreads; lupin flower as an egg substitute for baking; couscous-like coarse lupin meal for “vegetarian Bolognese sauce”, tabbouleh or vegetable fillings; lupin noodles; meat substitutes; shredded, roasted lupin seeds as a caffeine free coffee substitute.

Many lupin products are not only soybean free but also gluten free, offering an alternative to persons suffering from respective allergies or intolerances.

7.4 Image and Consumer acceptance

To date, lupins are nearly unknown in Switzerland, but during the last years, some articles about lupins appeared carrying a positive image of the crop. Sympathetic traits are the ecosystem services and beautiful flowers of lupins, the absence of genetic engineering in all lupins traded on the market, and the positive health aspects of their analytical constituents. The same is true for Germany where lupins are better known but not Exceptions like Felix Olschewski’s blog “Urgeschmack” exist but form a minority (Olschewski 2014).

7.5 An interview with a Swiss lupin stakeholder

Interview with Christian Rytz from the feed mill Mühle Rytz, in Biberen (canton Bern). A family business with a long tradition, not only a mill for feed and human consumption, but also a cereal wholesaler with a strong organic branch active in the Swiss organic market since 1981. It is run by family members in the 9th generation. The interview took place per e-mail in late autumn 2016.

CA: Mister Rytz, at FiBL we work with lupins, and with our project we want to make lupins known in Switzerland and to test practicable cultivation regimes for lupins in organic farming (first for blue lupin).
CR: This is important.
CA: We also want to improve anthracnose resistance in white lupins.
CR: That would be brilliant!
CA: In 2015 and 2016, some articles about lupins and even a small film were published in Swiss media, we organized field days and information booths. Now I would bei intersted to know whether this year more farmers offered lupins to you?
CR: No.
CA: Did you buy Swiss-grown lupins in 2016 and if yes, how much? And if yes, was it from pure stand or mixed cropping?
CR: I only bought the harvest from a lupin field trial, from mixed cropping with oats.
CA: was the lupin quality of this batch satisfying?
CR: yes, the lupins were good and, contrary to our experience from faba bean/oat mixtures, also the oats. Oats from mixed cropping are often greyisch and light and don’t really meet our quality

requirements. The problem is that the oats reach maturity earlier than the legumes.
CA: In which feed mixture would you preferably use lupins?
CR: lupins are suitable as a premium protein source for all feedstuffs, be it poultry, cattle or pigs. In our opinion, the price is the problem. It doesn't allow the farmers to obtain a satisfactory contribution margin. Lupins are in direct competition with importet protein crops. There is no tariff protection.
CA: Would you buy more lupins in future so that we can recommend this to the farmers?
CR: We can buy lupins. However, as long as there are only small amounts we pay the (lower) pea price for them and use them mixed with peas. Should the amounts rise, we could integrate them separately into our formulations. But this would need at least 50t per year. Then we could also pay more for the lupins than for the peas due to the high protein content.
CA: So here we have the typical start-up difficulties and the farmers should join up to bring about the amount of 50 t... – Mr. Rytz, thank you for the interview.

8. References and links

Agristat 2017: https://www.landwirtschaft.ch/wissen/agristat/ (last visit 07.02.2017).

Arncken, Christine (2016) : Blaue Lupinen: 2015 top, 2016 passabel. In : Bioaktuell 10/2016, S.30.

Arncken, C; Böhler, D; Winzeler A; Rathgeb, U; Dierauer, H; Clerc, M. Hohmann, P; Messmer, M. (2016): Mischkultur mit Leguminosen im biologischen Anbau. Lecture given at the conference for the conservation and sustainable use of plant genetic resources for food and agriculture, (PGREL Fachtagung zur Erhaltung und nachhaltigen Nutzung von pflanzengenetischen Ressourcen für Ernährung und Landwirtschaft), Do, 17. November 2016, Inforama Rütti, Zollikofen bei Bern.

Arncken, C; Roggli, M; Messmer, M; Böhler, D; Hohmann, P. (2015): Stand der Forschung bei Lupinen. Presentation given at the organic arable crop conference of FiBL in Frick, 19.1.2016 in Frick (CH).

Australian Government, Department of Health and Ageing, Office of the Gene Technology Regulator (2013): The biology of Lupinus L. (lupin or lupine). Version 1. April 2013. URL: http://www.ogtr.gov.au/internet/ogtr/publishing.nsf/Content/biologylupin2013-toc/$FILE/biologylupin2013-2.pdf (last visit 20.08.20917)

Bähr M, et al., Consuming a mixed diet enriched with lupin protein beneficially affects plasma lipids in hypercholesterolemic subjects: A randomized controlled trial, Clinical Nutrition (2014), http://dx.doi.org/10.1016/j.clnu.2014.03.008

Bellof, G.; Halle, I.; Rodehutscord, M. (2016): Ackerbohnen, Futtererbsen und Blaue Süsslupinen in der Geflügelfütterung. Ufop-Praxisinformation. Union zur Förderung von Öl- und Proteinpflanzen e.V. (ufop), (ed.). Revised edition 2016. URL: https://www.ufop.de/files/8114/7859/9985/WEB_UFOP_1425_praxisinfo_bohnen_erbsen_lupinen_gefluegel_041116.pdf

BFS (2017a): Schweizerische Eidgenossenschaft, Eidgenössisches Departement des Inneren, Bundesamt für Statistik: „Raumnutzung – Taschenstatistik 2017".
URL: https://www.bfs.admin.ch/bfs/de/home.assetdetail.2421443.html (last visit 05.08.2017)

BFS (2017b): Schweizerische Eidgenossenschaft, Eidgenössisches Departement des Inneren, Bundesamt für Statistik: „Landwirtschaft und Ernährung – Taschenstatistik 2017“.
URL: https://www.bfs.admin.ch/bfs/de/home/statistiken/land-forstwirtschaft.gnpdetail.2017-0186.html (last visit 05.08.2017)

Bio Partner (2016): Personal communication to some exhibitors at Bio Partner day 2016, Bio Partner being the biggest wholesaler for organic products in Switzerland.

Bio Suisse (2017): Übernahmebedingungen für Knospe-Futtergetreide Bio Suisse.
URL:http://www.bioaktuell.ch/fileadmin/documents/ba/Markt/Ackerbau/Futtergetreide/uebernahmebedingungen_Futtergetreide_2017_neu.pdf

Böhler, D.; Dierauer, H.-U. (2011): Merkblatt Biolupinen, FiBL (last revision 2012).
URL: https://shop.fibl.org/chde/1143-biolupinen.html

Böhler, D. (1998): Die Lupine eine Alternative? Diplomarbeit. Schweizerische Hochschule für Landwirtschaft. Zollikofen.

Bundesamt für Landwirtschaft BLW (2016): Agrarbericht 2016. URL: www.agrarbericht.ch
Bundesamt für Landwirtschaft BLW (2017a): Instrumente – Direktzahlungen – Einzelkulturbeiträge. URL:
https://www.blw.admin.ch/blw/de/home/instrumente/direktzahlungen/einzelkulturbeitraege.html (last visit 29.08.2017)

Bundesamt für Landwirtschaft BLW (2017b): Instrumente – Direktzahlungen – Landschaftsqualitätsbei-träge. URL:
https://www.blw.admin.ch/blw/de/home/instrumente/direktzahlungen/landschaftsqualitaetsbeitrag.html (last visit 30.08.2017)

Bundesamt für Meteorologie und Klimatologie MeteoSchweiz (2014): Klimawandel Schweiz 1963-2013. URL:
http://www.meteoschweiz.admin.ch/content/dam/meteoswiss/de/Klima/Zukunft/doc/mch_klimawandel_63-13_high.pdf

Bundesinstitut für Risikobewertung (BFR) (DE) (2017): Risikobewertung des Alaloidvorkommens in Lupinensamen. Stellungnahme vom 27. März 2017. URL:
http://www.bfr.bund.de/cm/343/risikobewertung-des-alkaloidvorkommens-in-lupinensamen.pdf

Clerc, M; Klaiss, M; Messmer, M; Arncken, C; Dierauer, H; Hegglin, D; Böhler, D. (2015): Mit Mischkulturen die inländische Eiweissversorgung verbessern. Agrarforschung Schweiz 6 (11-12): 508-515.

Dierauer, H-U; Clerc, M; Böhler, D; Klaiss, M: (2017): Erfolgreicher Anbau von Körnerleguminosen in Mischkultur mit Getreide. FiBL Merkblatt Nr. 1670, URL: https://shop.fibl.org/chde/1670-koernerleguminosen-mischkulturen.html

Dierauer, H.; Clerc, M.; Böhler, D.; Kupferschmid, C.; Rudolf von Rohr, R. (2013) Mischkulturenanbau – Praxisversuche 2013. Zwischenbericht.

URL:
http://www.bioaktuell.ch/pflanzenbau/ackerbau/koernerleguminosen/mischkulturen/praxisversuche-mischkulturen.html

Dierauer H-U; Böhler D. (2004): Merkblatt Lupinen, FiBL (Version 2004)
Dissanayaka, D.M.S.B.; Wickramasinghe, W.M.K.R:; Buddhi, M.; Wasaki, J. (2016): Phosphorus-mobilization strategy based on carboxylate exudation in lupins (Lupinus, Fabaceae): A mechanism facili-tating the growth and phosphorus acquisition of neighbouring plants under phosphorus-limited conditions. Expl Agric.: 12 pp. Cambridge University Press 2016. doi:10.1017/S0014479716000351

Erdin, D.,(2017): Schätzung der Schweizer Ackerfläche für 2016
URL: https://www.sbv-usp.ch/fileadmin/sbvuspch/06_Statistik/Agristat-Aktuell/2016/160912_Agristat_Aktuell.pdf (visited 05.08.2017)

FAOSTAT (2017): http://www.fao.org/faostat/en/#data/QC/visualize (visited on Feb. 8, 2017)

Feiler, U.; Nirenberg, H.I. (1998): Eine neue klassische Methode zur Bestimmung des *Colletotrichum*-Befalls an Saatgut von *Lupinus* ssp. Nachrichtenblatt Deutscher Pflanzenschutzdienst 50 (10), S. 259-262.

FiBL (2016): Project data base. Project “Eiweiss swiss made”
URL: http://www.fibl.org/de/projektdatenbank/projektitem/project/517.html (last visit 29.08.2017)

Fischler, M., (1989): Die Kultur der Lupine (Lupinus albus L.) - Analyse des Wachstums und der Entwicklung sowie von verschiedenen ertragsbildenden Faktoren. Diplomarbeit, Institut für Pflanzenbauwissenschaften, ETH Zürich, Prof. Dr. P. Stamp. (cited according to Nawrath and Vetter, 2002)

Gesellschaft zur Förderung der Lupine (GFL) (ed.): (2017): Lupinen. Anbau und Verwertung., 62 pp.
URL: http://lupinenverein.de/wp-content/uploads/2017/04/LUPINEN-3.pdf

Harzic, N. (2017): Nathalie Harzic, breeder at Jouffrai-Drillaud, personal communication.

Heinz, M. (2016): Markus Heinz, breeder of Saatzucht Triesdorf, (Bavaria), personal communication, June 2016.

Howieson, J.G.; Fillery I.R.P.; Legocki A.B.; Sikorski M.M.; Stepkowski, T.; Minchin F.R.; Dilworth M.J. (1998): Nodulation, nitrogen fixation and nitrogen balance. In: Gladstones, J.S.; Atkins, C.A.; Hamblin J. (eds): Lupins as crop plants: biology, production and utilization. CABI, Oxon, pp. 149- 180.

Jacobs, A.(2015): Mehr Vielfalt in der Landwirtschaft – eine Alternative zu Soja. Neue Zürcher Zeitung, 11.9.2015. – In the online version of the article, a film is embedded: „Vom Feld auf den Grill – die Vielfalt der Lupine“. URL: http://www.nzz.ch/video/vom-feld-auf-den-grill-die-vielfalt-der-lupine-0_232ntwow (last visit 6.12.2016).

Jahreis, G.; Brese, M.; Leiterer, M.; Schäfer, U.; Böhm, V. (2016): Legume flours: Nutritionally important sources of protein and dietary fiber. Ernahrungs Umschau 63(02): 36–42 This article is available online: DOI: 10.4455/eu.2016.007

Jossi, P. (2016): Lupine – Hülsenfrucht mit grossem Potenzial. LID Mediendienst Nr. 3277 vom 17. Juni 2016.
URL: https://www.lid.ch/medien/mediendienst/detail/info/artikel/lupine/ (last visit 13.08.2016).

Klein, F. (2017): Fritz Klein, Bioland-Hof Klein in Wertheim near Würzburg, Germany, lupin farmer and bee-keeper, personal communication.

Landwirtschaft Schweiz: URL: http://www.landwirtschaft.ch/wissen/agristat

Lee, Y.P.; Mori, T.A:; Sipsas, S.; Barden, A.; Puddey, I.B.; Burke, V.; Hall, R.S.; Hodgson, J.E. (2006): Lupin-enriched bread increases satiety and reduces energy intake acutely. Am J Clin Nutr. 2006; 84: 975-80.

Lehmann, B. (2014) : Nachhaltige Eiweissversorgung der Nutztiere als erstes Leuchtturmprojekt der Qualitätsstrategie. Schweizerische Eidgenossenschaft, Bundesamt für Landwirtschaft. URL: http://docplayer.org/23691019-Nachhaltige-eiweissversorgung-der-nutztiere-als-erstes-leuchtturmprojekt-der-qualitaetsstrategie.html (last visit on 29.08.2017)

Losand, B.; Pries, M.; Steingass, H.; (2016): Ackerbohnen, Futtererbsen und Blaue Süsslupinen in der Rinderfütterung. Ufop-Praxisinformation. Union zur Förderung von Öl- und Proteinpflanzen e.V. (ufop), (ed.). URL:
https://www.ufop.de/files/8614/7869/8275/WEB_UFOP_1425_praxisinfo_bohnen_erbsen_lupinen_rind_041116.pdf

Lucas, M. M.; Stoddard, F. L.; Annicchiarico, P.; Frias, J.; Martinez-Villaluenga, C.; Sussmann, D.; Duranti, M.; Seger, A.; Zander, P.M.; Pueyo, J. (2015): The future of lupin as a protein crop in Europe. Frontiers in Plant Science 6, Article 705, 1-6. doi: 10.3389/fpls.2015.00705.

Lupinen-Netzwerk (2017) : URL : http://lupinen-netzwerk.de/ (last visit 30.08.2017)
Moquet, (2014): Lupin: les points clés de la conduite. Prèsentation Réunion Protéagineux 04-02-2014. URL: https://www.evenements-arvalis.fr/_plugins/WMS_BO_Gallery/page/getElementStream.html?id=24517&prop=file

McNaughton, D. (2017) : Lupin bulletin (White lupin). (David McNaughton, British lupin seed wholesaler of Soya UK, sends a lupin bulletin to his seed producers. Personal communication.)

Nawrath M. and Vetter R. (2002): Anbau- und Verwertungsstrategien für Sojabohnen und Weiße Lupinen im ökologischen Landbau unter besonderer Berücksichtigung des N-Haushalts. Abschlussbericht zum Projekt 1.2.2: Gefördert durch die EU-Gemeinschaftsinitiative INTERREG II Oberrhein Mitte-Süd. ITADA-Sekretariat: 2 Allée de Herrlisheim, F-68000 Colmar Tel.: 0(033)389 22 95 50 Fax: 0(033)389 22 95 59 eMail: itada@wanadoo.fr www.itada.org

Notz, C. ; Alföldi, T. (2012) : « Feed no food » - Den Kraftfuttereinsatz überdenken. Bioaktuell 2012 (4), 4-6. URL: http://orgprints.org/21119/1/Seiten_aus_ba-d-2012-04.pdf
Ökolandbau.de (2015) : Ökologischer Lupinenanbau. Latest update 1.10.2015. (last visit 30.08.2017). URL: https://www.oekolandbau.de/erzeuger/pflanzenbau/spezieller-pflanzenbau/koernerleguminosen/lupinen/

Ökolandbau.de (2017): 100 Prozent Biofütterung – der aktuelle Stand der Forschung. (Last update: 30.09.2016). URL: https://www.oekolandbau.de/erzeuger/tierhaltung/spezielle-tierhaltung/schweine/aus-der-forschung/100-prozent-biofuetterung/
Olschewski, F. (2014): Ist Lupinenmehl gesund? URL: https://www.urgeschmack.de/ist-lupinenmehl-gesund/

Perler, O., (1991): Die weisse Lupine - Versuchsergebnisse der Jahre 1985-1989 und eine Literaturstudie. Landwirtschaft Schweiz. 4(9). (cited according to Nawrath and Vetter, 2002)

Reinhard, H.; Gehriger, W. (1988). Lupinen. (cited according to Nawrath and Vetter, 2002)
Roth-Maier, D.A.; Paulicks, B.R.; Steinhöfel, O.; Weiss, J. (2004): Inhaltsstoffe, Futterwert und Einsatz von Lupinen in der Nutztierfütterung. Ufop-Praxisinformation. Union zur Förderung von Öl- und Protein-pflanzen e.V. (ufop), (ed.). URL: https://www.ufop.de/files/4113/4080/8202/RZ_Praxisinfo_Lupine_071004.pdf

Rytz, C. (2016): Personal communication, 29.12.2016.

Schachler, B.; Schmiechen, U.; Sauermann, W. (2016): Anbauratgeber Süsslupine. Ufop-Praxisinformation. Union zur Förderung von Öl- und Proteinpflanzen e.V. (ufop), (ed.). Revised edition 2016. URL: https://www.ufop.de/agrar-info/erzeuger-info/futtererbsen-ackerbohnen-suesslupinen/anbauratgeber-blaue-suesslupine/

Schweizer Bauernverband (2017): Statistiken Pflanzenbau.
URL: https://www.sbv-usp.ch/fileadmin/sbvuspch/06_Statistik/Pflanzenbau/SES_2015_Kapitel_2.pdf (last visit 6.12.2016).

Specht, N., Siegenthaler, U. & Schiess, C., (2000): Optimierung der Anbautechnik von Süsslupinen zur Produktion von Eiweissfutter. Semesterarbeit. Schweizerische Hochschule für Landwirtschaft. Zollikofen. (cited according to Nawrath and Vetter, 2002)

Spiegel, A.-K.; Gronle, A.; Arncken, C.; Bernhardt, T.; Hess, J.; Schmack, J.; Schmid, J.; Spory, K.; Wilbois, K.-P. (2014): Leguminosen nutzen. Naturverträgliche Anbaumethoden aus der Praxis. Bundesamt für Naturschutz (BfN) Deutschland, Bonn (ed.): 142 S. URL: https://shop.fibl.org/CHde/1655-leguminosen.html?ref=1 (last visit 30.08.2017).

Swissgranum (2017): Getreide, Ölsaaten und Körnerleguminosen – Schätzung Anbauflächen und Ernteprognose von Wintergetreide und Raps. Bericht Nr. 2/2017. URL: https://www.swissgranum.ch/files/2017-05-26_schaetzung_anbauflaeche_2017_stand_26.5.2017.pdf

Szuszkievicz, R.(2016): Molecular detection and control of *Colletotrichum lupini*, the causal agent of anthracnose disease, in lupin seed (*Lupinus albus*). Master thesis, Aarhus University, DK, Agrobiology - Organic Agriculture and Food Systems (EUROrganic), 1st Supervisor: Senior Scientist Bent Jørgen Nielsen, Department of Agroecology - Crop Health (AU, Denmark)). 2nd Supervisor: Senior Scientist Pierre Hohmann, Department of Crop Sciences (FiBL, Switzerland).

Verbund ökologische Praxisforschung (vöp) (2014): Strategieoptionen zur Realisierung einer 100%igen Biofütterung bei Monogastriern im ökologischen Landbau. URL:

http://www.bioland.de/fileadmin/dateien/HP_Dokumente/Flyer_und_Broschueren/voep_dossier__optionen_biofuetterung.pdf

Von Baer, E. (2014): plant breeder of Semillas Baer, Chile. Personal communication.
Weber, M.; Preissinger, W.; Bellof, G. (2016): Ackerbohnen, Futtererbsen und Blaue Süsslupinen in der Schweinefütterung. Ufop-Praxisinformation. Union zur Förderung von Öl- und Proteinpflanzen e.V. (uf-op), (ed.). URL: https://www.ufop.de/files/4114/7972/0847/WEB_RZ_UFOP_1421_praxisinfo_bohnen_erbsen_lupinen_schweinefuetterung_211116.pdf

Weber, M. (2016): Inhaltsstoffe von Lupinen und Sojabohnen deutschlandweit geprüft. Proteinmarkt.de Fachartikel (March 2016). URL: https://www.proteinmarkt.de/fileadmin/user_upload/Inhaltsstoffe_von_Lupinen_und_Sojabohnen.pdf

Weber, M. (2017): Inhaltsstoffe von Lupinen und Sojabohnen 2016 deutschlandweit geprüft. Proteinmarkt.de Fachartikel (March 2017). URL: https://www.proteinmarkt.de/fileadmin/user_upload/260417FA_Inhaltsstoffe_von_Lupinen_und_Sojabohnen_2016.pdf

Weiss, M.; Fitzel, T. (2015): Optimierung von Lupinenmehl für die Aquakultur (Verbundvorhaben). Project description. URL: http://orgprints.org/28725/

White, P.; French, B.; McLarty, A.; Grains Research and Development Corporation (2008): Producing lupins. Department of Agriculture and Food, Western Australia, Perth. Bulletin 4720.
URL: http://passthrough.fw-notify.net/download/502610/http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

Willer, H. (2017): Schweizer Biolandbau-Statistik 2016. In: Bioaktuell.ch
URL: http://www.bioaktuell.ch/markt/zahlen-und-fakten-biolandbau/biolandbauzahlen-schweiz.html (last visit on 05.08.2017)

Zorn, A. and Lips, M. (2016): Wirtschaftlichkeit inländischer Körnerleguminosen. Agrarforschung Schweiz 7 (6): 284-289.

Traditional maize varieties in Portugal: Challenges and opportunities due to their underutilization status - Literature and farmers interview survey

MC Vaz Patto[1*] & PMR Mendes-Moreira[2]
[1] ITQB NOVA (*cpatto@itqb.unl.pt)
[2] IPC (pmm@esac.pt)

Origin of this neglected resource from a commonly cultivated species

Maize (*Zea mays* L.) is the second most important cereal in the European Union (source: Eurostat), and the main cereal crop in Portugal (source: INE).

Portugal, by its privileged historical and geographical position as an enter point of new species into Europe, was among the first European nations to adopt maize in its agricultural systems, more than five centuries ago. Maize arrived in Portugal from America during the late XV and XVI century and spread rapidly to all the country. The idea of hybridization among different maize introductions all over the country, rather than a slow northward dispersion accompanied by selection for earliness from one only germplasm introduction is supported in the case of Portugal. The Portuguese maize germplasm display no close relationship with any American types, but share alleles with both Caribbean and North American flints (Vaz Patto et al., 2004). From South to the Portuguese North-Western region, maize suffered several centuries of natural and human selection giving rise to the traditional Portuguese maize landraces adapted to the different environments existing in the country.

However, after World War II, Portugal was also one of the first European countries to test the American maize hybrids. These were initially not well accepted by the Portuguese farmers due to several handicaps such as late maturity or dent kernel type, not fitted for food or polycropping systems. Nevertheless, several national breeding stations were established in Portugal during the 60's, releasing very successful adapted hybrid varieties based on inbreds developed from Portuguese and American germplasm. Accordingly, an enormous decrease in the number of cultivated landraces occurred by replacement with these hybrid varieties especially in more favorable environments (Moreira, 2006; Vaz Patto et al., 2012). Presently the maize traditional varieties represent less than 1% of the national maize production and face a real risk of disappearance and thereby losing a valuable source of germplasm for meeting the future needs of sustainable agriculture.

Efforts have been made to reduce genetic erosion of Portuguese germplasm and several germplasm collection expeditions took place during the 70's and 80's, and also recently (Vaz Patto et al., 2007). In addition a very successful participatory plant breeding (PPB) and on farm conservation project (VASO) has been conducted since 1984 to improve yield of the Portuguese open pollinated varieties (OPV) in sustainable farming systems (Pêgo & Antunes, 1997; Moreira et al., 2009). Presently, in this PPB project the identification of agronomic and specific quality traits is being conjugated with molecular characterization so as to exploit efficiently the local diversity and produce varieties that are superior in marginal environments, but with a broad genetic base and a high quality level (Vaz Patto et al., 2012). The most promising maize populations at agronomic, molecular and quality level, collected during the last maize germplasm expedition (Vaz Patto et al., 2007), were used together with the VASO improved OPVs for the development of composites and hybrid populations with specific quality traits, maintaining high genetic diversity. These composites and hybrid populations can be an alternative to yield improvement and to avoid the collapse of this interesting germplasm. In addition also new composite populations with increased precocity are being developed, based

upon the most agronomic superior Portuguese maize OPVs and some American populations (Vaz Patto et al., 2012).

Although facing a real risk of genetic erosion, In particular less favorable Portuguese regions, known by their high quality maize bread, farmers keep on cultivating maize traditional landraces. Most of the Portuguese maize landraces are flint (hard endosperm) types with good characteristics for the maize leavened bread (called 'broa') production. 'Broa' production still plays an important economic and social role on Central and Northern Portuguese rural communities (Vaz Patto et al., 2007). Traditionally selected landraces demonstrate technological capacity and taste/aroma characteristics (highly valued for bread production) over yield and maintain genetic diversity to increase adaptability to a large variety of edaphic/climatic conditions, such as drought or aluminium toxicity (Pêgo & Antunes, 1997). This bread making ability seems to depend on a range of particular traits not found on the available commercial hybrid varieties, and this is probably why maize landraces have not, in these regions, been totally replaced by hybrid varieties (Vaz Patto et al., 2012). Indeed the high yielding dent (softer endosperm) hybrids have been rejected by farmers and consumers for 'broa' production. Sensorial analysis with a consumer panel revealed a similar positive assessment among broas from different maize traditional varieties and the lowest scores for hybrid maize broa (Carbas et al., 2016). This study also showed that texture was the most relevant attribute for consumer acceptability of the maize bread broa. As starch is the main compound in maize flour, the texture of baked 'broa' and detected differences between 'broa' made from softer and harder maize may be explained by starch gelatinisation properties (Brites et al., 2010) and the different flour particle distribution (Carbas et al., 2016).

Farmers' survey

Maize is definitely a deep-rooted crop in the Portuguese rural tradition and the available genetic variability of its landraces offers a superb challenge for breeding for special quality traits (Vaz Patto et al., 2012).

During a field expedition to the Central region of Portugal, to collect these enduring maize landraces (Vaz Patto et al., 2007), we performed several interviews to farmers still cultivating traditional varieties (Fig 1). In this region farmers grow maize landraces in association with other crops, following a traditional intercropping practice. The collected landraces represent important sources of genes and genes combinations not yet available for crop quality breeding programs and due to their intrinsic quality traits (that promoted their maintenance in cultivation) are the best candidates for expanding the already existing participatory breeding program (VASO) to other regions with more emphasis on quality breeding. Around 38 farmers were interviewed using the questionnaire depicted in Table 1.

Figure 1. Collection mission in 2005, farmers group photos (Vaz Patto et al., 2007)

Table 1. Farmers interview questionnaire

1. Farmer name	
2. Field location (Municipality, Village, and Place)	
3. Maize traditional variety sample information	
3.1. Plant architecture	*3.1.1. How told are your maize plants?*
	3.1.2. How high is the ear insertion in the maize plant?
	3.1.3. How many ears do you get per maize plant?
	3.1.4. What is the color of your maize grain traditional variety?
	3.1.5. Did you ever detected the presence of ear fasciation in your maize traditional variety?
3.2. Agronomical practices	*3.2.1. When do you sow your maize traditional variety? Manually or mechanically?*
	3.2.2. When do you harvest your maize traditional variety?
	3.2.3. Do you perform any rotation in time with your maize crop? What are the other crops included in the rotation?
	3.2.4. Do you cultivate your maize in an intercropping system simultaneously with other crops? With which crops?
	3.2.5. Do you apply any fertilizer? What kind of fertilizer?
	3.2.6. What are the main problems/concerns of this traditional maize variety? Plant lodging? Pests? Others?
	3.2.7. Do you perform any selection on your maize traditional variety? What kind of selection?
	3.2.8. How long have you or your family cultivated this maize traditional variety?
3.3. Production uses	*3.3.1. Why do you keep cultivating a traditional maize variety?*
	3.3.2. With what objective do you produce your maize traditional variety? For human food and/or animal feed?
	3.3.3. What broa recipe do you use?
4. Associated stories, memories, cultural heritage	

During these interviews, 50 different (yellow and white) maize landraces were collected (Fig 2), and later on characterized using pre-breeding approaches and conserved in cold storage (Vaz Patto et al., 2007). The most enthusiastic farmers and most promising genetic resources were included and are being selected under a participatory approach through the SOLIBAM and the DIVERSIFOOD projects

as a way to increase the use value of this traditional germplasm and, by doing so, promote in-situ/on-farm conservation and halt their serious genetic diversity erosion.

In relation to the **traditional maize varieties plant architecture**, farmers' interviews indicated that on average these varieties were characterized by plants 2m tall, and with an average high of ear insertion of 1.25m. These maize plants were prolific with an average number of two ears per plant. Indeed these values were later on validated through a comparative field trial that took place under the same environmental conditions at Coimbra, Portugal (Vaz Patto et al., 2007). Yield values (seed production at 15% humidity) collected from this same comparative field trial varied from 754.4 Kg/ha till 3757.2 Kg/ha and was on average 1982.39 Kg/ha (Fig 3).

Figure 2. Sample of a collected population under mission in 2005 (Vaz Patto et al., 2007).

Figure 3. Field trials multiplication and evaluation at Coimbra during 2006.

From the 50 different maize traditional landraces sampled in this expedition, 28 had yellow/orange and 22 white kernels. The majority of the samples were of flint endosperm type and only two of them were semi-flint types. These traditional varieties had been cultivated by the farmer's families for more than 200 years, with the exception of the semi-flint types that were more recent acquisitions. The majority of the interviewed farmers cultivated only one traditional maize variety, but about ¼ of them maintained two or even three different traditional varieties depending on their different precocities, soil types, different resistances and especially different end-uses. In this last

case farmers maintained at least a yellow and a white variety, being generally the yellow variety for animal feed and the white one for human food (bread production). 66% of the collected traditional varieties showed some degree of ear fasciation and this was a trait that was considered by many of the interviewed farmers as favorable to a certain extent (to keep seed diversity potential) when performing seed selection.

In relation to the used **agronomical practices and adaptation to low input systems**, interviewed farmers indicated that the most common sowing-harvesting times were May-September or April-August, but also some longer cycles were practiced with some varieties such as April-September or May-October/November. In about 60% of the cases sowing was manually performed and the most common maize rotations were with a second crop such as annual ryegrass (42% of the cases), or rye (29% of the cases), or in a three crops rotations with annual ryegrass followed by rye (in 12% of the cases), or with a mixture of rye/oats/wheat, followed by rye (in 17% of the cases). About 80% of the farmers interviewed cultivated the traditional maize variety in an intercropping system simultaneously with other crops, and the farmers that were not performing these intercropping systems had at least use them in the past (Fig 4). The most common companion crop was common beans (in 70% of the cases), followed by a mixture of pumpkins and common beans, or common beans and chickpeas.

Figure 4. Intercropping maize with common beans (VASO project).

All the interviewed farmers were applying manure to their maize traditional variety crop but in about 70% of the cases they applied also a little amount of a N chemical fertilizer (nitrolusal) at sowing, or at weeding or at the first watering.
Several pests were among these **maize farmers' main concerns**. In particular *Agrotis* spp. and *Ostrinia nubilalis*, but also *Sesamia nonagrioides* were mention in 48% or 43% of the cases respectively. Also problems with wild pigs or plant lodging were a concern to 43% of the interviewed farmers. In relation to plant lodging, in most cases this was overcome with a detasseling practice that reduced plant height after flowering.
These farmers kept their seed for sowing the following season and in the majority of the cases (67%) performed some **kind of selection** (Fig 5).

Figure 5. Farmer doing selection in the store mission in 2005 (Vaz Patto et al., 2007).

This selection was mainly focused on the ear traits (75% of the cases), that should be big, determinate and in some cases fascinated (Fig 6), but could also focus on plant traits (25% of the cases) especially to reduce ear insertion high or increase the precocity of the crop.

Figure 6. Maize populations with a high degree of fasciation.

The interviewed farmers kept on cultivating these maize traditional varieties mainly because hybrid varieties were not as good as these ones for broa bread production (38% of the cases). Nevertheless also a higher quality for feed due to tender and/or sweeter stalks and leaves (31% of the cases), or due to a smaller seed size (needed for poultry feed) (19% of the cases) or a reduced bloating susceptibility, a heavier seed, less water requirements or shorter cycle were also identified as **reasons not to give up on the traditional varieties for the hybrid ones**. Indeed the majority of the interviewed farmers (65%) were using these traditional varieties for a dual food (bread) and feed (tassels, leaves, stalk and grains) purpose. Only 20% of the farmers were using these varieties just for feed, and in this case using only yellow/orange varieties, or just for food (15% of the farmers) using white varieties. White maize is the preferred choice by some Portuguese rural populations for broa production (Fig 7, Fig 8), due to cultural and historical reasons. Indeed in the 18th century, when the maize was the main cereal used for bread making, white bread (wheat) was the most appreciated, symbolizing wealth and prestige (Carbas et al., 2016). In this context white maize flour was the most suitable for obtaining a bread most similar to the wheat expensive bread.

Figure 7. Traditional oven from northern Portugal

Figure 8. Traditional maize bread in a traditional oven

Several medicinal uses of particular parts of these traditional varieties maize plants were also mentioned by the interviewed farmers. This is the case of using infusion from dry yellow maize silks to treat kidney diseases, or infusion from the red dark grains to treat diarrhea in humans, or the use of the maize silks and ear bracteoles directly to treat diarrhea in sheep.

Presently the broa maize bread can have a very potential **specific market niche**, the celiac disease people, if obtained from 100% maize flour. Gluten enteropathy (coeliac disease) is a serious chronic disease, caused by an inappropriate immune response to dietary wheat gluten or similar proteins of barley or rye. Maize is a gluten-free cereal, thus suitable to produce foods addressed to celiac patients. Baking assays were performed and demonstrated that bread making technology could be satisfactorily applied to produce 100% maize flour gluten-free "broa" (Brites et al., 2010).

Nevertheless, this leavened bread is traditionally obtained from a mixture of maize and other cereals (rye or wheat) flour. Different recipes were indicated by the interviewed farmers still producing broa bread. Their majority produced a more than 75% maize flour broa bread (90% sieved whole meal maize flour on average), mixing it most commonly with rye flour. Only one farmer was using a maize/wheat mixture. In addition, the broa recipe had also in all cases, hot (boiling) water, salt, and leavened dough from the late "broa" (acting as sourdough).

Broa recipes

As shown from the farmers interviews performed in the Central Portuguese region, there are many recipes to prepare "broa". This empirical process leads to an ethnic product highly accepted for its distinctive sensory characteristics. It is known that the quality of "broa" is the result of empirical knowledge that is very closely related to the quality of the maize variety (endosperm hardness, being traditional flint types harder than hybrid dent types), kernel processing, blending flours and baking procedures, including fermentation and baking (Vaz Patto et al, 2012).

An adapted traditional broa formulation (from Carbas et al., 2016) could include 75% of maize flour, 25% of rye flour, 2.8% (w/w, flour basis) sugar, 1.76% (w/w, flour basis) salt, 1% (w/w, flour basis) dry yeast (Fermipan, DSM, Holland), 10% sourdough (w/w flour basis) and 100% (v/w flour basis) water. Sourdough should be prepared using the same recipe of broa and be kept at 25 °C during 12 h before its use.

Bread making process may consist in mixing the maize flour with 80% (v/w, flour basis) boiling water containing 1.76% salt, for 5 min, in a bowl of a kitchen machine. Dough should be left idle till cooling to 27 °C, then the remaining ingredients (including 20% water containing 2.8% sugar, 1% dry yeast and 10% w/w flour basis of sourdough) should be added and the dough kneaded again for 8 min and left resting for bulk fermentation at 25 °C for 90 min. After fermentation, the dough should be manually molded in balls of 400 g and baked in the oven at 270 °C for 40 min.

References

Brites C, Trigo MJ, Santos C, Collar C & Rosell CM (2010) Maize based gluten free bread: influence of processing parameters on sensory and instrumental quality. Food and Bioprocess Technology, 3(5): 707-715.

Carbas B, Vaz Patto MC, Bronze MR, Bento da Silva A, Trigo MJ & Brites C (2016) Maize flour parameters that are related to the consumer perceived quality of “broa” specialty bread. Food Science and Technology Campinas, 36(2): 259-267.

Mendes-Moreira PMR, Pêgo S & Vaz Patto MC (2009) On-farm Conservation Portugal – Vaso Project - a Long-term Conservation Programme. In: European landraces onfarm conservation, management and use. (Veteläinen M, Negri V, Maxted N, Eds.). pp. 275-282. Bioversity Technical Bulletin No. 15. Bioversity International, Rome, Italy.

Mendes-Moreira PMR (2006) Participatory maize breeding in Portugal. A Case Study. Acta Agronomica Hungarica, 54(4): 431-439.

Pego S & Antunes MP (1997) Resistance or tolerance? Philosophy may be the answer. In: Pego S, Martins R. (eds.) Proceedings of the XIX Conference of the International Working Group on *Ostrinia nubilabis* and other maize pests, 30 August-5 September 1997, Guimarães, Portugal. IWGO, 303-341.
Vaz Patto MC, Satovic Z, Pego S & Fevereiro P (2004) Assessing the genetic diversity of Portuguese maize germplasm using microsatellite markers. Euphytica, 137: 63-72.

Vaz Patto MC, Moreira P, Carvalho V & Pego S (2007) Collecting maize (*Zea mays* L. convar. mays) with potential technological ability for bread making in Portugal. Genetic Resources and Crop Evolution, 54(7): 1555-1563.

Vaz Patto MC, Mendes-Moreira PM, Alves ML, Mecha E, Brites C, Bronze R & Pego S (2013) Participatory plant quality breeding: An ancient art revisited by knowledge sharing. The Portuguese experience. In Plant Breeding From laboratories to Fields (Andersen SB, Ed.), Chapter 10, pp. 255-288. InTech.

Rivet Wheat

1. **Rivet wheat origin**

Durum and rivet wheat evolved from domesticated emmer (Zohary et al 2012), whose ancestor, wild emmer (*T. turgidum ssp. dicoccoides)*, appeared for the first time on the Fertile Crescent. Civilization movements during the Neolithic lead to the spread of domesticated emmer throughout Europe. Its posterior evolution and adaptation to different environmental conditions resulted on agronomic differences between rivet and durum wheat. Rivet became rather tolerant to frost, wind and humidity and durum more suitable for warmer temperatures and stable conditions (Oliveira, 2012).

According to literature on archaeological findings, there are two possible routes for the arrival of rivet wheat: one is via Mediterranean (Maier, 1996) and the other one through Balkans and the Carpathian Basin (Kirleis & Fischer, 2014) ; this latter would be related to hexaploid wheat distribution. The Mediterranean route seems to be more congruent with ancient rivet distribution, documented by findings from Neolithic, in Catalonia and South of France (Mottes et al., 2009; Rottoli & Castiglione, 2009).

Other archaeological findings (Capdevila et al., 1997) evidence that emmer was present in Iberian Peninsula on Neolithic Period. This early entrance and isolation on diverse Northern regions would allow the evolution and adaptation to different environments, giving the diversity that we find nowadays available at the Spanish Germplasm Bank (CRF-INIA).

Figure 1 : Pétanielle Blanche by Vilmorin.

2. **Rivet wheat history : limits, benefits and cultural uses**

Their long-term selection in different environments gave rivet wheat populations a huge genetic variability that carries the capacity to resist fungal diseases (Denaiffe et al. 1928). As their evolution happened on cold and mountainous regions, they are able to grow in poor and in rich soils, as well as in humidity, cold and windy climate (*ibid.*).

2.1. Rivet wheat limits: Why a forgotten crop?

Landraces were largely cultivated until modern plant breeding appeared on 20th century and modern and uniform varieties with higher yields substituted them (Roussel et al., 2004). John Letts, archaeologist and grower of heritage grains, specialized in thatched roofs in England, stated that "*on the 80's those landraces [rivet wheat] disappeared on the field and become all substituted by modern varieties"*. Its disappearance was linked to agricultural mechanization and rural exodus: modern machines had difficulties to thresh wheats with barbs as rivet.

Rivet is a late wheat, occupying the soil for a long time (from October-November to August) (Denaiffe et al. 1928). Its ripening was uneven and it has a late heading (Moir and Letts, 1999), which gave it a bad popularity when compared to the uniform modern varieties. Another reason of decline is its height (around 1.80m), often combined with windy and rainy conditions, that can cause lodging of some populations and posterior germination on the soil. The long straws used to be kept for cattle feeding. However, since the 40', imported soya predominated for cattle feeding thanks to its high protein content (Weiler, 2009), giving another reason to leave rivet growing.

Concerning technological aspects, rivet was considered as a "*bad quality wheat, due to its low protein content, compared to durum*" (by Magdalena Ruiz, INIA researcher) for pasta elaboration and "*with mediocre bakery quality*" (Denaiffe et al. 1928) for bread making. Its low technological gluten content and off-white color used to give non-soft and non-white bread, contrarily to dominant trends of global demand.

2.2. Rivet wheat benefits: Why was it used for?

Rivet wheat hard kernel provides high quantity of semolina for pasta and biscuit elaboration. In addition to special aromas, this trait made rivet a popular crop in France and England (Dusseau, 1931). In Auvergne French region, biscuit and pasta factories were built and worked during the 19th and 20th centuries, using the so-called "blé rouge glacé" (vitreous red wheat) that Dusseau identified as rivet. During the first half of 20th century, in Northeastern Spanish regions, grains used to be cooked and eaten as rice in a traditional dish called "trigo perlado" (pearl-shaped wheat). In England, rivet wheat, also called Blue Cone and Rampton's rivet, was largely grown during the 19th century and mostly used for biscuit making (Moir and Letts, 1990). However, its use dated back to Middle Age when houses used to be built with thatched roofs in Southern England. For some of those roofs, rivet spikes were chosen due to their length and resistance (Moir & Letts, 1999).

In France, rivet wheat was usually grown on central regions (Berry and Auvergne). We could also find it in Germany, Switzerland, Italy, Spain and Greece.

Figure 2 : Petanielle Noire de Nice by Vilmorin, 1880

3. Rivet wheat and environment

3.1. Relationships with mycorrhiza

Arbuscular Mycorrhiza designates the symbiotic formation between a plant root and a fungus called Arbuscular Mycorrhiza Fungi (AMF) that belongs to the monophyletic phylum Glomeromycota (Schüßler et al. 2001). They can be found on the 80% of terrestrial plants and they are well valued on sustainable agricultural ecosystems because of their multiple benefits on plant and ecosystem: effectiveness on phosphor assimilation and on inaccessible water resources (Garbaye, 2013); biotic and abiotic stress resistance (Sánchez-Romera, et al., 2016); soil structure and fertility improvement (Lozano Sánchez et al. 2015). Agricultural practices as tillage and use of inputs (Lin et al., 2012) are known to reduce the development of mycorrhiza.

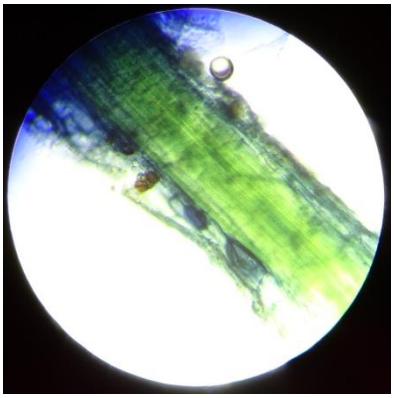


Figure 3. Mycorrhiza microscopic observation in the rivet population Nonette de Lausanne

The degree of colonization and the benefits depends on the host (Hetrick et al., 1993). For some wheat landraces as rivet, colonization seem to be more beneficial than for modern wheats (Kapulnik & Kushnir, 1991). However, little is known about the compatibility between rivet and AMF. A rivet population called Nonette de Lausane showed a percentage of colonization (30%) similar to bread wheat.

4. Agronomy of rivet wheat

Rivet has a round kernel that can be white, red or grey. It is able to grow on poor and rich soils, on mountainous, cold and humid regions. Some rivet populations can resist extreme and windy conditions thanks to their strong straw, while others have weaker straws and may lodge. In most cases, their heavy and barbed spikes used to be curved and inclined over the soil (Vilmorin, 1880).

Rivet wheat cultivation follow the same cycle as soft wheat: sowing takes place around October-November (on Northern regions) and November-December (on Southern ones). Seeding density is often between 150-250 seed/m^2. Heading occurs around May-June, spikes may reach until 1.80 m. Rivet is harvested on July-August, its yield aproximates 25 qx/ha. This may vary greatly according climate, since early summer storms can cause an important lodging. Diseases are not a problem for rivet landraces: they are highly diversified crops, able to tolerate diseases without compromising productivity. This robustness is also noticeable regarding weeds: the dense vegetation they produce impedes weed growing.

5. Important quality aspects and current uses of rivet wheat

An interest to grow again rivet in France started in 2006 with an initiative of an organic agriculture peasant group (GABB Anjou) which started taking out several wheat varieties from different Germplasm Banks (Clermont-Ferrand in France, but also Spanish, Italian, German, Polish) before multiplying them. After seed transfer through associations (as "Réseau Semences Paysannes) other peasants and groups (as Odyssée de L'Engrain at the GAB65) started to grow and process rivet wheat. Consequently, more than 30 landraces are being multiplied nowadays in different French regions, but two landraces, "Poulard d'Auvergne" and "Nonette de Lausanne" and one population mixture (with 9 varieties from different origins) are the most cultivated.

Figure 4. Peasant associations' logos

Technological analyses on kernel reflect its quality and it allows to define its destination. The first analyses made on rivet landraces thanks to DIVERSIFOOD project showed great differences between them. The kernel hardness index indicates whether the flour is more appropriated for bread or pasta and pastry. Protein content may vary between 10 and 15%, gluten content between 18 and 32 %. Consumers' testimonies suggest an easier digestibility when compared to modern wheat varieties.

Bakers that tested rivet on bread detected the release of special aromas. Although some of them noticed that rivet dough is too strong and elastic for bread making, elasticity properties vary greatly among landraces. Dough elasticity and extensibility depend on gluten quantity and quality, especially on the gliadin/glutenin ratio which may vary a lot. Therefore, an adaptation of dough preparation and fermentation is required to obtain a good volume and to stick out rivet's appreciated organoleptic characteristics. A mix of rivet with with soft wheat flour facilitates preparation still conferring new aromas to bread. Organoleptic properties of rivet landraces, different among varieties, are sometimes comparable rye because of a brownish color and a dense crumb.

Testing sessions studied the perception of rivet flavors with four rivet populations: Blanco de Corella, Petanielle Noire, Turgidum di Maliani, Auvergne GAB65 and other wheat varieties: Renan (modern soft wheat), Rouge de Bordeaux (landrace of soft wheat), and Miradoux - a durum wheat modern variety, largely used for pasta making. Panelists evidenced different flavors and textures between each rivet population and with soft and durum wheat. A special biscuit-like taste, unusual in bread, was found.

Figure 5. During bread and pasta tasting sessions

6. Rivet wheat from farmer's perspective

We transcribed here an abstract of an interview made with Florent Mercier, a farmer growing rivet wheat whose experiments and initiatives allowed the rivet project to start in France, in collaboration with the French Agronomic Institute, INRA.

How and why did you start growing rivet wheat?
I first saw Rivet wheat in a field on the south of France, more than 10 years ago, and I really appreciated its diverse colors and shapes. Later when I discovered the book "Les Poulard d'Auvergne" ("Rivet from Auvergne" in French) I found plenty of poetry and I completely fell in love. So I decided to start experiments with Rivet in 2007. I got grains from the Spanish conservatory INIA and from the French one Clermont-Ferrand.

Which populations do you grow nowadays?
I created a mixture of 9 varieties that I selected after 9 years of growing Rivet, they are from different countries: Spain, Italy and France. As pure, I appreciate some Spanish varieties for its flavor and quality, as Blanco de Corella, Jejar de Valencia, Bizargari. with white grains of good flavor and which gives good yield. However I grow different varieties and I experience with mixtures, crossings to see all the potentials of Rivet.

How does it behave on the field?
It does not give a huge yield, now we are around 20-25qx/ha, but it depends on the region and the year, the weeks previous to harvest are critic because rainfalls may cause flooding and germination and so impossibility to harvest. But we are working on how to save this issue.
Concerning diseases and weeds we had no problem until now, we just sow and leave it until the harvest, it compete very well against weeds thanks to its huge vegetation that overshadow them.

What about its kernel quality?

Its kernel its half hard, some varieties more than others, it could be interesting to see which varieties are harder and classify them and to use them according its hardness on bread, pasta or other elaboration. Anyway the baker will need to adapt its techniques to work with Rivet, because it has a more sticky texture. It is a question of getting habituated, it is a cultural aspect. Contrarily, its flavors are largely appreciated by consumers.

What would you like to know about Rivet?
Wheter other countries grow it, where, and to have some seeds from them to test varieties that are currently used. As it is in the case of Italy, where Rivet was used but very few seeds have been included on Germplasm Banks. I would like also to know its nutritional content, and characterize the varieties according its kernel hardness.

9. Rivet wheat network

A network of farmers that grow Rivet nowadays in France is shown here. Three groups were defined to better organize visits and interviews that allowed to know more about current agronomic benefits and limits of Rivet, as well as wishes and potential research questions proposed by farmers.

Figure 6. Rivet network map. Including current producers of rivet wheat in three regions: northern (green), western (orange) and southern (yellow); and a group of interested producers (purple).

7. Recipe

Pasta of rivet may be prepared as one prefers. A recipe with local and seasonal ingredients is the ideal.

Zucchini and two cheeses pasta

Ingredients (4 persons):
250 g rivet pasta
2 zucchinis
500g cherry tomatoes
Basil
Fresh sheep and cow's cheese
Olive oil and salt

1. Cut and cook the zucchinis on olive oil
2. Boil water with olive oil and salt, and cook pasta during 4 minutes. Then reserve it.
3. Cut and cook lightly the cherry tomatoes with basil.
4. Pour the zucchinis and tomatoes over the pasta and add both cheeses and basil at the top.

Bon appétit!

9. Literature cited

Capdevila, R. B. i, Alonso, N., Canal, D., Echave, C., & González, I. (1997). Archaeobotanical remains of hulled and naked cereals in the Iberian Peninsula. *Vegetation History and Archaeobotany*, *6*(1), 15–23.

Denaiffe, Colle & Sidoror (1928). Les blés cultivés. Graineterie Denaiffe. Ardennes
Dusseau, A. (1931) Contribution à l'étude écologique du blé. Les blés d'Auvergne. Essai sur la culture du blé et particulièrement des poulards d'Auvergne dans le Puy-de-Dôme.

Garbaye, J. (2013). *La symbiose mycorhizienne: une association entre les plantes et les champignons*. Editions Quae.

Hetrick, B. A. D., Wilson, G. W. T., & Cox, T. S. (1993). Mycorrhizal dependence of modern wheat cultivars and ancestors: a synthesis. *Canadian Journal of Botany*, *71*(3), 512-518.

Kapulnik, Y., & Kushnir, U. (1991). Growth dependency of wild, primitive and modern cultivated wheat lines on vesicular-arbuscular mycorrhiza fungi. *Euphytica*, *56*(1), 27–36. http://doi.org/10.1007/BF00041740

Kirleis, W., & Fischer, E. (2014). Neolithic cultivation of tetraploid free threshing wheat in Denmark and Northern Germany: implications for crop diversity and societal dynamics of the Funnel Beaker Culture. *Vegetation History and Archaeobotany*, *23*(1), 81–96. http://doi.org/10.1007/s00334-014-0440-8

Lin, X., Feng, Y., Zhang, H., Chen, R., Wang, J., Zhang, J., & Chu, H. (2012). Long-Term Balanced Fertilization Decreases Arbuscular Mycorrhizal Fungal Diversity in an Arable Soil in North China Revealed by 454 Pyrosequencing. *Environmental Science & Technology*, *46*(11), 5764–5771.

Lozano Sánchez, J. D., Armbrecht, I., & Montoya Lerma, J. (2015). Hongos formadores de micorrizas arbusculares y su efecto sobre la estructura de los suelos en fincas con manejos agroecológicos e intensivos. *Acta Agronómica*, *64*(4), 289–296. http://doi.org/10.15446/acag.v64n4.46045
Maier, U. (1996). Morphological studies of free-threshing wheat ears from a Neolithic site In southwest Germany, and the history of the naked wheats. *Vegetation History and Archaeobotany*, *5*(1–2), 39–55.

Moir,J.,Letts,J.,(1999).Thatch. Thatching in England 1790 –1940. English Heritage Research Transactions,vol.5.James & James (Sciencepublishers),London,pp.218.

Mottes, E., Petrucci, G., Rottoli, M., Visentini, P., 2009. Evolution of the Square Mouthed Pottery culture in Trentino-Alto Adige, Veneto and Friuli: cultural,chronological, palaeo economic and environmental aspects. Gortania 31,97e124. - Recherche Google. (n.d.). Retrieved May 20, 2016,

Oliveira, H. R., Campana, M. G., Jones, H., Hunt, H. V., Leigh, F., Redhouse, D. I., Jones, M. K. (2012). Tetraploid wheat landraces in the Mediterranean basin: taxonomy, evolution and genetic diversity. *PLoS One*, *7*(5), e37063.

Rottoli, M., Castiglione., 2009. Prehistory of plant growing and collecting innorthern Italy, based on seed remains from the early Neolithic to the Chalcolithic(c. 5600e2100 calc B.C.). Veget. Hist. Archaeobot. 18, 91e103. - Recherche Google. (n.d.). Retrieved May 20, 2016

Roussel V, Koenig J, Beckert M, Balfourier F (2004) Molecular diversity in French bread wheat accessions related to temporal trends and breeding programmes. Theor Appl Genet 108:920–930

Sánchez-Romera, B., Ruiz-Lozano, J. M., Zamarreño, Á. M., García-Mina, J. M., & Aroca, R. (2016). Arbuscular mycorrhizal symbiosis and methyl jasmonate avoid the inhibition of root hydraulic conductivity caused by drought. *Mycorrhiza*, *26*(2), 111–122.

Schüβler, A., Schwarzott, D., & Walker, C. (2001). A new fungal phylum, the Glomeromycota: phylogeny and evolution. *Mycological Research*, *105*(12), 1413–1421.

Singh, A. K., Hamel, C., Depauw, R. M., & Knox, R. E. (2012). Genetic variability in arbuscular mycorrhizal fungi compatibility supports the selection of durum wheat genotypes for enhancing soil ecological services and cropping systems in Canada. *Canadian Journal of Microbiology*, *58*(3), 293–302.

Vilmorin-Andrieux (1880) Les meilleurs blés. MARCHANDS GRAINIERS, Paris

Zohary, D., Hopf, M., & Weiss, E. (2012). *Domestication of Plants in the Old World: The origin and spread of domesticated plants in Southwest Asia, Europe, and the Mediterranean Basin*. Oxford University Press on Demand.

Weiler, N. (2009). Comment se nourrir sans soja OGM. Retrieved August 7, 2016, from http://www.bastamag.net/Comment-se-nourrir-sans-soja-OGM

Tomatoes – neglected genetic resources: an overview from Switzerland

Philipp Holzherr
ProSpecieRara PSR
Philipp Holzherr
Bereichsleiter Garten-, Acker- und Zierpflanzen
Unter Brüglingen 6
4052 Basel
philipp.holzherr@prospecierara.ch

Schweizerische Stiftung
für die kulturhistorische
und genetische Vielfalt
von Pflanzen und Tieren

Image references: If not otherwise referenced, all images ©ProSpecieRara

1. State of art of tomato diversity in Switzerland

1.a. Tomatoes in everyday-use

Tomatoes are probably the most used vegetable in Switzerland, be it bought as fruits, as plant seedlings or as seeds – tomatoes are a very attractive vegetable. The yearly Swiss tomato production volume is over 40t, and 30t more are imported yearly, mostly from Italy, Spain and the Netherlands. A Swiss person consumes in average **over 10 kg of tomatoes per year, which is on top of the list compared to other vegetables** (tomatoes round and cherry 10.47 kg, carrots 8.5 kg, iceberg salad 4.65 kg, peppers 4.4 kg) [34] There couldn't be found any statistics about the plants and seed commercial volume of tomatoes in general. From the experiences of plant markets by the NGO ProSpecieRara, we estimate tomatoes as the most bought vegetable species in the spring. In the garden centres of the partner Coop, tomato plants make out the most sold product among the plant assortment of ProSpecieRara varieties, as well as among the vegetable plants in total[35]. In the campaign «Stadt-Tomaten» of ProSpecieRara since 2014, the foundation promoted the growing of tomatoes on balconies, and the harvesting of seeds for own grown plants.

1.b. The tomato diversity in Switzerland

In Switzerland the task of collecting and conserving neglected vegetable varieties is mainly done by the governmental Swiss Gene Bank of Agroscope[36] as well as by ProSpecieRara. In total they currently conserve **184 old open pollinated tomato varieties**. Compared to other vegetables, a tomato variety can fairly easily be maintained by private gardeners.

Therefore the activities with tomatoes are much more spread among private gardeners, in garden centres and among farmers than registered by agricultural statistics. Naturally this has a big impact on tomato varieties in use, as in private gardens many more varieties can be used than in the professional production. The total number of used tomato varieties in Switzerland is therefore very hard to estimate. Collecting of plant varieties is not any more a regional restricted affair, but a global activity. Especially vegetables like tomatoes that are promoted by seeds, are essentially open to every person worldwide as long they have access to the Internet. The abundant tomato diversity in gardens is therefore not only based on the Swiss plants and seed offers, but also on the international seed trade.

Still there might be drawn a picture about the everyday tomato varieties for an average consumer (that is, one without gardening ambitions), by estimating the varieties used by vegetable farmers and the varieties seen in vegetable commerce.

As of 9.7.2017 there are **3832 entries of tomatoes on the EU database of registered plant varieties**[37]. For the Swiss market there are no further officially registered tomato varieties, with

[34] http://www.gemuese.ch/Ressourcen/PDF/Politik/CHGemuesebau_BROSCHURE_LID.PDF

[35] personal message from R. Pietrek, Coop, plant product manager of Coop Schweiz, 2017

[36] https://www.bdn.ch/organisations/acw/

[37] http://ec.europa.eu/food/plant/plant_propagation_material/plant_variety_catalogues_databases/search/public/index.cfm

exception of 6 so called niche varieties for a limited commercial volume. An overview of the effectively used tomatoes in Switzerland is best given by the promoted varieties of seed traders.
For this literature overview the offers of the most important seed traders have been analysed, if catalogues or webshops were available (see appendix). From the resulting list it can be seen that at around **150 different tomato varieties**[38] are recommended for the professional Swiss tomato production, of which **more than 120 varieties are hybrids**. Again, niche producers might as well use many other varieties from worldwide seed offers. But for the mass production of supermarkets, the gastronomy and alike these numbers should be appropriate.

From the sole view of diversity, the tomato crop seems very diverse and abundant in various niches. The crop has the most number of varieties entries on the EU database of registered plant varieties compared to all other vegetable crops (followed by Chili/Pepper and Lettuce). And also in the Swiss seed offers from vegetable seed traders tomatoes are most abundant compared to other vegetables. But even the available diversity of **tomato *types*** nowadays is impressive. The following categories of tomato types seem to be the most common ones:

Medium sized tomatoes (Image: www.gomeal.de)

Tomatoes on the vine (Image: jardinage.provence.free.fr)

[38] note: this list includes some varieties of the ProSpecieRara conservation, which were selected as feasible for the professional production, and which therefore are promoted with the ProSpecieRara label

Beefsteak tomato (Image: www.specialtyproduce.com)


San Marzano type (Image: www.specialtyproduce.com)


Roma type (Image: balconygardenweb.com)

Cocktail tomatoes (Image: www-backyardfarms.com)

Cherry tomatoes, type Datterino (Image: www.fruitsdelaterre.com)

Cherry tomatoes, single fruits or on the vine

Often further descriptions of the varieties would allow to define even more tomato types, and sometimes seed trade companies would come up with new definitions of types or subtypes, as e.g. «balcony-tomatoes», «strawberry tomatoes», «mini-San Marzano», etc. In most cases the tomato types are made out by their fruit shape and size. But also if harvested by single fruits or on vines is important, as well as the growing type. Some platforms would even offer types of specific use in the kitchen, as «Flaschentomaten» for tomatoes especially appropriate to sauces, or «Salattomtaten» that are best used raw as salads. But there are not a few cases, in which a variety could be assigned to more than one type, and in general there might be discussed, if it wasn't for the better to conduct only a few category types in order to honour the rich diversity of individual varieties that cannot be classified so easily.

From variety to variety fruits do differ a lot in their **colours**, like diverse variants of red, orange yellow, green, brown, black, white, as well as striped patterns. Similar there are many variants of fruit's **shape**. These colour and shape variants used to be solely in the focus of gene banks and NGO's like ProSpecieRara until the early 2000's. Only since a decade tomato variants of shape or colour became of interest to a larger audience, and in supermarkets as well as in the gastronomy there can be found a certain diversity of various colours and shapes. However on farm markets the range of colours and shapes is even wider. Together, on these points of sale, there can probably be found the total range of varieties that are promoted by seed traders for the professional production (e.g. the mentioned 150 different varieties).

1.b. Neglected tomato varieties

Another important characteristic of tomatoes is their large potential of different flavours. Opposed to colour and shape, which became the focus of breeders since the last two decades, **taste and flavours** have been neglected for a long time. Only in recent years some single offers of «very sweet» or otherwise «very flavourful» tomatoes are made by seed companies and tomato producers, and breeders try to enhance taste properties in modern varieties. But in general taste and flavour have been the focus only of private gardeners, of collectors and of conservation organisations like the NGO ProSpecieRara. We are sure, this was a big reason for the success of old tomato varieties, that ProSpecieRara started to promote among private gardeners through plant markets and the seed catalogue, as well as among consumers through the supermarket Coop, since the 1990's and since 2003, respectively. Before then, commercial tomatoes had lost the typical tomato flavour. And still today, the taste of common commercial tomatoes (of whatever shape and colour) can be generalized as «with some sweetness, high sourness, firm flesh and a hard skin» but «without any significant other flavours». However old and neglected tomato varieties often offer their very special flavour characteristics (see paragraph 2.). Of course in some cases these can also be of negative nature, as e.g. the tendency to mealy flesh of some varieties.

So why have the more flavourful varieties been neglected? Respectively, why fell flavour and taste out of the breeder's focus?

The reason is found within the demands of modern commerce. Production and commerce prefer firm tomato fruits of a long shelf life. Ripening processes should practically stop after harvest, and the fruits should be robust to accidental damage from harvest to transport up to selling. But of course already during the ripening at the plants, tomatoes should not take any damage from stress situations because of pests, disease or environmental factors. This resulted in modern tomatoes of very firm flesh and thick skin. A rather high sourness content probably helps as well enabling a long shelf life, and even enhancing certain durability in cold storage. However a slow ripening process does not at all enhance the development of flavours.

Therefore breeders tried to avoid tomatoes of soft flesh and of thin skin, and chose fruits of a reduced ripening process after harvest, and obviously of high sourness content. In other words – a lot **of taste properties have been pushed in just one direction**, if by accident or intentionally. As a by-product, breeders obviously lost the flavours in their tomatoes. A recently published study from the U.S.A. found that modern commercial tomato varieties contain significantly lower amounts of many of the important flavour chemicals than older varieties. The study could locate the genetic loci that affect these chemicals[39]. In some cases, they were close to genetic loci that affect agronomic properties, indicating that selection on such properties accidently removed also the flavour loci.

The existing old and neglected varieties often would not fulfil the mentioned requirements of modern commerce. Further, several important agronomic characteristics of old varieties are inferior as well, as e.g. growing behaviour or resistance to diseases. This causes big problems for professional producers who still try to grow old varieties. They need to put in more effort in the cultivation and face a higher risk for yield loss, and last but not least smaller yields in general.

Therefore, although tasty old varieties are much appreciated by private gardeners, and although these varieties kind of have a renaissance on balconies, beneath house walls and in hobby gardens, as well as to some degree on farm markets, old varieties are rather rare to be found in green houses of professional vegetable producers, that produce for the mass demand of price sensitive markets.

As mentioned in paragraph 1.a. around 150 varieties in everyday-use on the Swiss vegetable market is impressive, and indeed among these varieties can be found a broad diversity of different tomato types, colours and shapes. But as stated above, there is a big diversity in flavours and taste of another 150 old and neglected varieties that are rarely found on the market. Now what these two groups sets even more apart is their genetic profile. Stunning 120 varieties of nowadays tomatoes are hybrids, which therefore make out over 80% of the varieties used in professional production. Therefore **neglected tomatoes could also be equalled with open pollinated tomatoes**.

1.c. Summary: State of art of tomato diversity

From the previous paragraphs it can be stated in short:

- In everyday use in Switzerland a broad diversity of tomato types and tomato varieties can be found – of no other species seed lists and vegetable offers are available in such diversity, around 150 varieties are in professional use.
- The tomato diversity of professional use is made out by hybrid varieties to a large part (> 80%).

[39] «A chemical genetic roadmap to improved tomato flavor», D. Tieman et al., Science 355 (6323), 391-394, 2017 Jan 27.

- Still another 150 neglected and old varieties exist in Switzerland, and they have a rich diversity of flavours and taste, which lacks the in-use varieties almost completely
- Through private gardeners neglected and old varieties are still in use to some degree, and for private conservation their open-pollinated nature is important.

2. Description of the crop

As a classification and description of all possible tomato types and varieties is a task that could fill books. We restrict this description to some notable tomato varieties and characteristics, respectively, which are seldom found among everyday tomatoes.

2.a. Rare colours

From our experiences with average consumers, many people state out that «a tomato has to be red». And in fact, the red colour is still dominant on the tomato market. However among cherry tomatoes, recently added offers in supermarkets contain yellow tomatoes, as well as black ones, that is tomatoes of a darker red, and sometimes even striped fruits.

But **green** tomatoes are seldom seen in vegetable offers. They ripen into a bright green that can dive into yellow. The most famous green variety is probably 'Green Zebra', a variety originating in the U.S.A. and bred by open source breeder Tom Wagner. Green tomatoes face two main issues: For one, green tomatoes are often associated with «not ripe» by consumers, which lessens their appeal a lot. On the other hand, in green varieties the fruits of the right degree of ripeness are very hard to detect by farmers. For example, at the moment where fruits of the variety 'Green Zebra' change into yellowish they have to be eaten soon, because shelf-life decreases rapidly afterwards; but before no significant colour change can be detected, so farmers need to have other clues on ripeness, as the firmness of fruits.

Of a very special interest are **white** tomatoes. The colour can range from snow-white to cream-white. Interestingly, white varieties almost always are of very faint flavours, and they lack sourness almost completely (see 2.c.).

Only recently varieties of a **deep black** emerged from crossings with wild tomatoes. A private breeder of the ProSpecieRara-Network is developing such varieties in Switzerland, in cooperation with Tom Wagner. The fruits have a high content of anthocyanin, at least during maturing, but often the tomatoes would change into other colours when ripe, indicating a certain loss of these contents.

Image: www.varietas.ch

2.b. Rare shapes, extreme sizes

The classic tomato is of oval to round shape, be it as fruits in cherry size or in the most common average size. Since several decades in Switzerland also the oblong fruits with a marked tip of the San Marzano type are in use, although at the beginning mostly by imported conserves. Only in recent years the 'San Marzano' tomato or its descendants are offered as fresh vegetable in supermarkets.
Since a decade, three further shapes became more popular as well. Fruits of the Datterino type are also of oblong shape with a marked tip, but in cherry size, and sometimes with a faint dent lengthwise. And among cocktail tomatoes the plum shaped tomatoes are similar but a bit bigger sized, and without dominant tips or dents. On the other end of the size range, big tomatoes of the beefsteak type appear in heart-shaped form, sometimes with some furrows lengthwise.
Beside this already impressive variety range, among neglected varieties there can be found many more shape variants.

The old variety 'Marmande' offeres a tomato fruit of middle to big size with many **furrows**, and a rather deep stem base. There are several varieties in similar shape.

Other varieties have even deeper furrows, so deep, that cross section reveals slices similar to flowers, as e.g. in the variety 'Gezahnte

Bührer-Keel', which originates in Mexico, where it was known under the name 'Zapotec'.

In the variety 'Reisetomate' («Tomato for travel»), the furrows are so deep, that they connect, and that cicatrize at the seam. This allows to break the fruit apart along the seams and therefore to snack one fruit over a whole day without dropping juice.

Some other very dry tomato varieties are reminiscent of **block peppers** in their shape. Interestingly, the fruits also are very hollow and not juicy at all, jus like a pepper.

Image: Sativa Rheinau AG

Where most of the «heart-shaped» beefsteak varieties are reminiscent of an animal heart, or could also be described as drop-shaped with deep furrows, others would be more similar to the **classic heart** symbol. The fruits have broad shoulders and almost no furrows, they run into a pointed tip.

Among cherry tomatoes there are varieties of a round fruit that contain a **marked tip**, like in the variety 'Piennolo'.

Other cherry tomatoes are of **pear shape**. By the way, this shape sometimes can occur in single fruits of cocktail varieties that normally are of plum or egg shape, and sometimes some fruits of the date tomatoes (Datterino type) appear as well in pear shape.

At this point we like to mention as well the possible range in size. On markets cherry tomatoes are to be found with a fruit weight of 10-20g. Among collections there are tomatoes of only **5g or less**, in most cases these are so called «wild tomatoes», collected in nature and without a lot of breeding selection. They became of interest in recent years as they provide spectacular, intense flavours.

On the other side of the range beefsteak tomatoes on markets would reach fruit weights up to 300g. Maybe larger fruits would occur as well in modern varieties, but commercial quality demands would deny such fruits. Anyway, some old varieties can have regularly fruits of 500g, but would reach **up to 1kg per fruit** if grown properly.

Another note to the shape of old neglected varieties: Often non-commercial varieties are very **heterogeneous** in fruit size, and sometimes also in fruit shape (see the example of pear shaped fruits above). Heterogeneous fruits make the handling of a variety more complex, from production to the Point of Sale. In marketing, packs with various fruits sizes are estimated as less appealing. Therefore it is recommended to pack tomatoes of similar size into a given package[40]. But generally the heterogeneity can be a further reason for the neglected state of old varieties.

2.c. Rich flavours and taste properties of old varieties

[40] «Schweizerische Qualitätsnormen für Gemüse», by swisscofel & VSGP: http://www.qualiservice.ch/uploads/normen2017/de/Tomate.pdf

The basic taste properties are sweetness, saltiness, bitterness, sourness and umami. These can be detected by tongue. Other flavours are detected by nose retronasally. These make out the so-called aroma.

From tasting experiences with various tomato varieties over recent years, ProSpecieRara found, that the intensity of tastes and aroma are strongly connected to agronomic characteristics of the production. Generally we found that greenhouse production let the fruits not develop the same taste and aroma richness, as they would gain from outdoor production, for example in a garden on a sunny wall and with moderate manuring and slow growing. A hard description of tastes and flavours of a certain variety has therefore always to be taken carefully.

We therefore omit to present detailed taste description of certain varieties, but try to give an overview about some taste characteristics, which can be found among neglected varieties. A detailed analysis of chemical components, which make out various flavours has been provided by Tieman et al.[41]

Sweetness seems to be in the breeder's focus in recent years, as there are some examples of very sweet commercial varieties. So this is not a quality anymore to be found only in neglected varieties. Here and there the sweetest varieties are among cherry tomatoes. Some introduced wild tomatoes shine particularly with their high sugar content, so we think that the highest sweetness still can be found among the neglected varieties. In some varieties we found the sweetness to develop stronger towards autumn, maybe there is a connection between cooler temperatures and sugar content.

Few sourness often results in mild tomatoes. Although such tomatoes are not appealing to everyone, there are certain people who very much appreciate the very mild tomatoes. These can be found particularly among beefsteak tomatoes, and we found especially the yellow and white colour variants very mild.

[41] «A chemical genetic roadmap to improved tomato flavor», D. Tieman et al., Science 355 (6323), 391-394, 2017 Jan 27.

Fruity aroma can range from very specific associations as e.g. «cherry flavour» or «lemon flavour» to a general perception of just «fruit flavour».

Spiciness is sometimes mentioned by sampling persons when they have vague impressions on which they cannot be put the finger. Sometimes it's associated with **herb aroma,** but probably this impression results from various overlapping flavours that could contain a certain degree of the basic tastes as well, e.g. umami and saltiness.

Tomato aroma is as well a summarizing of several flavours combined. Interestingly everyone has a notion for this term, although it is triggered probably by different chemical flavour components for every person.

Firm flesh of low water content is found mostly in large beefsteak tomatoes. It is associated with a tender flesh, and appreciated for salads or sugo. Some tomato varieties are almost completely built by the beefy structure, and the seed chambers where normally the most abundant water content lies, are very small.

Thin skin is a trait of many old varieties and appreciated by tomato fans, but it often comes connected to a high sensitivity to cracked fruits on the stem base. Note, that also a thin skin can sometimes be tough to bite, but in general it tends to be rather tender.

2.c. Establishment of the tomato in Europe

Tomatoes originate from Central and South America and have been introduced in Europe after the discovery of America. Although the tomato was known in Europe since the 16th century, the German doctor and botanist Friedrich Alefeld would still write in 1866 about the tomato, that is «Essbarer Liebesapfel» (engl. edible love apple): «Im nördlichen Teil unseres Gebietes nur als Zierpflanze gezogen, im südlichen aber seines Nutzens wegen als Zukost- und Suppenpflanze.» (analogous translation: «In the northern part of our region it is grown only as ornamental plant, but in the southern part it is grown because of its use as side dish plant and as soup plant.») Only in the 1920's the tomato got common in kitchens of the german-speaking area, a bit earlier in cities, a bit later in the countryside.[42] Then it had developed to a role player in private gardens, and even contributed to some degree to food safety during the world wars.

The tomato diversity at the beginning of the 20th century could be tracked again by analysing the seed offers at that time. Tomato offers were obviously not as enormous as nowadays. For example a German plant catalogue from 1921[43] has its seven tomato varieties listed not under an own vegetable category, but among the kitchen herbs. Already then though, there existed quite some number of types of different tomato varieties. But the broad tomato diversity of nowadays developed during the 20th century.

3. Relationship between neglected tomato varieties and the environment

[42] «Das Lexikon alter Gemüsesorten», M. Serena, M. Suanjak, F. Pedrazzetti, B. Brechbühl, AT Verlag, Aarau und München, 2014

[43] «Haupt-Katalog über Gemüse- und Blumen-Samen, Stauden, Dahlien, Baumschulartikel, Gruppen- und Topf-Pflanzen», Nonne & Hoepker, Ahrensburg bei Hamburg, 1922

Compared to the common tomato production, we don't expect many differing aspects concerning environmental impacts of older varieties. We are not aware of any existing research on this specific topic. We estimate, that the smaller yields of old varieties in similar production as modern varieties, the longer growing period and a higher susceptibility to diseases, probably result in an inferior life cycle assessment (LCA). The emission effects (in kg CO2-eq/kg) of tomato's production[44] and consumption[45] may be on a rather high level, depending on the production manner. So there might be an environmental cost by producing old varieties of less yields and higher risks.

On the other hand, we'd like to point out, that some LCA's include impact on local wild plant diversity, but they never cover the long-time values of a high, or low cultivated crop and varieties diversity, respectively.

As tomatoes in southern European countries are produced not only in greenhouses, but also in the field, there need to be said, that this would just not be feasible for countries north of the Alps. The disease *Phytophtora infestans* is an omnipresent problem of the outdoor production. Susceptibility to this fungal disease is not a problem only of old varieties, but of the modern commercial varieties as well. Production risk of outdoor tomatoes is far too high, even with existing so called «robust» varieties – up to know there is just no resistant variety in commercial production. Since a decade there are trials to breed resistant outdoor tomatoes by crossings with wild tomatoes, and especially with the focus on organic agriculture[46].

4. Seed management of neglected tomato varieties

As stated in paragraph 1., the tomato diversity for professional use is made out by hybrid varieties to a large part (> 80%). However, neglected, old varieties are open pollinated. Tomatoes are self-pollinating to a high degree, and they are not sensible to inbreeding. Harvest and cleaning of seeds is easily made, and as seeds are ripe at the time of harvest, there hasn't to be made extra efforts for seed propagation. Tomato conservation of the neglected varieties is therefore basically easy to made also by private gardeners.

This might be a reason, why modern tomato breeders only develop hybrid varieties that cannot be multiplied by farmers.

On the other hand, tomato seed propagation for a professional production is not so trivial, as the prevention of diseases and viruses has to be made sure of. So farmers are naturally inclined to buy their seeds from professional traders or directly from seed propagators. Often the production process is spread over several enterprises, and e.g. producers of young plants fulfil several quarantine measurements concerning viruses and diseases. They would decline any seed from seed producers without the required quality standards.
However, also in private seed multiplication there are easy accessible methods to eliminate viruses like TMV, yet without the possibility to analyse success. An acid milieu as it occurs during the

[44] http://wikifootprints.org/en/Vegetables

[45] «Ökobilanzierung Früchte- und Gemüseproduktion – eine Entscheidungsunterstützung für ökologisches Einkaufen», A. Zhiyenbek, C. Beretta, F. Stoessel, S. Hellweg, ETH Zürich Institut für Umweltingenieurwissenschaften, 2016, online available: https://assets.wwf.ch/downloads/2017_01_oekobilanz_fruechte_und_gemuese_d_1.pdf

[46] «Tomatoes for organic outdoor production. Breeding methodology and regional development of varieties», H. Becker, B. Horneburg, Georg-August-Universität Göttingen, 2009

common fermentation method of harvested seeds can kill viruses, which are located on the outside of the seeds[47].

5. Agronomy of neglected tomato varieties

5.1. Susceptibility to diseases

As with many other neglected varieties of other crops, also old tomato varieties suffer from **susceptibility to occurring diseases**, as they lack breeding selection. Although old varieties are grown in a network of many people and although by that conservation of these open pollinated varieties is done «in the field», there is almost never selection pressure under a professional environment. A participatory project of Arche Noah in Austria faces this problem and wants to develop open pollinated varieties under a professional environment[48].

ProSpecieRara faced this issue during production experiences of old varieties for the supermarket Coop since 2003. Organic tomato production needs to deal with the fungi ***Cladosporium fulvum***. Up to recent years modern varieties were resistant against the existing fungal strains of *C. fulvum*. However, old varieties almost always suffer from *C. fulvum.* In organic greenhouse production this causes serious yield loss, depending on the weather from year to year. ProSpecieRara therefore started a breeding project with one variety as an experiment to cross in the necessary resistances, and to re-select on the old tomato type.

[47] personal message from D. Altenbach, Scientific Director, Bioreba AG, CH-4153 Reinach BL1, 2015

[48] «Das Bauernparadeiser-Projekt», Link: https://www.arche-noah.at/sortenerhaltung/sorten-entwickeln/das-bauernparadeiser-projekt See also other contributions in the DIVERSIFOOD project from the partner Arche Noah.

Cladosporium fulvum on tomato leaves of an old variety that was grown organically in the greenhouse.

Note: in recent years a new strain of *C. fulvum* has broken through the resistances, and modern varieties as well are not any more safe from the fungi. Organic production is therefore facing generally a problem with *C. fulvum,* and it is to be expected that various existing commercial varieties will be neglected in future years, when new and resistant varieties appear on the market.

5.2. Yield factors and physiologic stress

There are several **yield** or **input aspects** (efforts of manpower)**,** which can exclude an old variety from professional greenhouse production if not fulfilled or if they provide one of several issues:

- determinant growing – production wants unlimited growing
- plant growing time – production needs fast growing plants
- tendency to secondary sprouts – production wants as few cultivation efforts as possible to remove secondary sprouts
- frequency of fruit vines – production needs a steady rate of fruit vines
- appropriate numbers of fruits per vine – neither too few nor to many fruits, appropriate numbers depend on the fruit calibre
- fruit ripening period – production needs short ripening periods
- fruit ripening on the vine – production needs simultaneous ripening of all fruits on one vine
- steadiness – production wants all these characteristics until the end of season without exhausting symptoms of the plants

Ideally everything on the above list is granted for a variety, but as can be expected, neglected varieties often would not offer these characteristics in a satisfying way. Some factors can be pushed to a certain degree by cultivation measurements, but sometimes the **plant capability** is not feasible to an intense cultivation. For example this can be seen by **curled leafs**, a reaction of tomato plants to too much fertilisation, which is shown by various old varieties in a totally different way. Some varieties show no reaction at all, others would curl their leaves strongly. For the plants, this is their solution to deal with a not beneficial stress factor.

Another occurring stress factor is the lack of calcium, which causes **blossom end rot**. The reason is often not a lack of available calcium in the soil, but an unsteady water supply in the fruit during hot and dry days. As a by-product of bad water supply in the fruit, also too few calcium is delivered. Plant cells then build up too instable. By tendency tomatoes of large fruit size are more susceptible to blossom end rot, but it can occurs easily also in tomato types of smaller fruit sizes.

After all these negative agronomic aspects of neglected varieties, there is to mention, that determinant growing types can be of value especially in **pot cultivation** in private gardens and on balconies. On the other hand some of the mentioned issues are just not important in private gardens, e.g. *Cladosporium fulvum* would only occur in greenhouse production, and highest yield quantities are not the main reason to grow tomatoes for many private gardeners.

6. Quality aspects of neglected tomato varieties

As shown in paragraph 2. old and neglected tomato varieties can provide a rich diversity of colours, shapes and flavours. These characteristics are the most prevalent motivation for gardeners to grow these tomatoes. Often if once appreciated, they would look for their chosen variety every year, or they would start to harvest seeds themselves. If some agronomic or some quality issues would occur in a private garden, they often would not be of big importance. So it can be said, that **qualities of colour, shape and flavour** practically exclusively determine the success of an old variety in private gardens.

For the professional production and commerce it is totally different. From our experiences we estimate quality issues the most important reasons for exclusions of neglected varieties, even before agronomic problems. A **minimal fruit quality** is virtually the basic requirement for a tomato variety to be used in professional greenhouse production. If some of the following characteristics are an issue, a variety won't be feasible for professional greenhouse production and commerce:

- sensitivity to cracked fruits on the stem base – due to thin skin often seen in old varieties of large fruit size
- tendency to not closed fruit tips – seen in beefsteak tomatoes, where the fruit seems to grow from several sides together and connects by building seams
- sensitivity to blossom end rot (see paragraph 5.)
- sensitivity to greenbacks – some varieties would basically always suffer from this phenomenon, regardless of more or less presence of triggering factors
- sensitivity to cracking fruits during harvest – this can occur to fruits of thin skin that stick strongly to the stem base
- sensitivity of fruits to pressure during handling and transport – transport damage can be mitigated to a certain degree by appropriate wrapping
- fast and not stopped ripening process after harvest – this reduces shelf-life significantly and causes producers to harvest at an even earlier time

The last issue is not seldom with old varieties, and really important to heed. It restricts them to direct sellers and private gardeners, where tomatoes can be used practically on the same day as harvest. In some border cases the short shelf-life can be mitigated by an earlier harvest, but it is a compromise to be made, as of course flavours cannot develop according to their potential. This can lead to a paradoxical situation, when you really want to market this one flavourful tomato variety, but due to a short shelf-life you have to harvest the fruits very premature, and in the end your product, although successfully not yet being decomposed at the point of sale, it just has no more flavour than any other commercial tomato.

7. Potential uses of neglected tomato varieties

As stated in paragraph 1., tomatoes are a well known vegetable, and there are not many further uses to be expected explicitly with old varieties. Still there are some interesting characteristics than cannot be found in commercial varieties.

7.1. Chances of flavourful tomatoes in the gastronomy

Again, flavours and taste properties are most outstanding among neglected varieties. It may seem natural, that the **gastronomy** already long ago has committed to flavourful varieties. But the contrary is true. In the gastronomy prices, product availability, product steadiness, all are important issues. And whereas consumers appreciate very attractive, visual characteristics of tomatoes at the point of sale, customers of restaurants would not be able to be aware of these visual traits in the same way in the processed meals. There is hope though.

Since a few years there is a trend going on also in Switzerland called «Nordic kitchen», originating in the north of Europe and known famously by the gastronomy concept of Noma, Copenhagen (noma.dk). The philosophy appreciates the diversity of products in their individual nature, and tries to authentically conserve their natural flavours and properties during procession. In context of such trends the tomato diversity and their various flavours could be valued anew in the gastronomy. As stated out, the neglected varieties often are not feasible to commerce. So for this to work, direct connections between farmers and chefs have to be made, as to deliver the daily tomato harvest directly into the kitchen. This would allow letting the tomatoes develop their full flavour range.

7.2. Healthy aspects of some tomato varieties

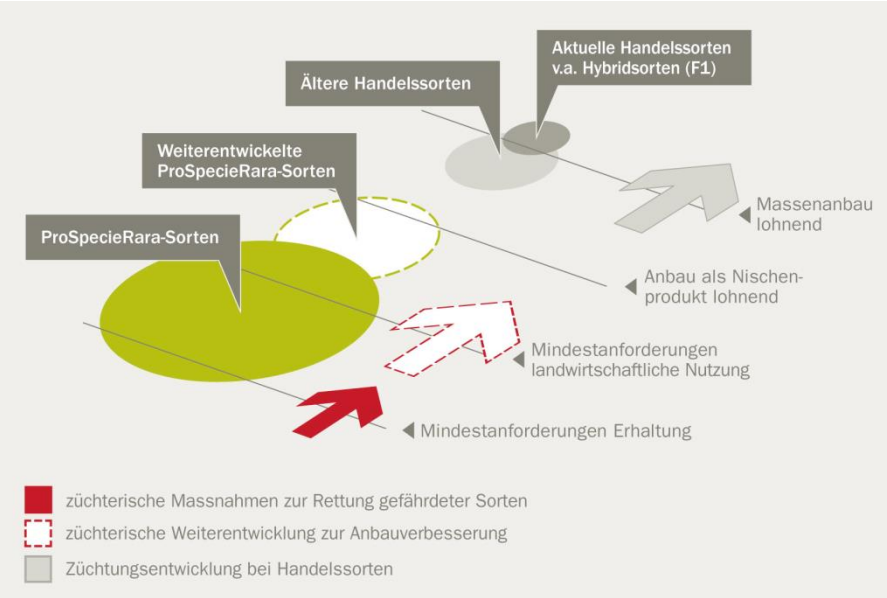
In some tomato varieties, some flavour and taste properties are found pushed to the extreme, e.g. in the anthocyanine rich black tomatoes, or in the very mild white tomatoes without any sourness. Such very special traits could be an argument to **health aspects**. Indeed ProSpecieRara got feedback from people suffering to gout, which would appreciate very much the acid-free and mild tomato varieties.

7.3. Breeding with tomato diversity

To **make interesting neglected tomato varieties fit professional production**, and to reach the market with such varieties, they would need some treatment in one way or the other, as stated in the paragraphs 1. to 6. ProSpecieRara successfully implemented some four neglected varieties organically produced in the supermarket Coop since 2003, others would fall out again after some years of selling, and many would make it only to agronomic trials, but never to the point of sale at the supermarket. Some of these, together with further old varieties made it also to plant selling of the same supermarket.

From the experiences we can say, that successful old varieties may fit professional greenhouse production and marketing in the supermarket also if not on the production level of nowadays hybrid varieties. But they can't lack in every need of the professional system. You could say, their production level lies somewhat beneath modern varieties, but not too far beneath (see image below). To make them still compete on the market, consumers need to be willing to pay higher prices for these varieties. Only then producers would be willing to deal with lower yields and especially to take the risk of product loss from bad seasons (e.g. in the case of a fierce pressure of *Cladosporium fulvum*, see 5.1.).
But the margins are narrow, and from all the neglected varieties only a few would make it, even with support from higher prices and a label to emphasise the special products. Several **breeding initiatives** therefore started to make old varieties fit nowadays production and commercial needs. In some cases selection from a heterogeneous population would already enhance their level. But e.g. in the case of

Example provided by ProSpecieRara: Overview of the assumed production level of old varieties (green) compared to modern hybrids (dark grey) and commercial varieties from before some years (bright grey). ProSpecieRara does not aspire to bring old varieties to the level of mass production (first line on the right), but to reach a level where niche production and professional marketing is possible (second line). For this the old varieties need to be developed by breeding



resistances, crossing with modern varieties is necessary.
The main goal of such breeding initiatives should be to **bring tomatoes with extraordinary flavour characteristics onto a feasible production level.** Probably some characteristics will always contradict, like a tender, thin skin vs. robust fruits without cracking and transport damages. So, the goal cannot be to keep all the awesome flavour characteristics and still compete with the agronomic best varieties of mass production. But according to the cases of ProSpecieRara in Switzerland, and of Arche Noah in Austria, it is possible to market varieties of an inferior production or quality level, if they really provide unique and valued properties, along with a good marketing, a label, and appropriate higher prices.

7.4. Open pollinated tomato varieties in private gardens

Last but not least it is important to repeat once again, the significance of the neglected tomato diversity, and particularly their nature of **open pollination**, for private gardeners. In the campaign «Stadt-Tomaten»[49] of ProSpecieRara since 2014, the big interest of private people in rare varieties in their own garden or on their balcony, is shown impressively within feedbacks and the loyalty of participants over the years. The manual to your own sowing, growing and harvesting of tomatoes in a pot, and then further to your own seed harvest for the next year, is appreciated very much. And for many this is not only the first step to their own tomato seeds, but to the growing and multiplication of many further crops. So the **open pollinated tomatoes become ambassadors for the diversity** of neglected varieties in general – an idea ProSpecieRara would be glad to see spreading in other European countries as well.

8.Conclusions

The mentioned ideas in this overview go along the existing European project TRADITOM[50]. The project focuses on the identification and valorisation of European traditional tomato varieties and their cultural practices. We strongly recommend to the interested reader to also check the TRADITOM project. ProSpecieRara doesn't claim to have covered above all the aspects of tomato diversity, but we hope to have provided at least the most important experiences with old tomato varieties from Switzerland.

9. List of References

[1] http://www.gemuese.ch/Ressourcen/PDF/Politik/CHGemuesebau_BROSCHURE_LID.PDF

[2] personal message from R. Pietrek, Coop, plant product manager of Coop Schweiz, 2017

[3] https://www.bdn.ch/organisations/acw/

[4] http://ec.europa.eu/food/plant/plant_propagation_material/plant_variety_catalogues_databases/search/public/index.cfm

[6] «A chemical genetic roadmap to improved tomato flavor», D. Tieman et al., Science 355 (6323), 391-394, 2017 Jan 27.

[7] «Schweizerische Qualitätsnormen für Gemüse», by swisscofel & VSGP: http://www.qualiservice.ch/uploads/normen2017/de/Tomate.pdf

[49] www.stadt-tomaten.ch

[50] http://traditom.eu/

[8] «A chemical genetic roadmap to improved tomato flavor», D. Tieman et al., Science 355 (6323), 391-394, 2017 Jan 27.

[9] «Das Lexikon alter Gemüsesorten», M. Serena, M. Suanjak, F. Pedrazzetti, B. Brechbühl, AT Verlag, Aarau und München, 2014

[10] «Haupt-Katalog über Gemüse- und Blumen-Samen, Stauden, Dahlien, Baumschulartikel, Gruppen- und Topf-Pflanzen», Nonne & Hoepker, Ahrensburg bei Hamburg, 1922

[11] http://wikifootprints.org/en/Vegetables

[12] «Ökobilanzierung Früchte- und Gemüseproduktion – eine Entscheidungsunterstützung für ökologisches Einkaufen», A. Zhiyenbek, C. Beretta, F. Stoessel, S. Hellweg, ETH Zürich Institut für Umweltingenieurwissenschaften, 2016, online available: https://assets.wwf.ch/downloads/2017_01_oekobilanz_fruechte_und_gemuese_d_1.pdf

[13] «Tomatoes for organic outdoor production. Breeding methodology and regional development of varieties», H. Becker, B. Horneburg, Georg-August-Universität Göttingen, 2009

[14] personal message from D. Altenbach, Scientific Director, Bioreba AG, CH-4153 Reinach BL1, 2015

[15] «Das Bauernparadeiser-Projekt», Link: https://www.arche-noah.at/sortenerhaltung/sorten-entwickeln/das-bauernparadeiser-projekt See also other contributions in the DIVERSIFOOD project from the partner Arche Noah.

[16] www.stadt-tomaten.ch

[17] http://traditom.eu/