IHC 2022
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ANGERS - FRANCE
HYBRID

HORTICULTURE FOR A WORLD IN TRANSITION

Press Reviews

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› Panorama of French horticulture

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IHC 2022
INTERNATIONAL HORTICULTURAL CONGRESS
ANGERS – FRANCE
www.ihc2022.org

France is honored to host the 31st International Horticultural Congress (IHC) in August 2022. This is a great event to take place at Angers in the Loire Valley. The organizing committee is aiming for a high-level scientific event that will encourage collaboration as well as the three way connection between research, education, and industry. The IHC2022 is the best opportunity to enhance exchanges on science, knowledge and culture between southern and northern countries.

Over one week, IHC2022 will gather more than 3,000 participants. The backbone of the congress is the series of plenary sessions and about 25 symposia. Workshops, business meetings, side events, student job dating, etc. will in addition allow participants to meet, connect, discuss and debate around a central motto: "HORTICULTURE FOR A WORLD IN TRANSITION". IHC2022 will indeed address major topics and issues related to Horticulture around four main priorities:

- Competitiveness and skills for the horticultural sectors,
- Food, health and well-being,
- Sustainability of production systems,
- Adaptation to climate hazards and mitigation solutions.

This world-class congress is a unique opportunity to discover the city of Angers and its area through a week-long rich program of social events, and also the Loire Valley, Britany and so many French regions after the congress through various professional and touristic tours, in order to enjoy some pieces of the French "Art de vivre", made of rich cultural heritage and creative cuisine.

A series of articles specially designed for *Chronica Horticulturae* will set up an overview and highlight some specificities of horticulture in France[1] from this issue until August 2022. An editorial team including Agnes Grapin and Jean-Claude Mauget (Agro-Campus Ouest Angers), Jean-Luc Regnard (Montpellier SupAgro), and Rémi Kahane (CIRAD Montpellier) is dedicated to finding contributors among scientists and professionals to give a taste of the French realities, specialties, challenges and research in horticulture, in the European and international context. Just a way to attract you to Angers on 14-20 August 2022!

Diversity of horticultural production in metropolitan[2] France

France offers a great diversity of territory and landscapes that correspond to a wide range of micro-climatic situations. These production areas are associated with equally diverse sociocultural traditions and practices concerning food, healthy consumption, and well-being (Figure 1). As a result, in the sectors that make up Horticulture[3], the range of French production and products resulting from their transformation is extremely diverse. By juxtaposing fruit and vegetables, ornamental and nursery crops, plants for essential oils, and herbal, medicinal and aromatic plants (HMAP), the number of plants cultivated or harvested is estimated at more than 20,000. French plant diversity includes specific territories and origins that command value added benefit for fruit and vegetable product chains (Figure 2).

Agronomically speaking, the cropping systems are diverse. They include an intensive soilless system in greenhouses, which allows a finely tuned control of environmental conditions (vegetables, flowers), mechanized industrial cropping (plants for essential oils, vegetables for processing), "market gardening" (vegetables for direct sale, aromatic plants and herbs), fruit cropping systems, and nurseries. Most of these sectors are labor intensive. Further downstream, even if one considers only the first postharvest processing that is sometimes carried out by producers themselves (e.g., drying herbs, distilling aromatic plants), the technical operations are also diverse, to cover the multiplicity of commercial outlets. These operations mobilize specific materials and knowledge bases.

Presentation of the different sectors

Considering the above-mentioned diversity in a value chain approach that constitutes the core business of FranceAgriMer, three groups of production with several main characteristics have been distinguished (Table 1).

Issues and challenges

In the 1960s and 1970s, the large number of crop production and the heterogeneity of farms could be perceived as indicators of delayed French agriculture and its difficulty to adapt to modernity. However, this perception has greatly changed. Diversity is nowadays regarded as an essential condition that enables the adaptation of agricultural and horticultural farms to market constraints and societal expectations.

In the context of urban sprawl, which induces a quest for naturalness, horticultural productions of the three different sectors convey very positive values for health and well-being, and resilience to climate change. Beyond the maintenance of local markets with fresh products, horticulture for landscaping and leisure is perceived to play a key role, for example by limiting urban heat island effects and greening urban spaces.

The downstream industry has made no mistake, when referring to the potential benefits of horticultural produce crossing all sectors: healthy food ("eat five fruits and vegetables each day"), health food supplements extracted from plants (booming of nutraceuticals), plant natural cosmetics, alternative medicines based on plants, etc. With a slight delay, produce from ornamental horticulture are more and more appreciated for their "well-being" effects besides their decorative interest/function.

[1]Metropolitan and overseas departments including French West Indies, Mayotte and Reunion islands.

[2]The data presented in this article do not include French overseas territories and departments. They also exclude the wine sector, the cider and perry industry, as well as derived alcohols and spirit drinks.

[3]In France, the term "horticulture" is sometimes restricted to the sectors of ornamental and nursery production. It is not the case here.

Figure 1. Fruit and vegetable Eiffel Tower at the International Agriculture Fair, Paris, 2014. ©Jacques Bousiquier.

The positive current context is likely to be sustainable according to multiple general or sectoral studies analyzing consumer expectations. In the long-term however, it does not offer a perspective of profit for the sectors concerned, in particular for producers who must constantly adapt to a set of constraints through innovation.

The special issues for fresh produce

While some primary products are immediately processed on farm, the destination of many products is to be sold fresh, such as fruit and vegetables, herbs and aromatic plants, cut flowers, and potted plants. Being perishable, i.e., not easily storable or only shortly, these products also show a sensitivity to climatic conditions, more importantly than in other agricultural sectors, both in terms of supply and consumption. Moreover, competition between products or even among species is real, and substitution occurs at both the distribution and consumption stages (e.g., juice vs. fresh fruit). This situation requires permanent adaptation capacities for the upstream sector (producers), onset of reliable information networks (on markets, costs, prices), and adapted logistics organization. In view of what exists for the horticultural sector in other countries, such as floriculture in the Netherlands, French horticulturists have room for improvement in terms of economic and logistical organization and data management.

Means of production

For the most intensive production systems, horticultural companies are capital-intensive and implement high technical knowledge in cropping, adaptation to climate change or prevention of meteorological hazards, and protection against pests and diseases. As horticultural farms are labor intensive, they often have to comply with many social responsibilities within the various labor markets, while having to address imperatives of the global market.

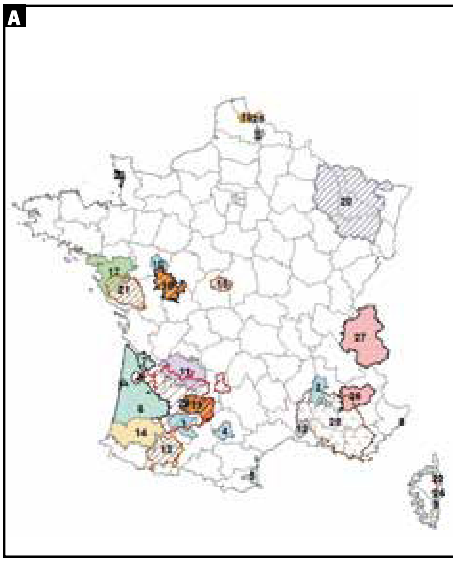
The French horticultural production chains are characterized by contrasting environmental impacts. Heated glasshouses consume fossil oils and generate greenhouse gas. However, they can use cogeneration to optimize the energy management, and carry out integrated biological protection systems, in order to lower the use of phytochemicals. Moreover, plastics are now frequently used for mulching, covering tunnels, netting against hail or to control pests. This occurs despite most plastics being hard to recycle.

Vegetable production systems have become particularly diversified, from open-field production for the processing industry, heated and lighted greenhouses, to market gardening systems in open air or under low shelters. It must be highlighted that different systems can co-exist on the same farm.

The French fruit production has evolved towards a regional specialization (Figure 3). The plantation of productive orchards has largely turned towards fresh produce markets with a strong development of integrated fruit production (IFP) as a standard. From 2000 to 2010 (according to the periodical national survey of the French Ministry of Agriculture), the national fruit potential lost 25% of its area, but was restructured thanks to new varieties better adapted to markets, and orchards managed according to the IFP principles (for apple, pear, peach, nectarine and apricot) (Figure 4). To these already common trends, some emerging goals have more recently been added such as: zero pesticide residue and high environmental value.

At the same time, the organic shares of fruit and vegetables grew in production: from 2001 to 2012, the area of organic fruit production increased from 4.0 to 12.5%, while that of organic vegetables rose from 1.8 to 4.0%. This trend even accelerated between 2012 and 2016 according to the French organic agency[4]. Such a trend can be verified at the consumption level: from 1999 to 2012, the global market for organic fruit and vegetables was multiplied by four, and was estimated to have doubled from 2015 to 2016, this segment representing nowadays about 10% of the market share (Figure 5).

The French ornamental production sector is strongly challenged by low-cost or highly organized countries. It has also experienced a concentration of companies with the disappearance of almost half of them over the last



Nr.	Protected geographical indications (PGI)	
1	Ail blanc de Lomagne	(garlic)
2	Ail de la Drôme	(garlic)
3	Ail fumé d'Arleux	(garlic)
4	Ail rose de Lautrec	(garlic)
5	Artichaut du Roussillon	(artichoke)
6	Asperge des Sables des Landes	(asparagus)
7	Asperges du Blayais	(asparagus)
8	Citron de Menton	(lemon)
9	Clémentine de Corse	(tangerine)
10	Echalote d'Anjou	(shallot)
11	Fraise du Périgord	(strawberry)
12	Fraises de Nîmes	(strawberry)
13	Haricot tarbais	(dry bean)
14	Kiwi de l'Adour	(kiwifruit)
15	Lentilles vertes du Berry	(lentil)
16	Lingot du Nord	(dry bean)
17	Mâche nantaise	(cornsalad)
18	Melon du Haut Poitou	(cantaloupe)
19	Melon du Quercy	(cantaloupe)
20	Mirabelles de Lorraine	(mirabelle)
21	Mogette de Vendée	(dry bean)
22	Noisette de Cervione	(hazelnut)
23	Poireaux de Créances	(leek)
24	Pomelo de Corse	(grapefruit)
25	Pommes de terre de Merville	(potato)
26	Pommes des Alpes de Haute Durance	(apple)
27	Pommes et Poires de Savoie	(apple & pear)
28	Pruneaux d'Agen	(dry prune)
29	Thym de Provence	(thyme)

Nr.	Protected geographical indications (PGI)	
1	Abricots rouges du Roussillon	(apricot)
2	Ail violet de Cadours	(garlic)
3	Béa du Roussillon	(potato)
4	Chasselas de Moissac	(grape)
5	Châtaigne d'Ardèche	(chestnut)
6	Coco de Paimpol	(dry bean)
7	Farine de châtaigne corse	(chestnut flour)
8	Figue de Solliès	(fig)
9	Huile essentielle de lavande de Haute-Provence	(lavender essential oil)
10	Lentille verte du Puy	(lentil)
11	Muscat du Ventoux	(grape)
12	Noix de Grenoble	(walnut)
13	Noix du Périgord	(walnut)
14	Oignon de Roscoff	(onion)
15	Oignon doux des Cévennes	(onion)
16	Piment d'Espelette	(pepper)
17	Pomme de terre de l'Ile de Ré	(potato)
18	Pomme du Limousin	(apple)

15 PDOs also exist for olives and olive oils, and 1 for walnut oil.

Figure 2. Mapping of regional horticultural labels in metropolitan France: A. Protected geographical indications; B. Protected designations of origin.

[4]https://www.agencebio.org/.

Figure 3. Citrus germplasm collection orchards managed by INRA in San Giuliano, Corsica. ©INRAe.

Figure 4. Harvesting of apples cropped under hail nets in the Valois region, north-east of France. ©Jean-Luc Regnard/ Montpellier Supagro.

decade. In recent years, this sector decided to restructure and create various differentiation tools (brands, certification and quality labels) in order to meet the expectations of consumers and citizens in terms of environmental, social, economic and health performance (Figure 6).

The perfume, medicinal and aromatic plant sector (PPAM) has largely benefited from the market demand for natural produce with a 40% increase in production area over the last five years. For these crops, which are mostly transformed, the specific investments focused both on cropping (mechanization) and on processing (dryers, distilleries). With the implementation of technical means that were largely lacking until the end of the 80s, the production schemes have been greatly modernized (Figure 7), reassuring the customers of these quality materials, and discouraging them from switching to other supply solutions (competition of synthetic vs. natural produce).

The challenges for research, experimentation and innovation

For all sectors, applied research, experimentation and innovation are considered essential components of their development, of their economic sustainability and therefore, of their permanency in the national territory. For example, despite the diversity and the quality of the offer, the French fruit and vegetables sector suffers from a lack of competitiveness at export. To analyze this situation, the Ministry of Agriculture and Food mandated FranceAgriMer to identify the factors that negatively affected the agricultural and agri-food trade balance in recent years, and establish a diagnosis at national level. This analysis will be carried out by a working group under FranceAgriMer supervision, bringing together specialists in value chain economy across various ministries and professional bodies. It aims to imagine practical solutions towards a better future in terms of market share and export capacity.

Figure 5. 'Cantaloupe' melon on a market in Britany.

Reducing the use of plant protection chemicals is one of the major issues facing producers today. Given the multiplicity of species, varieties, and growing environments, research needs are huge. Due to the rapid decline of the use of phytosanitary chemicals, the horticultural sectors set up alternative methods whose objectives are to meet the expectations of reducing the negative impacts of crop production on the environment, to develop high quality products, and to avoid horticultural producers left in technical dead ends. It should be noted that many of these crops gather modest acreages compared with other field crops such as cereals. Accordingly, the phytochemical companies invest little resources for these crops and a large part of the chemical uses are described as "minor", meaning that they result from the transposition of solutions for another crop. This work is frequently performed by technical institutes (see Table 1).

Biocontrol is now widely developed in all sheltered production units and in orchards. It contributes to a significant reduction in the use of conventional phytochemical treatments. Biocontrol includes both uses of macroscopic biocontrol agents such as auxiliaries, of microorganisms, and of natural products in crop protection (plant extracts, products of animal or mineral origin), as well as the use of chemical mediators (volatile compounds). For example, INRA studies the vegetable plant protection effects of macro organisms such as trichogramma. These micro-hymenoptera, whose larvae develop in the eggs of lepidopteran pests, are effective parasitoids to hinder the development of caterpillars of harmful species (e.g., tomato moths). However, these methods have partial effects, and new challenges appear every time with new pests: for instance, today no method is effective for controlling certain invasive species such as the spotted wing drosophila (*Drosophila suzukii*, severe pest on red fruit) or the brown marmorated stink bug (*Halyomorpha halys*). Thus, although biocontrol is a real alternative to pesticides, it still needs to increase its effectiveness, by coupling its use with other levers: physical protection methods such as insect nets often installed in addition to anti-rain nets, rainproof plastic sheeting, and mass trapping.

For sheltered ornamental productions, alternative techniques to the reduction of treatments by growth regulators (narcotics) have also been developed, consisting for example of mechanical and automated stimulation of plants (project "@Casper" led by Astredhor).

For field crops, important work is being done on alternative techniques to chemical weed control, some using the most advanced techniques (e.g., geolocation of plants, automatic detection and treatment of weeds, autonomous robots).

For perennial perfume crops such as lavender, innovative inter-row plant cover techniques have been developed to hinder the spread of leafhoppers (*Hyalesthes obsoletus*), vectors of the phytoplasma (*Candidatus Phytoplasma solani*) responsible agent for the dieback of lavender (*Lavandula* spp.) fields. Incidentally, this work[5] highlighted other

[5]http://www.sauvegarde-lavandes-provence.org/images/Programme-Euclide-light.pdf.

Figure 6. Branding French ornamental produce as a quality criterion for consumers. ©Agnès Grapin/ACO Angers.

Figure 7. Mechanical harvesting of lavender in Provence, south of France. ©CRIEPPAM.

Box 1. EUFRUIT[6] project (3 years, 2016-19)

The project consortium consisted of 21 members, including research institutes, universities, and industrial partners who represent key parts of the fruit supply chain, from 12 European countries. Through a multi-actors approach, the EUFRUIT project (funded under the European Horizon 2020 research support program) aimed to improve the implementation of research outcomes into practical and applicable knowledge that will directly benefit the highly challenged European fruit sector. The difficulties met are of technical, sanitary or environmental nature, as well as economical (market), while the fruit sector is trying to meet the expectations of consumers and ensure the sustainability of farms. Within EUFRUIT an international knowledge platform has been created (http://kp.eufrin.eu/) on the following four thematic areas:

- Performance of new fruit varieties,
- Reduction in pesticide residues,
- Postharvest fruit quality,
- Design of sustainable fruit production systems.

It has been possible to share a complete vision between researchers and practitioners in the perspective of a reduced use of synthetic phytosanitary products, what allowed a reduction in chemical residues in the fruit and a smaller footprint on the environment.

This project has highlighted the strong development of alternative methods to chemical pesticides, be it bio-control or physical control methods (orchard netting against pests, plastic cover against diseases), or a combination of both.

Box 2. Research and development players in the fruit and vegetable sector

- The Interprofessional Technical Center for Fruit and Vegetables (CTIFL) is the leading applied research organization in the French fruit and vegetable sector, serving the different professionals from production to commercialization. Its annual activity program is based on the sector strategic program, aligned on a budget of over 20 million Euros consisting of professional funds (extended voluntary contribution), research and experimental funds related to program grants or competitive projects (European or national calls), and private funds. CTIFL carries out activities of experiment and research, innovation transfer, economic and regulatory intelligence, training and dissemination of information and knowledge to horticultural professionals. Recognized as a competent authority, CTIFL is in charge of the control and certification of fruit propagation materials, excluding strawberry plants. CTIFL is present in the main French production basins with four regional centers, which constitute, in partnership or in association with regional experiment stations, an experiment network unique in Europe.
- Regional experiment stations: the French fruit and vegetable sector also benefits from a network of ca. 30 experimental stations located in their territories in connection with the multiplicity of species and regional issues. This historic network (80s) is of great importance because it has significant experimental capacities. It addresses regional issues linked to CTIFL and according to priority needs. The funding of these stations can be private and/or public. The proximity of producers favors a quick dissemination and transfer of results.
- Scientific interest groups (GIS):
  The GIS Fruits, created in 2012 with 22 partners (INRA, CTIFL, CIRAD, professional organizations, higher education, etc.), aims to contribute to sustainable development oriented innovation in fruit crops through the production of scientific and operational knowledge. It seeks to support changes in the fruit sector by triggering and promoting research, experiment, extension and training activities. The GIS PicLeg (stands for Integrated Production of Vegetable Crops) was created in 2007. It enables the development of vegetable crops and cropping systems taking into account societal expectations reconciling food quality, environmental impact, economic performance of farms and social requirements. Its field of study takes into account all modes of production (open field, soilless, greenhouse and shelters). In the framework of a ten-year agreement (2017-2027), two themes are developed: strengthening the knowledge and the design of low-input cropping systems at the plot scale, and developing new actions around diversification and organization of food systems at the scale of farms, territories and vegetable value chains.

[6]https://eufrin-test2-9fy.micusto.cloud/?id=55.

■ Table 1. Main economic and structural characteristics of the various horticultural sectors in France[a]. Sources: data from the French inter-professions, Ministry of Agriculture and the French customs (mean data for 2016-2017). NA: Not applicable (for acronyms of French organizations, see Box 2&3).

Horticultural sectors	Ornamental horticulture, floristry & landscaping	Herbs, medicinal & aromatic plants (HMAP)	Fruit & vegetables
General data	53,000 firms (farms and companies): production, trade, landscaping Jobs: ca. 170,000 employees Annual sector turnover: 14 billion € including sales of flowers & foliage, nursery plants: 2.5 billion € (direct consumption stage)	ca. 5,000 producers (not necessarily specialized) Annual sector sales: more than 5 billion € (consumption stage, variable data depending on the scope of products considered)	75,000 firms (farms) Vegetables: 5.3 million t (including 35% for processing industry) Potatoes: 7.0 million t Fruit: 2.7 million t (including 20% for processing industry) Annual sector turnover: 16.5 to 18.0 billion € (consumption stage, potatoes excluded) Processing industry: 144 units Annual industrial turnover: 2.9 billlion € (consumption stage)
Activities in the upstream production chain	Plant material propagation: production of seeds (ornamentals & vegetables), cuttings, young plants & transplants, etc.		
Activities of the production sector	Flowers, foliage, potted plants & bedding plants, nursery plants (trees & shrubs), bulbs, etc.	Fresh plants or plant components (herbs)	Fruit & nuts, bramble fruit Vegetables issued from open field or shelters, cultivated mushrooms
First use/first transformation activities	Bouquets, sheaves, flower arrangements, etc.	Drying or distillation (frequent at production stage) Other processing operations requiring industrial facilities (e.g. deep-freezing)	Canning, deep-freezing, ready-to-eat (fresh-cut or processed), sugar-preservation, oil extraction, jams & beverages (e.g. juice), fermentation, pickling, etc.
Second transformation activities	None	Perfume, aromas, nutraceuticals, drugs, food supplements, etc.	Fruit mix, mixed vegetables, agri-food industries
Other plant use	Landscaping for communities or individuals	NA	NA
Sale activities	On-farm sales, fairs and city markets, garden-centers, mass retails, florists, online sales	On-farm sales, agri-food industries	On-farm sales, primeurs and city markets, specialized fresh retails, mass retails, online sales Private and collective catering
Production units	3,300 (as main activity)	ca. 5,000 (farms)	Fruit: 27,600 farms Vegetables: 30,800 farms (including 6,000 dedicated to processing) Potato: 19,900 farms
Production surfaces	15,000 to 16,000 ha (including shelters: 1,600 ha)	53,000 ha	Fruit: 170,000 ha Vegetables: 220,000 ha (including shelters: 7,500 ha) Potato: 165,000 ha
Trade/sales	18,900 firms including: - 395 wholesalers, - 15,100 florists, - 3,400 garden-centers	Many trade channels, depending on the nature of plant extracts and uses	Shipping & export business: 350 Wholesalers (including central purchasers): 1,168 Primeurs and specialized fresh retails: 11,700 Hyper- & supermarkets: 12,776 Importers: 150
Landscaping	30,250 firms	NA	NA
Annual turnover (production stage)	1.6 billion € (50% finished plants/50% nursery plants)	0.15 billion €	8.1 billion €
Evolution	Reduction in the number of farms, reduction in the number of jobs (full time equivalent)	Sharp development: +40% over the last 5 years	Fruit crops overall in decline vs. stability for vegetables Significant increase in the organic products segment: +16% of sales in 2017 Slow decrease in consumption of fresh and processed vegetables, stability for fruit
Offer grouping	ca. 15 producers' organizations	ca. 15 producers' organizations	225 producers' organizations, 300 cooperatives (partial double count)

Import	0.9 billion €	2.45 billion € (essential oils)	Fruit: 4.7 billion € Vegetables: 2.1 billion €
Export (value)	56 million €	2.2 billion € (slightly processed), more than 10 billion € (finished products)	Fruit: 1.6 billion € Vegetables: 1.1 billion €
Production staff number	19,300	6,000	450,000 (including 250,000 seasonal jobs)
Inter-branch organisations	VAL'HOR	CIHEF (essential oils)	INTERFEL ANIFELT
Signals of quality (certification or labelling)	Red labels and Blue Plant label, high environmental value (HEV[b]) and milieu programma sierteelt (MPS[c]), Fleurs de France, etc.	1 PDO + 1 PGI (Figure 2) Organic farming certification, Red labels, etc.	18 PDO + 28 PGI (Figure 2) 24 Red labels, etc.
Technical institutes	ASTREDHOR with a network of 10 regional stations	Network of 4 entities, including ITEIPMAI Partnerships with organic agriculture institutes (ITAB, GRAB)	CTIFL and a network of 27 regional stations UNILET (processed vegetables) Arvalis (potato) Partnerships with organic agriculture institutes (ITAB, GRAB) CTCPA (Technical institute for food industry)
Public research	INRA centers (Angers, Sophia Antipolis, PACA Avignon) Joint research units with higher education organizations & joint technological units with other partners	INRA centers (Angers, Clermont-Ferrand, Evry) French higher education organizations in partnership with CRIEPPAM & ITEIPMAI	INRA centers (Angers, PACA Avignon, Bordeaux, Corsica, Montpellier, Rennes, Toulouse) CIRAD (Montpellier) Joint research units with higher education organizations & joint technological units with other partners

[a]Metropolitan France, including Corsica, and excluding the French West Indies, French Guyana, La Réunion and Mayotte islands.
[b]https://agriculture.gouv.fr/hev-certification.
[c]https://www.my-mps.com/en/, mainly used in the ornamental sector.

favorable effects of plant cover in terms of tolerance to drought and heat on the dry soils of the Provence highlands where most of these plants are cropped.

Developing innovation

Beyond the technical solutions expected by each commodity chain for the resolution of their cropping problems and the reduction of their production costs, research and innovation largely contribute to the dynamics of the chain concerned. This is particularly the case of "produce innovation," whether it is about releasing new varieties or increasing the processed value of secondary metabolites (Box 1).

This axis of innovation is particularly important in the HMAP sector, where the market life of an end-product can be ephemeral, whereas a rapid turnover is observed (over 1,000 monthly applications on the registration portal for food supplements). For processed products, innovations in the processing are also crucial and can greatly influence the future of a crop production. This is the case, for example, with the modernization of harvesting operations, upstream of a distillation plant for essential oils, that can greatly contribute to the development of aromatic or medicinal plants.

In the fruit and vegetable sector, innovation is the key driver for the agroecological transition and for securing the quality of the produce (especially food safety of fresh produce to be processed) (Box 2-3). In the sector of processed fruits and vegetables, the Qualiveg-2 technological mixed unit supported by the Technical Center for the Conservation (and processing) of Agricultural Products (CTCPA) and the National Institute for Agricultural Research (INRA) in Avignon, is in charge of developing collaborative projects related to organoleptic, health and nutrition quality of fruit and vegetable produce. Innovation ultimately increases value and contributes to the competitiveness of French industries that are strongly challenged internationally by countries with lower production costs. Organizational innovation is sought as well, such as corporate social responsibility (CSR) implemented downstream in value chain companies generally, which contributes to local or at least national sourcing.

Foresight studies at FranceAgriMer

What would happen if, in 25 years, the fruit tree breeding is controlled by the processing industry? If ornamental plants are only cultivated for their capacities of phytoremediation of polluted soils, storm water management, urban temperature mitigation, etc.? If climate change completely upsets the list of varieties of fruit and vegetables cultivable in France? If the food stores totally disappear? And if ...?

Because the long-term future is neither predetermined nor predictable, because it opens many options, and because it never emerges from the void but from the present, which holds heavy tendencies and weak signals as well, foresight studies allow consideration of the room to maneuver that actors have to favor the arrival of a desirable future, or at least chosen in part. These studies make use of a systemic approach that brings into perspective each question raised in relation to different possible constructions of the future world. Since its creation in 2009, FranceAgriMer has coordinated a series of foresight studies within the agricultural and horticultural sectors (Box 4) to jointly build common representations of these sectors and to discern scenarios for the future. Once a foresight study is completed, the actors of the concerned sector are invited to analyze the consequences of the various emerging scenarios. Then, from the subsequent debate on the future, possible scenarios of evolution can emerge, giving rise to a collective strategy for the sector.

Box 3. Research and development players in the ornamental and nursery chains

- ASTREDHOR, the technical institute of horticulture, was created in 1995. It now includes a national unit and six regional units, grouping ten experimental stations distributed in the different French horticultural production basins. It mobilizes a total of 105 employees (87 full time equivalent) of whom 75% are scientific staff. Its consolidated budget is 6.9 million Euros. Its scientific project is structured for the period 2018-2022 around five major challenges for the sector:
  - development of alternative production systems and accompanying related transitions,
  - development of green engineering and the consideration of ecosystem services provided by plants,
  - emergence of new industrial recovery opportunities for the bioeconomy,
  - adaptation of companies to economic developments and markets,
  - emergence of "connected" horticulture.

  ASTREDHOR is involved in different partnership arrangements at the European, national or regional levels.
- ITEIPMAI: applied research and experiments in medicinal and aromatic plants are mainly carried out under the aegis of this national technical institute by a network of four technical structures including ITEIPMAI, the Regional Interprofessional Center for Experimentation in Perfume, Aromatic and Medicinal Plants (CRIEPPAM) specialized in the Mediterranean cultures and their first transformation, the National Repository of Perfume, Medicinal and Aromatic Plants (CNPMAI) ensuring the germplasm conservation, and Agriculture Chamber of the Drôme department. This network brings together about 55 permanent staff for an annual budget of about 4 million Euros. Partnerships with public research centers are established as needed, depending on the nature of the projects. Insofar as these productions are of little interest to plant breeders, phytosanitary firms and manufacturers of agricultural equipment, the field of investigation of these organizations is very broad: genetic improvement, crop protection, weeding, mechanization of crops, first transformations, and technical support.

Box 4. Foresights applied to French horticulture: example of the scenario "Fruit varieties for the future"

At FranceAgriMer, a small team carried out foresight exercises to meet the demands of the agricultural sectors. Based on a method developed in the 90s by Michel Sebillotte at INRA, this team implemented various methodological complements allowing for scale changes (from national to local, from the whole sector to a profession, etc.), and the passage from micro- to macro-scenarios. A dozen exercises have been carried out since 2009 for plant and animal sectors. For horticulture in particular, the studies were as follows: Foresight on fruit & vegetables (October 2009 - October 2011), Foresight on ornamental horticulture (March 2012 - March 2014), Foresight on the cider value chain (March 2014 - January 2016), Foresight on fruit varieties for the future (April 2016 - November 2018), Foresight on the French HMAP sector (in progress from June 2018). A comprehensive report and a synthesis were published from these analyses, as well as the organization of participatory presentations. For example, the foresight on fruit varieties of the future produced four contrasting scenarios:

- Variety innovation for orchards adapted to climate change,
- Dynamics in fruit breeding under control for demanding consumers,
- A slow fruit variety creation for a low price market,
- Transformers driving variety innovation.

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› Vegetable seed sector in France

Richard Brand, Marie-Christine Daunay, Dominique Daviot, Rémi Kahane and Emmanuelle Laurent

Introduction

Vegetable production in France (Box 1) has developed since the 19th century from traditional "vegetable belts" along the fertile river plains near urban centers, such as the valleys of Seine and Loire, Rhône and Var rivers (Figure 1a). Intensive production developed from the beginning of the 20th century in areas with favorable soil and climate, in particular in French Flanders (St Omer, for cauliflower and winter vegetables), upper Seine valley (asparagus and "green" vegetables), central France (Orléans and Sologne, for asparagus, strawberry, cucumber), Brittany (St Malo basin for cauliflower, potato), western France (Nantes basin for carrot, corn salad, leek, lily of the valley), and southeastern France (Provence and Hyères region, for Mediterranean vegetables).

From 1950 onwards, several areas became specialized: Normandy (carrot, turnip, leek and winter vegetables), Brittany around Roscoff and Plougastel (cauliflower, onion and shallot, potato, strawberry, tomato), Limagne plain (garlic, shallot), southwestern France (tomato from Marmande, beans and strawberry from Villeneuve-sur-Lot, melon), Camargue (melon, tomato), and around Perpignan (chicory, lettuce, tomato). More recently, highly mechanized open field crops have developed: melon in the Charentes, carrot in the sandy soils of the Landes, onion in the Beauce plain. Production under glass or plastic cover, which ensures early production, progressed from 1960 onwards because it secures also the visual quality of the product. The use of plastic and cellulose-fiber protecting materials contributed to the intensification. The original notion of "primeurs" has been altered because internationalized production carried by lorries now supplies Europe all year round.

The production of vegetables for food processing is progressing with varieties adapted to highly mechanized technical routes (bean, broccoli, celery, gherkin, onion, pea, spinach, sweet corn, tomato), produced in northern and southwestern France, Brittany, Saône and Rhône valleys.

Seed quality (germination vigor, grading coating and priming) and variety adaptation (hybrid vigor in particular) have enabled precision sowing in the field to become widespread. For crops grown under cover and field crops with transplanted seedlings, seed quality and sanitary requirements have contributed to the widespread use of seedlings

Box 1. Economic data on vegetable production in France

French vegetable production (7,500 ha under cover, 210,000 ha in the open field) amounts to 6 million tons (Mt), 30% of which are industrially processed (Oberti et al., 2020). The huge matching seed market for growers is supplied by French and many foreign companies (particularly Dutch, American, Japanese, Italian companies), as well as multinationals.

More than 1 billion tons of vegetables are produced per year in the world, 72% of which are produced in Asia (China alone produces 400 Mt). France ranks third as vegetable producer in the European Union (EU) and exports 1 Mt (Lor, 2015). Importations of tomato (500,000 t), carrot, squash, melon, onion, and salad mostly originate from Spain, Italy and Morocco, for a total of 1.9 Mt. Annual consumption (mostly carrot, tomato, lettuce, melon, bean and brassicas) is about 126 kg per capita, over 50% of which are supplied by supermarkets. It is a lower consumption than in Turkey (first consumer in Europe), Italy and Spain (the two first consumers in the EU).

The share of family gardened production fell significantly from 1980 onwards, but has risen up in recent years: 16.5 million gardeners produce vegetables in France. This represents a substantial amateur seed market.

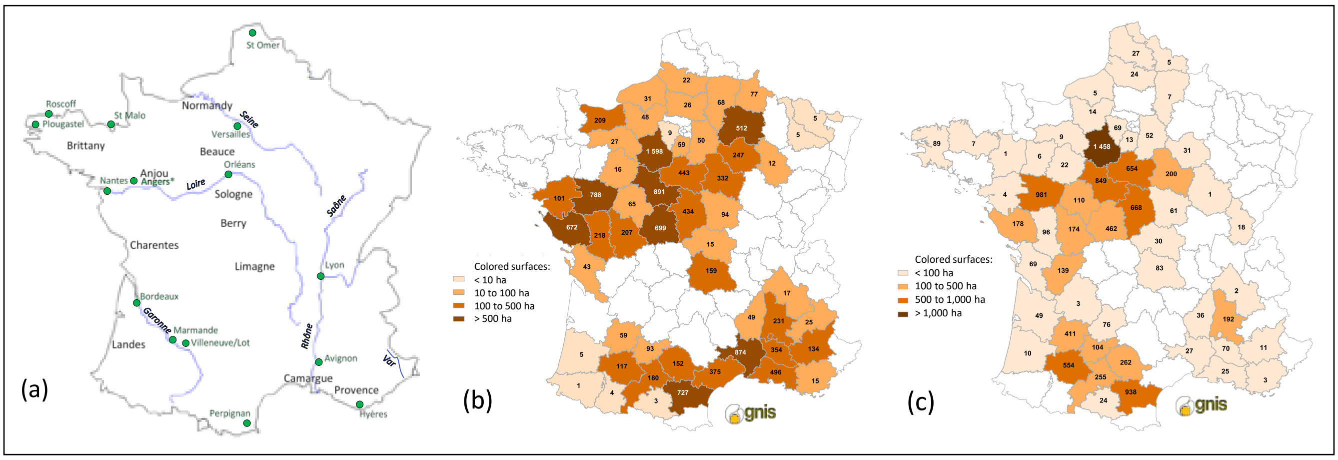

Figure 1. Geographic distribution of vegetable and seed production in France: a) Historical vegetable production areas. Rivers (blue), towns (green) (* place of IHC2022) cited in text; b) Total seed production of small seed vegetables, 9,675 ha in 2019; c) Total seed production of pulses, 12,205 ha in 2019 (Source: GNIS).

› Uniform radish (A) (Photo ©INRAe), fennel (B) and turnip (C) hybrids (Photo ©HMClause).

and the development of an industrial seedling production chain (1,500 nurseries, GNIS, 2016).

Until the end of the 19th century, vegetable growers traditionally cultivated and sometimes improved their local varieties. From then, selections and new varieties were increasingly released by private seed companies. As early as 1950, breeders and seed producers jointly invested in genetic improvement and seed technology to make available high-performance varieties coupled with high quality seed produced in selected regions. Supported by public research, technical institutes, extension services, networks of agro-technicians and high quality agricultural education, the vegetable seed sector achieved a high level of organization and technical performance that serves as a model throughout the world since 1980.

Since 2000, there is a public concern for setting up environment friendly production practices and for producing healthy food. The vegetable seed sector participates in the development of agro-ecological and organic agriculture in France, Europe and elsewhere.

The strength of the French vegetable seed sector is based on several assets, among which public regulations, public and private research and partnership as well as a diversity of soils and climates.

This article reviews the main characteristics, since 1950, of vegetable species breeding, of vegetable seed industry organization in France in terms of market, research and teaching, of seed production and the contribution of the vegetable sector to the agro-ecological transition.

History of vegetable breeding and vegetable seed companies

France is known throughout the world for its seed companies

The de Vilmorin family began seed selection at the end of the 18th century. It created in France, in a significant way, a dynamic seed production and breeding activity, which took off at the end of the 19th century. From the 1960s, the companies Clause, Tézier, Caillard, Société de Production Grainière (SPG), later Gautier Semences, and many others developed into a vast network of 400 vegetable seed companies (breeders, producers and seed brokers) spreading from the Loire valley (Boret, Brivain, Camus, Cesbron, Curis, Fautrat, France Graines, Giladeau, Godineau, Griffaton, Guillard, Hodebourg, Moreau, Toumelin), Paris basin and the north (Blondeau, Cayeux, Lecouf-Maillet, Mollard-Sanrival, Peltier, Séminor, Simon Louis), the east (Denaiffe, Fabre, Lafitte, Voltz), to the Rhône valley (Bourget Sanvoisin, Blain, Ducrettet, Genest, Girerd, Gondian, Mirabel, Ribot & Faure, Rivoire-Lavergne) and the southwest (Catros Gérand). There are still 80 vegetable seed production and marketing companies in France in 2020.

Conservative breeding of heirloom varieties

During the 20th century, these establishments, in contact with vegetable growers, collected, maintained, improved and produced several hundreds of varieties and local populations formerly created by the vegetable growers. These are the old varieties and populations from the public domain, the specific heritage of French vegetable growers, maintained by conservative selection, still available to the sector (Box 2).

Creative selection

Until 1960, Vilmorin and Clause were the pillars of vegetable breeding thanks to their research sections dedicated to varietal creation and production techniques. Vilmorin breeders created improved varieties, including the first F_1 hybrid tomato variety in France, 'Fournaise' (1956). From 1955 onwards, the National Institute for Agricultural Research (INRA[1]), in partnership with private seed companies, also became involved in research and creative breeding. As early as 1970, these actors created modern varieties, hybrids or not, that met the technical criteria required by large scale producers and marketers. The vegetable distribution sector requires homogeneous products that

› Capsicum pepper: rectangular and horn types with diverse colors (Photo ©R. Brand)

Box 2. Ancient varieties and populations in the public domain

Thanks to the quality of French conservative breeding, vegetable growers have access to healthy and well germinating seeds of old populations, selections (formerly called "races") created in the 19th and the first part of the 20th century. Until 1970 this conservative selection focused on uniformity and adaptation of the varieties to market requirements. Examples include open pollinated varieties of carrot (e.g., Nantaise, Colmar), population varieties of cauliflower in Brittany, leek (e.g., d'Eté, d'Automne, de Gennevilliers, de Carentan, Bleu de Solaise), onion (e.g., de Mulhouse, d'Auxonne, de Roscoff, de Trébons, de Lézignan), which still provide an economic alternative to hybrids. As early as 1980, the seed companies joined together to form the Union of Vegetable Variety Maintainers (SMVP), in order to continue and harmonize the maintenance work. Nowadays, other structures carry out this work (e.g., the Carrot Crunchers Association). The varieties are registered in the French Official Catalogue and the list of official maintainers is available at GEVES (Group for the Study and Control of Varieties and Seeds; www.geves.fr).

[1]INRA became INRAE the 1st of January 2020 (https://www.inrae.fr/en/about-us)

are easy to pack and transport, and that are adapted to mass production, whether mechanized or automated. Breeders took these objectives into account and added an essential agronomic component: resistance to bio-aggressors. Indeed, the intensification of vegetable production favors the incidence of many diseases and parasitic attacks that generate heavy damage in the field and post-harvest. In order to reduce the phytosanitary burden, breeders introduced resistance genes into new varieties by cross-breeding.

INRA and IRAT (which later became part of CIRAD, Centre de Coopération Internationale en Recherche Agronomique pour le Développement) also worked on vegetables adapted to tropical zones, either in research stations located in the French West Indies (adaptation of tomato to humid and hot climates, resistance of tomato to begomoviruses, resistance of tomato and eggplant to bacterial wilt), in New Caledonia, and in La Réunion island (improvement of "lontan" vegetables, resistance of solanaceous crops to bio-aggressors), or in partnership with public institutions in Africa (work on 'Galmi' onion in the 1960s in the Niger valley).

A true international industrial force

Vilmorin integrated the Limagrain seed cooperative group in 1975, and was joined later on by other vegetable seed companies such as Harris Moran, Clause and Tézier, all of them forming the group Vilmorin & Cie. With the acquisition of Ferry Morse, Nickerson, Kyowa, Hazera, Henderson and Mikado, the group became, in 2019, the world leader in vegetable seeds. Other French vegetable seed companies, such as Gautier Semences, ASL (melon), Hoquet (chicory), Darbonne and Marionnet (strawberry and asparagus), are becoming European leaders. Other forms of economic organizations also develop vegetable breeding activity such as agricultural cooperatives (Top Semences, Unisem, Sicail and GIE Ail drômois for garlic and shallot), grower groups (Organisation Bretonne de Sélection (OBS) for shallot and *Brassicaceae*), and family businesses (Technisem for tropical markets, Agrosemens for organic seeds). In 2020, about 30 French companies are breeding and/or marketing new varieties of vegetables. This high concentration of seed companies is due to the internationalization of markets and the high cost of research. Many foreign companies set up their research stations in France to select, produce and sell vegetable seeds in France or for world markets: Syngenta, Bayer-Monsanto, BASF-Nunhems, Rijk Zwaan, Enza Zaden, Bejo, Sakata, Takii, are present in the lower Rhône and the Loire valleys, and in the southwest. Their vegetable breeding research centers located around Avignon and Angers are part of the European seed centers, together with Den Haag-Enkhuisen in the Netherlands, Latina in Italy, Valencia and Almeria in Spain.

During the last fifty years, seed production in France has been concentrated in a few geographical areas such as Loire, Rhône, and Garonne valleys, and Beauce plain. Seed crops under tunnel are developing in France (e.g., lettuce, and carrot, cauliflower, cucurbit and solanaceous hybrids) to guarantee a high level of sanitary quality together with parental lines security. Seed production also moved far abroad (Australia, Americas, North and East Africa, India, China) for cost efficiency reasons.

After a period characterized by "captive" seed markets such as North Africa for historical reasons, seed markets became increasingly international from 1980 onwards and mobilized the French breeding teams. This trend began with the development of vegetable production basins in the Canary Islands, Morocco, Italy and Spain. The seed market extended progressively to other large scale production areas such as Eastern Europe, Turkey, Middle East, and further on to the USA, South America, India, South-East Asia, and China. This global change contributed to a genetic mixing between the cultivated types of most crop species. It accompanies the diversification of vegetables and contributes to a rapid renewal of research themes.

This market widening is reflected in increased profits of the French seed industry, which competes with the USA, the Netherlands and Japan: in 2019, France was the first European seed producer and the second European seed exporter (see section on Vegetable seed production in France).

The dynamism of public-private research & breeding

In 2020, more than 20,000 varieties of about 40 vegetable species are registered in the European catalogue and satisfy the EU market, out of which more than 2,500 varieties are registered in France (200 new varieties per year). Since the 1950s, French breeding has been characterized by a strong partnership between public and private research, which has led to considerable progress in terms of yield regularity, visual uniformity and appearance, adaptation to packaging, physiological adaptation to a diversity of cropping systems and environmental conditions, and resistance to bio-aggressors. In 2016, the French seed sector invested €116 million in research, i.e. 25% of its turnover (GNIS, 2016).

Very early on, public research accompanied the development of the seed vegetable sector, with the creation, in 1965, of the Association of the Creators of Floral and Vegetable Varieties (ACVPF), chaired by INRA. This association provided training for breeders, and until 1978 instilled a dynamic of cooperation between its members for the evaluation and use of genetic materials created by INRA. Then, public research became increasingly financed by short term contracts and compartmentalized programmes, accessible via competitive calls for tenders. Outstanding public researchers have succeeded each other in managing the genetics and vegetable breeding programmes at INRA Avignon, Rennes, and Versailles. The seed companies have grouped together within the National Federation of Vegetable Grains and Seeds (FNGSP), which became the French Seed Union (UFS), with a plant breeding section, and at the European level in the European Seed Association (ESA). The French Breeders Association (ASF since 1962), and the European Association for Research on Plant Breeding (Eucarpia since 1956) ensure the continuous training and network meetings of breeders (www.selectionneurs.asso.fr and www.eucarpia.org, respectively).

The preservation of genetic resources

Facing the growing importance of varietal selection, and genetic erosion of crop heirloom diversity, the French public authorities set up in 1995 a national system for a mutualized management of genetic resources, in the form of networks for species of economic interest. Partners are institutional organizations (INRA, GEVES, agro-engineering schools, CIRAD for tropical and subtropical species), seed companies, seed banks and other national, regional or local organizations acting in the field of genetic resources conservation. Coordination is ensured as follows:

- Fruit *Solanaceae* and melon: INRAE Avignon,
- Artichoke and cardoons, chicory, onion, lettuce: GEVES Angers and Cavaillon,
- *Brassicaceae* and carrots: Agrocampus Ouest Rennes and Angers,
- Grain legumes: INRA Dijon,
- Strawberry: CIREF Bergerac.

These networks operate under the aegis of the national coordination structure for plant genetic resources (www.geves.fr/plant-genetic-resources/national-coordination/national-coordination-structure/). They maintain, describe and evaluate more than 15,000 ancient or foreign varieties, genotypes of particular interest, together with wild forms and relatives. Their objectives are to secure and maintain the genetic integrity of the collections over the long term, to mutualize regeneration, conservation, description and evaluation efforts, and to space out regeneration cycles. Other priorities include the visibility of the collections and their valorization, through an increased use in research and breeding programs. A challenging question concerns the conservation of the genetic diversity and progress created over the last decades as F_1 structures. A source of genes for breeders, these collections are outstanding materials for deciphering the molecular structure of genetic diversity, as done in particular for tomato, pepper and carrot.

European collaboration for genetic resources is facilitated via the long term input of the European Cooperative Programme for Plant Genetic Resources (www.ecpgr.cgiar.org/), as well as via EU time limited projects devoted to genetic resources management and conservation (Daunay et al., 2011).

Box 3. Hybridization of genera and species

In *Cichorium intybus* (chicory and bitter leaf chicory) and *C. endivia* (plain and curled leaf chicory), cross-breeding between species has been carried out on a few genotypes to create plain and curled leaf with tuberous roots suitable for production in growing chambers.

In zucchini, *Cucurbita pepo*, partial resistances to *Zucchini yellow mosaic virus* (ZYMV, genus *Potyvirus*), *Watermelon mosaic virus* (WMV, genus *Potyvirus*), *Cucumber mosaic virus* (CMV, genus *Cucumovirus*) and powdery mildew have been introduced from *Cucurbita moschata*, *C. okeechobeensis* or *C. ecuadorensis*.

In lettuce, *Lactuca sativa*, wild species were used to introduce:

- the *L. virosa Nr* gene of resistance to the black aphid (*Nasonovia ribis nigri*) by using *L. serriola* as a bridge species,
- *Bremia* resistance genes from *L. saligna* and *L. virosa*.

In tomato and pepper, wild species are commonly used to introduce disease resistance traits.

In *Brassica* spp. for which the resource of cross-compatible species is large, innovative crosses are being made (e.g., multi-jet broccoli, cabbage). Interspecific crosses allow also the introduction of tolerance to cabbage hernia (*Plasmodiophora brassicae*).

Research at the cutting edge of plant biotechnology

Since 1950, methods and tools have undergone major developments, first in cell biology and in vitro culture: micropropagation, somatic embryogenesis, haplodiploidization via androgenesis or gynogenesis, rescue of embryos from interspecific crosses, protoplast fusion (Daunay et al., 2007). Some major works carried out in France are worth mentioning:

- Control of the propagation of garlic and shallot by meristem culture (INRA Avignon and Ploudaniel), in vitro propagation of asparagus (INRA Versailles) and artichoke (INRA Avignon), which led in particular to the vegetative propagation of commercial material such as certified *Onion yellow dwarf virus* (OYDV) free plants of garlic and shallot, and hybrid structures of leek and asparagus,
- Control of somatic embryogenesis in carrot (seed companies),
- Haplodiploidization in *Solanaceae* and cucurbits (INRA Avignon), in *Brassica* (INRA Versailles) and umbelliferous plants (seed companies),
- Rescue of embryos resulting from interspecific crosses in *Solanaceae* and *Cucurbita* spp. (INRA Avignon),
- Fusion of protoplasts in *Brassica* (University of Orsay, INRA Versailles and seed companies) and chicory (University of Lille and seed companies).

French research has been at the forefront in developing these techniques for the improvement of many vegetable species. One of the major contributions of biotechnology is probably the deadlock break of intergeneric and interspecific hybridization (Box 3).

The burst of molecular techniques in the 1990s and their continuous evolution has revolutionized genetics, although the extent of their use in breeding schemes varies from one crop to another, and concerns mostly high cost return crops. Mapping and marking of genes and QTLs associated with traits of agronomic interest have allowed the development since the 2000s of marker-assisted selection (MAS) for disease resistance, male sterility, and pollen compatibility. Functional characterization of target loci involved in fruit quality, stress resistance and durability of resistance, access to allelic diversity thanks to sequencing, and genome wide techniques widen the way to an increasingly technical breeding.

French breeding success due to genetic improvement

Several publications review French vegetable breeding since 1955: Pitrat (2002), Pitrat and Foury (2003), Doré and Varoquaux (2006), Brand and Audergon (2013), Pitrat and Audergon (2015). We provide some examples of genetic advances and new released varieties originating from INRA and partners.

Conservative and sanitary selection of commercial material

Conservative breeding maintains genetic material as conform to itself and free of seed and plant transmitted bio-aggressors. It is successfully applied to the maintenance of open pollinated varieties and commercial or hybrid parental lines. Sibling crosses or in vitro culture are used for the maintenance of low vigor lines of allogamous species (e.g., asparagus, artichoke, onion, leek).

For most sexually propagated species, sanitary selection (choice of seed mother plants) and methods of prophylaxis during propagation (under insect-proof tunnel) are used to avoid seed-borne pests. As early as the 1960s, the production of healthy seeds was established on:

› Protected seed production of hybrid cabbage in Anjou (Photo ©E. Laurent).

- bean for the bacteria *Pseudomonas savastanoï* pv. *phaseolicola* and *Xanthomonas axonopodis* pv. *phaseoli*,
- lettuce for *Lettuce mosaic virus* (LMV, genus *Potyvirus*),
- spinach and corn salad for late blight (*Peronospora* spp.),
- tomato for *Tobacco mosaic virus* (TMV, genus *Tobamovirus*), *Pepino mosaic virus* (PepMV, genus *Potexvirus*), and *Clavibacter michiganense* subsp. *michiganensis*.

In 2015, 260 bio-aggressors were regulated worldwide, including 40 in the EU, to guarantee healthy seed trade, in accordance with the recommendations of the ISPM38 standard of the International Plant Protection Convention on international movements of seeds.

Vegetatively propagated species (garlic, shallot, artichoke, asparagus, strawberry) are subject to sanitary selection, with or without meristem culture. Mother and commercial plants are certified under the control of the Official Control and Certification Service (SOC). France is one of the major players in the world for marketing certified healthy plants of:

- garlic and shallot free from *Onion yellow dwarf virus* (OYDV, genus *Potyvirus*), *Leek yellow stripe virus* (LSV, genus *Potyvirus*), nematodes and *Sclerotinia* (performed by INRA Avignon and Landerneau) (Messiaen et al., 1993),
- strawberry free from nematodes, *Phytophthora cactorum* and *Verticillium dahliae* (performed by Centre Technique Interprofessionnel des Fruits et Légumes, CTIFL).

Diversification

Breeders continuously improve the genetic material to make it match as closely as possible the requirements of producers and marketers, in a diversified context of "terroirs", growing conditions (from open field green belts to off-ground crops, mechanized crops for food processing industries), and marketing techniques.

Diversification of the harvested products concerns mainly *Solanaceae* (tomato, pepper, eggplant), cucurbits (melon, zucchini, cucumber) and lettuce, species for which the selection effort has been the most important in France since 1985 (in terms of number of new registered varieties).

- Tomato for the French and European market. The plant has been adapted to the various agro-climatic environments of protected crops (aptitude for fruit setting, root vigor, homeostasis). The fruit has been diversified in terms of color, shape, firmness, homogeneity, even if the French market is still globally dependent on two ideotypes (sizes 150 and 200 g, firm, smooth, red fruit, without green collar).

› Uniformity in hybrid carrots in Sologne, France. A. Carrots nearly ready for harvest (Photo ©Vilmorin), B. Processing factory (Photo ©HMClause).

- Melons of Charentais, Spanish, Italian netted, "Galia", American, Korean or Japanese types. Sugar content, firmness, proportion of flesh, homogeneity of fruit presentation have been improved by genetic crosses between these types.
- Quadrangular peppers. The plant has been adapted to the various agro-climatic environments of sheltered cultivation (ability to set fruit, root vigor, homeostasis), thickness of the pericarp has been increased and fruit color has been intensified. The Mediterranean market is now interested in the horn type.
- Lettuce varieties. The plant has been adapted to various agro-climatic environments, in particular resistance to bolting and short day head formation, and new types have been proposed (e.g., semi heading, anthocyanin, oak leaf).

Diversification also significantly created new ideotypes for plain and curled leaf chicory (resistance to bolting), cabbage broccoli (large-spray plant), bean and pea (adaptation to mechanical harvesting), cucumber (gynoic, smooth epidermis fruit, now "beth alpha" types), zucchini (color).

Innovations

The technical conditions of production changed profoundly between 1960 and 1990 in the open field (precision sowing, mechanization). Seed quality was improved thanks to seed production techniques (e.g., quality, size, uniformity, health status). This changing environment induced profound changes in breeding objectives, and the creation of new varietal types, which we illustrate below with several examples.

Transforming the production system and the product: chicory endive

Chicory endive is the most significant example in France, for which breeders proposed around 1970 a technique transforming the traditional process of forcing outside in winter, in a pit with topsoil, with difficult working conditions, into a mechanized forcing system in air-conditioned growing rooms and hydroponic conditions, with varieties specifically adapted to form the endive without topsoil. The breeding effort was valorized in the form of F_1 hybrids, first created with the pollen competition system, and later on with the geno-cytoplasmic male sterility issued from the industrial chicory group (initially obtained by fusion of protoplasts with sunflower). Targeted traits included the ability to produce soilless "chicons" (the apical bud), and to produce roots physiologically suitable for hydroponic forcing, including under low input conditions, uniformity of presentation, postharvest storage of the endive, yield, brown axis tolerance, reduced bitterness, diversification of the earliness of the material to expand the production schedule, and herbicide tolerance.

Creating material adapted to intensive production: hybrids for allogamous species

The objective was to create uniform and vigorous varieties, adapted to mechanized production, capable of resisting climatic hazards and bio-aggressors, and productive. Breeding programs have targeted cross-pollinated vegetable species such as *Brassica* (Box 4), carrot, onion, radish, leek, turnip, fennel and beetroot.

In carrot, the improved varieties derived from traditional populations achieved remarkable yields until around 1975 (e.g., selections of improved 'Nantes half-long red', 'Touchon', 'Bureau', 'd'Amsterdam'). From 1980 onwards, the improvement of sowing techniques (switch from scattered to precision sowing), ensuring a better expression of the potentialities of each plant, made it possible to enhance the homogeneity provided by the F_1 hybrids. The use of three-way hybrids facilitated seed production by increasing seed productivity of the female parent. The genetic structure of hybrids allows the cumulation of many traits of interest, including resistance genes to various pathogens (*Alternaria dauci*, powdery mildew, cercosporiosis), resistance to bursting, root strength, resis-

Box 4. Hybrid structures in *Brassica* (Source: R. Prieur, Harris Moran-Clause Company)

In *Brassica*, the allogamy needed to maintain the heterogeneous population varieties was a hindrance to the development of homogeneous short-cycle production. European and Japanese breeders have opted for an F_1 hybrid structure thanks to the discovery of self-incompatible S alleles. The gain in homogeneity and vigor was significant, and hybrid formulations were developed for several *Brassica* species: head cabbage, cauliflower, cabbage broccoli, kohlrabi. However, selection work with S alleles required compatibility testing, and further self-incompatibility was not completely reliable.
Hence, innovation continued with the creation of F_1 hybrids of cauliflower and broccoli using male sterility, first of nuclear origin, then of cytoplasmic origin. This latter, found in Japan in radish "Ogura", was transferred by protoplast fusion to other vegetable *Brassica* as well as rapeseed. From the end of the 1990s, di-haploid lines, derived from in vitro culture of microspores of cauliflower and broccoli, were widely used as hybrid parents. Today, cytoplasmic male sterility in *Brassica* is widely used worldwide. Its use in Europe has contributed to the development of global markets for French and Dutch companies for cauliflower and head cabbage.

tance of foliage to mechanical harvesting, earliness and hardiness, high early yield and reduction of waste rate. Root quality was also improved: smooth and shiny epidermis, fine pivot, uniform color between xylem and phloem, absence of green collar. More recently, di-haploid lines are being used in hybrid parental combinations to increase the level of homogeneity of such varieties.
Seed technology (e.g., grading, vigor, ability to emerge at high summer temperatures) has accompanied the success of this varietal renewal, which is spreading worldwide. French and Dutch companies are still the leaders in these hybrid carrot global markets (Brand and Audergon, 2013).

Breeding for quality traits

Organoleptic and nutritional quality, dear to French gastronomy, is a lock that has been persistently ignored by breeders. For a long time, agronomists, producers and marketers have minimized the importance of this criterion by putting forward the concept of societal demand, which prioritized vegetables easy to transport and preserve, quick to process. Such criteria are far away from fruit organoleptic and cooking qualities. Let us quote some counter-examples where breeding has been convincing, by using empirical selection methods:

- for a quality product: example of French bean
  Breeding achievements on reduction of beans parchment and string is exemplary. The development of a quality bean industry, inherited from the French "filet" bean harvested by hand just before the string develops, led French breeders as early as 1975 to improve the "mangetout" bean for the fineness and straightness of the pod, and to adapt the architecture of the plant and its flowering to mechanical harvesting (crossing between crop groups including wild progenitors). Thus improved, a new bean type was born: the "wireless net" bean ("filet sans fil"). This new type currently concerns more than 50% of the beans sown in France for industry, and it is also appreciated by gardeners. However, there is a limitation to this improvement, because in the absence of string, growers, gardeners and consumers have a wrong perception of pod age. Too old fresh pods are frequently marketed, stringless and straight but containing nearly mature grains that are detrimental to pods palatability.
- for taste: examples of strawberry, melon and tomato
  Strawberry varieties combining the taste of wild strawberries and agronomic criteria of industrial strawberries have been created (INRA, CIREF - Interregional center for research and experimentation on strawberry, Darbonne and Marionnet breeding companies). Such varieties derive from the proof of concept named 'Garriguette' (INRA, 1972) and 'Mara des Bois' (Marionnet, 1992), and combine outstanding flavor and aromas together with yield, fruit firmness and preservation.
  For melon, breeding programmes for taste have been set up (e.g., sugar content), based on the use of genitors identified for their taste quality. In cucumber, lettuce, chicory endive and eggplant, breeding programs have focused on reducing bitterness.
  For tomato, INRA and French breeders worked from 1956 to 1985 to improve the traditional French tomato types ('Saint Pierre' and 'Marmande'). INRA focused on improving the fruit (red color homogeneity, elimination of spots, regularity of locules number, sugar/acid balance, resistance to cracking, slight firmness) and the plant for its plasticity of adaptation to various environments. They had a large success (from 'Montfavet H.63.5' to 'Ferline', and varieties released by the private sector). After the "long shelf life" period (see below section "Improving long storage ability"), a fundamental research program on fruit quality was developed in the 2000s by Dr. M. Causse at INRA. Measurement methodologies, genetics of quality traits, and material suitable for MAS were released (Navez et al., 2016).

Recently, the vegetable industry focused on improving the content of components favorable to human health, such as: enrichment of glucosinolates in cabbage broccoli, provitamins, vitamin C, flavonoids and carotenoids in pepper, provitamin A, vitamin C, β-carotene and lycopene in tomato and carrot, and selection for antioxidant properties of melons used in cosmetics.

› Shapes and colors of commercial tomato varieties released in 2015 (Photo ©R. Brand).

Breeding for adaptation to glasshouse production

Adapting crops to greenhouses, heated or not, and more generally to unfavorable conditions (short days, low light intensity, low temperatures, high humidity) has mobilized breeders since the 1970s. Some French achievements deserve to be mentioned:

- Breeding of lettuce able to form heads in short days and low light succeeded as early as the 1960s (initial Dutch work exploited by Dutch and French seed companies). It generated European production of lettuce under glasshouses and tunnels during winter. An equivalent work was carried out on radish (INRA Avignon and seed companies).
- Breeding of solanaceous crops for "cold temperature, short days, low light intensity" conditions and for disease resistance. From 1956 to 1970, breeders at INRA Avignon, relayed by those in the private sector, improved the fruiting capacity of tomato genotypes under cold conditions (pollen with better germination), in the field as well as in greenhouse, with aerated vegetation limiting foliage parasites. This work led to the creation of hybrids of the 'Montfavet 63-5' type (INRA, released in 1963, listed in 1973), then from 1975 onwards, of many hybrids from seed companies (e.g., 'Lucy', 1973, 'Carmello', 1979) that were successful in Europe, the Mediterranean area and the Middle East. An equivalent work was carried out on pepper (e.g., 'Lamuyo', 1973, 'Sonar', 1980) and eggplant (e.g., F_1 Bonica, 1973). These new genotypes contributed to the explosion of industrial greenhouse production in Spain, Italy and Morocco, from 1975 to 1985, with also the high contribution of Dutch, Italian and Spanish seed companies. Partial parthenocarpy was also used in tomato and eggplant. These programs were updated regularly to respond to the evolution of these markets, up to now. Hundreds of varieties were bred for these markets, with regards to firmness and later for organoleptic quality.

Intensification of glasshouse cultivation has induced serious soil microbiological imbalances, which breeders have addressed with varieties and rootstocks resistant to soil-borne pests and pathogens, particularly in tomato (e.g., *Fusarium oxysporum* f. sp. *lycopersici* (FOL), *F. oxysporum* f. sp. *radicis-lycopersici* (FORL), nematodes, *Pyrenochaeta lycopersici*, *Verticillium dahliae*), pepper (e.g., nematodes, *Phytophthora capsici*) and melon (*Fusarium oxysporum* f. sp. *melonis*). Since the 2000s, in a context of drastic reduction of chemical soil disinfection, breeding programmes mobilize genetic resources to meet this challenge. Rootstocks are selected, either within the crop species, from interspecific crosses, or from wild species. Targeted traits are root system vigor, resistance to pests and pathogens, suitability for long-lasting cultivation with low heat requirements (Torres and Brand, 2015). Since 2018, investigation into root vigor and

› Alonso' released in the 2010s by HM-Clause for the "charentais" melon market (Photo I. Mazal ©INRAe-GEVES).

architecture of solanaceous crops and melon genetic resources, has been undertaken (INRA Avignon and seed companies).

Controlling sexuality and its genetic determinants

In melon, monoecy was introduced in Charentais type from the variety 'Cantaloup d'Alger', at the beginning of the 1980s (work at Tézier company). Proof of concept was released as a smooth, non-netted, early, monoecious 'Charentais' type. Monoecy allows the economy of castration in the manufacture of commercial hybrids. Further, monoecious genotypes develop female flowers on the main stem, thus improving production earliness and reducing manual pruning cost. Gradually, the defects associated with monoecy (e.g., vitrescence, elongated fruit shape tendency) were reduced. Monoecy then extended to all types of melon in the world.

Such drastic changes of genetic structures and reproduction mode also occurred with nearly uniform seed propagated hybrids,

- for artichoke (INRA Avignon, Nunhems) replacing the traditional vegetative clones,
- for asparagus (INRA Versailles, Vilmorin, Darbonne, Marionnet) replacing OP populations.

Strategic turns

Breeding has taken several strategic turns over the past 70 years. We illustrate three of them: uniformity of varieties, resistance to bio-aggressors and improvement of vegetables postharvest.

Uniformity of varieties

The last 50 years were marked by a strong increase in variety uniformity, based on the spread of pure lines, exploited for themselves or as hybrid parents, and of clones for vegetatively propagated species. Hybrid structures have been created and became almost generalized for species with suitable floral biology and seed yield (Daunay, 2009). For some species, the control of male sterility has enabled industrial production of hybrid seeds. First used in solanaceous crops and cucurbits, male sterility was abandoned because of its cost and slight expression instability depending on agro-climatic conditions. Quite the contrary, hybrid seeds production with a male sterile component became widespread in *Brassicaceae* (INRA Versailles, INRA Rennes, seed companies), and *Umbelliferae* (INRA Avignon, seed companies).

Resistance to bio-aggressors

Vegetable production is affected worldwide by 10 to 50% of losses because of bio-aggressor damages. As early as the late 1950s, breeding began to create genetic material resistant to major bio-aggressors. Breeding

› Mechanical harvesting of onion inflorescences to extract seed in Poitou-Charentes, France (Photo ©F. Pavy).

for genetic resistance to fungi, viruses, bacteria, and insects deals nowadays with some 150 host/pathogen combinations (about 40 crop species), i.e. 240 research programmes in France to date. A national network managed by GEVES is responsible for the maintenance and distribution of crop reference and control materials as well as of pathogenic strain reference collections (MATREF network). French and European research teams have had great successes in introducing resistances in their commercial varieties.

Although the risks of circumvention of monogenic resistances by pathogens are well documented (e.g., lettuce/*Bremia lactucae*, pepper/*Tomato spotted wild virus* (TSWV), pea/*Ascochyta* and *Fusarium oxysporum* f. sp. *pisi*), they are still widely used and many of them have not been circumvented (e.g., the bean *Are* gene of resistance to *Colletotrichum*, the tomato *Tm2²* gene of resistance to any strain of TMV virus and the pepper *L1, L2, L3, L4* alleles (L locus) of resistance to TMV race 0 and *Pepper mild mottle virus* (PMMoV), all used for over 60 years.

Combining polygenic resistance mechanisms to monogenic ones, and/or to other protecting strategies remains a major challenge that mobilizes breeding teams. Research tracks are diversifying:

- Gene pyramiding. In pepper for example, the major gene *pvr2* of resistance to potyviruses, which decreases the virus population in the plant, is associated to a particular QTL which decreases the probability of appearance of viral mutants and thus delays the circumvention phenomenon,
- Identification of natural defense stimulators (NDS),
- Resistance management, such as alternating resistance genes in time and space, in order to limit host selection pressure on the pathogen.

French research is currently focusing on partial genetic resistance, whether or not associated with production techniques. Polygenic partial resistances are supposed to be more "sustainable" than monogenic resistances. Their use is relevant in the background of agroecology (Torres et al., 2018), where crop rotations, clay-humus complex, biological life of the soil, surrounding environment and production basin are considered all together.

Improving long storage ability

For tomato, since 1980, the specialization of production areas far from the French and North European consumer markets (e.g., Sicily, Spain, Canary Islands, Morocco) has led marketers to favor products with a long shelf life and resistance to transportation. For tomato in particular, fruit firmness was introduced from the early 1980s in INRA and seed company breeding programs, leading to the creation of French varieties derived from 'Ferline' F_1 (1986), and of hybrids for Mediterranean markets ('Cristina', 1990, then 'Elena'). Later on, the introgression of the *rin* gene in heterozygous state was generalized, among other reasons because of the world success of 'Daniela' (1989), and its numerous diversifications. The *rin* gene reduces ethylene production, carotenoid biosynthesis, fruit softening and aroma development. As a consequence, fruits are too firm, insufficiently colored (in autumn France glasshouse conditions) and lack of taste. Hence, *rin* has been replaced from 2005 onwards by polygenic constructions that allow external and inter-carpellar walls thickening and offer acceptable taste quality. These improved genetic types supplied the markets, first in the two caliber sizes sought after by supermarkets, then in new varieties resulting from diversification (Italian tomato, cherry, bunch, elongated, green, yellow, black types). However, from 2010 onwards, the soft so-called "authentic" old types (heirloom varieties) reappeared, such as 'Marmande', 'Ox heart', 'Pineapple', 'Crimean Black', 'Rose of Bern', mostly produced for local markets.

For melon, the Charentais type is characterized by a climacteric crisis leading to aromatic fruits of short term conservation. By successive crosses with Spanish types, French breeders managed to create Charentais type melons deprived of climacteric crisis. Hybridized with other firm melons from the United States (Eastern and Western types) and Japan, they created a new ideotype bearing sweet fruit with netted skin and a fruit shelf life of 5-6 days considered suitable for the market.

> From the 1950s to the present, France has played a major role in the genetic improvement of vegetable species to satisfy a worldwide demand for high-quality varieties and seeds. This results from a fruitful partnership between public (INRA, CTIFL, universities) and private research supported by several internationally invested seed companies driving the sector. This partnership must now accompany the transition of French and European markets towards agro-ecology, organic farming and territorialized food systems, in a context of less intensive production. This is essential for reducing the deleterious consequences of high production-oriented agriculture on human health and environment.

French model of professional organization for the vegetable seed sector

Structuring and regulation

For vegetables, the French professional organization set up very early close collaboration between public institutions and private seed companies, as a strategy of synergy between actors of the sector, in order to support research, innovation, industrialization and internationalization. As early as 1950, in order to organize the market and monitor the rights of variety users (farmers, industrialists and consumers), studies on marketed varieties were conducted, within the framework of the Permanent Technical Committee for Plant Breeding (CTPS) of Ministry of Agriculture, i) at INRA, ii) at the Ecole Nationale Supérieure d'Horticulture (currently Agro-Campus Ouest, Angers) in collaboration with seed companies. These studies led to the creation of the first official national catalogue of vegetable and strawberry varieties (1960).

From 1960 onwards, registration of varieties and seed lots quality control was structured within the CTPS, which is responsible for advising the Ministry of Agriculture on the regulation rules concerning their marketing. Variety registration was first delegated to INRA then to GEVES (1970). The "seed lot quality" section was delegated to the Official Control Service (SOC) whose management is entrusted to the National Interprofessional Seeds Group (GNIS). These bodies report to the CTPS, which gives its final advice and proposal to the Office in charge of varieties and seeds within the Ministry of Agriculture. This latter takes the official decision for registering a variety. European consultation and harmonization are being built within the Standing Committee on Seeds of the European Union, ensuring a free market for seeds and varieties in European territory. Other studies are also conducted at the National Seed Testing Station (SNES, https://www.geves.fr/about-us/national-seed-testing-station/) to characterize the quality of commercial seed lots. As a consequence, the seeds and varieties market is cleaned up and offers a quality guarantee to its actors.

In order to protect the rights of breeders of new plant varieties, the legislator introduced a Plant Variety Protection Act, in 1970 in France, which gives the breeder a reliable and time-limited right. This system is managed in France by the national plant variety office (Instance Nationale des Obtentions Végétales, INOV). An equivalent European right is granted by the Community Plant Variety Office (CPVO), which confers the right in the EU territory. The world Union for the protection of new varieties of plants (UPOV, established in 1961), harmonizes the technical and legal aspects in the form of international recommendations. France is very active in these bodies. The Director of INRA at that time was one of the active creators of the Plant Variety Right established by the Paris Convention in 1961.

The organization of national seed production and marketing is carried out by GNIS, which provides a forum for dialogue, exchange and decision-making between the professional actor groups concerned with seeds and seedlings, from the breeding of varieties to the use of seeds and seedlings. GNIS also provides a contractual framework for relations between seed companies and seed multiplication farmers. Its technical service, the SOC, is in charge of the quality control of seeds and seedlings by the French State (Box 5). GNIS also plays a role in promoting the vegetable sector in France and abroad.

The National Federation of Seed Multiplier Farmers (FNAMS) is the national structure that runs economic and technical aspects of seed production by farmers, and represents them at the economic and trade union level. FNAMS acts as a technical institute for seeds, the actions of which are financed by the inter-profession.

Since 1960, the French vegetable seed sector has evolved through a strategy of concertation with the French and European public authorities, both to promote contract research and to regulate the markets and guarantee a high quality level of varieties and seeds. The CTPS facilitated the matching between economic demands and interests of the actors, and relayed the syntheses and conclusions to the State's decision-making authorities. Since 1990, the French and Western European model has spread to Eastern Europe, the EU, the Mediterranean and African countries. It has strongly contributed to French and Dutch leadership in the world.

One question is whether this model is capable or not of adapting to the rapid all-scale changes induced by the global challenges. These include the agro-ecological transition, the adaptation of the regulation of varieties, seeds, and plant variety protection to the specificities of developing countries, as well as the necessity to guarantee food, nutritional and health security to human populations. The French vegetable sector has taken up these questions.

Research and education

State and professional bodies have structured plant breeding research and teaching at national level. As seen above, INRA has heavily invested in the vegetable sector by creating research units in plants genetics and breeding (stations in Versailles, Rennes, Avignon, Guadeloupe) and biotechnology (fruit and seed biology in Bordeaux). Other institutions have contributed to specific efforts on tropical vegetables (CIRAD), strawberry (CTIFL), chicory (CTIFL, Lille University), carrot, cabbage and cauliflower, crosne (*Stachys affinis*), sea crambe, tuberous celery (AgroCampus Ouest Angers and Rennes).

Agricultural education specific to vegetable breeding and grain crops has been organized to train:

- growers and technicians (BTS level in France, BSc in the Anglo-Saxon system): i) for vegetable production (e.g., agricultural high schools of St-Germain-en-Laye, Sainte-Livrade, Albi), and ii) breeding and seed production (e.g., agricultural high schools of Valence, Castelnaudary, Lille-Genech, Nermont, Pouillé),
- executives (BSc+1, MSc, PhD) in agro-engineering schools and universities (e.g., Paris, Rennes, Montpellier, Toulouse, Clermont-Ferrand, Beauvais, Angers, Lyon). For example, AgroCampus Ouest Angers and the University of Angers deliver a Master's degree in plant biology for seed and seedlings, supported by the Research Institute of Horticulture and Seeds (IRHS).

Vegetable seed production in France

The French vegetable seed industry is characterized by its know-how and the great involvement of its members. The various agro-climatic conditions available in France are suitable for producing seeds of many species. This production is carried out mainly in the open field, but also in insect-proof tunnels for pollination control. GNIS terminology for qualifying vegetable seeds distinguishes vegetable species that are harvested fresh and gathered under the generic epithet of "small seed vegetables" from pulses that are harvested as dry grains (garden pea, bean, lentil, chickpea, faba bean, etc.). Small seed vegetables include species belonging to the families *Apiaceae* (carrot, parsley, coriander, etc.), *Chenopodiaceae* (garden beet, spinach, Swiss chard, etc.), *Brassicaceae* (cabbage, radish, rocket, etc.), *Cucurbitaceae* (gourd, squash, melon, etc.), *Valerianaceae* (corn salad), *Asteraceae* (lettuce, chicory, etc.) and *Solanaceae* (tomato, eggplant, pepper).

France is the first producer and second exporter in Europe

With nearly 22,000 ha of multiplication in 2019, including 9,700 ha of small seed vegetables and 12,200 ha of pulses, France is the leading producer of vegetable seeds in the EU. Thanks to its recognized know-how in terms of quality, France is also the second largest exporter in Europe and has a positive trade balance of more than €260 million, in a highly competitive international environment. World trade in vegetable seeds was €3.6 billion in 2015. Europe, North America, and the growing Asian markets are the most profitable.

Seed production relies on a network of 2,500 farmer-multipliers and 96 seed companies that ensure rigorous monitoring, traceability and controls at every production stage. Nearly 1,500 nurseries throughout the territory also produce vegetable seedlings for growers and gardeners. Every year, more than 2,000 million seedlings are marketed, 90% of which are for the professional market. For certified crop plants, forty companies are specialized in the production of garlic, shallot and strawberry

Box 5. Vegetable variety and seed lot quality control

The official quality of a vegetable variety is assessed in France by two complementary systems. The variety is subject to mandatory standardized tests at European and world (UPOV) levels to verify its identity, uniformity and stability (D.H.S. test). Its identity card is drawn up with its main characteristics, including its genetic resistance to diseases. At the end of these tests carried out by GEVES, and on the proposal of the CTPS, the variety is registered in the Official Catalogue of Varieties and the Community Catalogue, which gives it a marketing authorization in the EU territory.

Its qualities of yield and adaptation to the agro-climatic and economic market context in France are tested in a non-obligatory manner by technical institutes: CTIFL, Union Nationale Interprofessionnelle des Légumes de Transformation (National Interprofessional Union of Vegetables for Processing, UNILET), regional stations as well as producer groups.

The quality of seed lots produced in France is controlled by the SOC in approved laboratories, on the basis of quality criteria such as species purity, germination and vigor, with harmonized tests at EU and OECD levels. GEVES-SNES coordinates these laboratories, especially for securing the application of the recommendations of the International Seed Testing Association (ISTA), in order to guarantee the exportations and importations out of the EU. Once a year SOC reports to the CTPS for its activity.

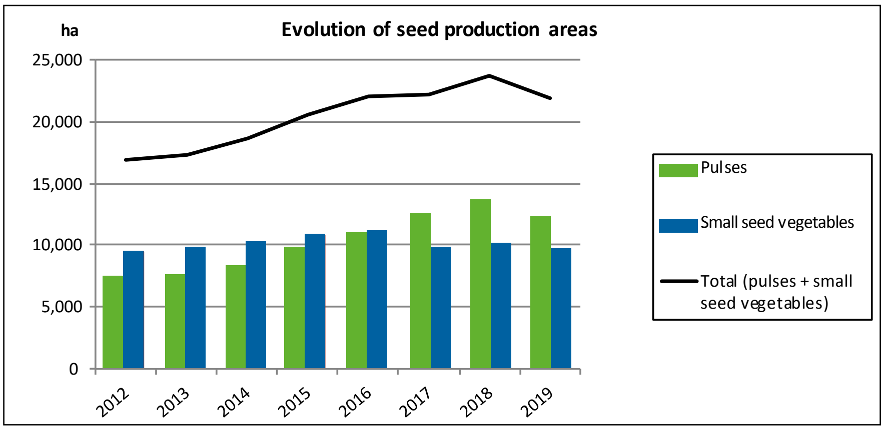

Figure 2. Evolution of acreage (in ha) of vegetable seed production in France between 2012 and 2019. Source: FNAMS.

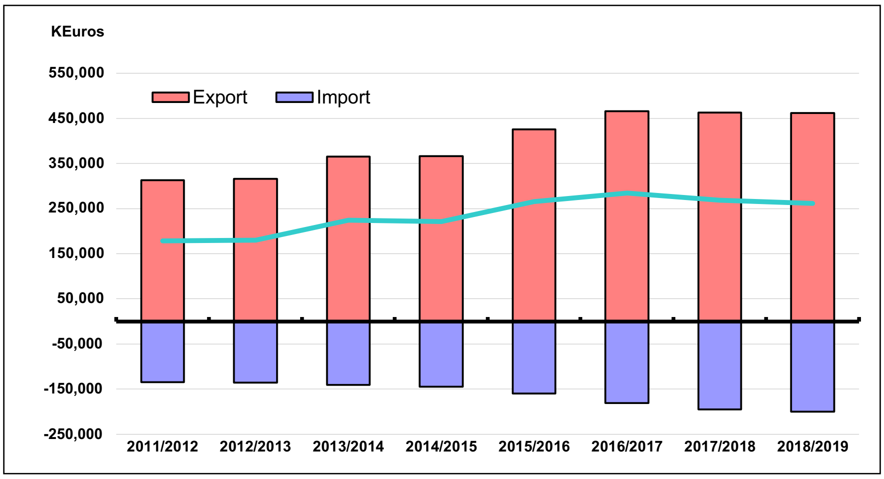

Figure 3. Evolution of the French net commercial balance (in kEuros) in vegetable and flower seeds between 2012 and 2019. Source: GNIS.

plants and asparagus claws. This activity represented 1,400 ha of multiplication in 2019.

Vegetable seed multiplication is spread throughout France in multiplication zones (Figure 1b,c). Each zone has specific soil and climatic conditions and "terroirs" favorable to 73 species: garden pea (4,300 ha), chickpea (4,050 ha), onion (1,990 ha) and carrot (1,530 ha) take up the largest areas. The total area devoted to vegetable seed production has increased steadily since 2012 (Figure 2), except a brief decrease in 2019, explained by 2017-2018 exceptional harvests.

Seed companies continue to rely heavily on the economic development of vegetable seeds. They invest 25% of their turnover in research and development, in order to create the varieties of tomorrow adapted to markets and environmental challenges.

The export value of vegetable and flower seeds, although stagnating in 2018/2019 compared to the previous seasons, jumped by 48% from €313 million to €462 million between the 2011/2012 and 2018/2019 seasons. During the same period, imports increased by 49% from €134 million to €200 million. The trade balance for vegetable seeds remains largely in surplus with a positive balance of €262 million, 92% of which is related to small seed vegetables (Figure 3).

Important technical work that contributes to the excellence of the sector

The results of the vegetable seed sector can be explained by important assets:

- a solid organization of the sector, which allows the production of quality seeds,
- favorable "terroirs" and climatic conditions,
- a structured network of farmer-multipliers with recognized technical know-how and specific equipment,
- a climate of trust between players in the sector regarding the confidentiality of multiplied varieties,
- rigorous monitoring of production by seed companies,
- close collaboration between farmer-multipliers and beekeepers, to ensure pollination of seed-bearing crops,
- sanitary control of production, with crops grown under insect-proof tunnels to avoid viral diseases, or in protected areas at high altitude. The sanitary control of the seeds produced implements numerous tests to guarantee the absence of 112 fungi, 42 bacteria, 71 viruses and viroids, 27 insects and 5 nematodes mainly on *Brassica*, beans, pepper and tomato.

Additionally, the production of vegetable seeds follows strict rules with controls at all stages, from multiplication to marketing, in order to provide quality seeds that meet the requirements of vegetable growers, nurseries and gardeners.

Each year, the GNIS vegetables and flowers section defines a program of technical activities meant to improve the production and quality of seeds multiplied throughout the territory, in terms of sanitary quality and specific purity (absence of seeds of other species). This program, implemented by FNAMS, aims at maintaining the competitiveness of the French industry.

In recent years, this program has focused on alternative methods for weeding and controlling diseases and pests: mechanical tools, robotics, biocontrol products, and integrated biological protection. This shifted orientation was accentuated in 2019 with part of the pro-

Box 6. Organic agriculture (OA) vegetable seeds to boost the development of OA

With changes in food consumption habits, and the growing concern of consumers for signs of product quality, the production of "organic" vegetables is strongly increasing in France, as indicated by the surface areas doubling over the last six years. Responding to this fast-growing market represents a challenge for the seed sector. The production of OA seeds is complex because it must meet a double requirement: the respect of the rules and standards applied to seeds, together with the respect of the OA specifications. Although the multiplication of OA vegetable seeds still concerns limited surfaces, it is constantly increasing. The production represented 740 ha in 2019 (333 ha in 2014) and mainly concerned lentil, chickpea, onion, radish, beetroot and carrot. With multiplications also carried out abroad, the range of OA vegetable seeds is growing strongly: in 2019, more than 1,250 varieties were sold by 35 seed companies. The seed sector aims at continuing this development and supporting farmer-multipliers in these more complex productions for further technical and economic success.

gram devoted to the control of vegetable seed production for organic agriculture (OA), from the time the crop is planted (Box 6). Results are regularly communicated to seed companies and to farmer-multipliers through technical meetings, technical circulars, brochures, a bimonthly magazine and the websites of GNIS and FNAMS (www.fnams.fr/produire/production-de-semences/potageres/).

Computerized management of crop location to ensure seed varietal quality

Among the qualities expected, the seed lot must correspond exactly to the chosen variety (conformity and purity). Varietal purity is directly related to pollination, which requires minimum isolation distances between propagation plots to avoid the arrival of undesirable pollen on the seed carrier field. Isolation distances take into account the floral biology of each species: autogamy (self-pollination) vs. allogamy (cross-pollination), entomophily (pollination by insects) vs. anemophily (wind pollination). Distances range from 100 m (for pea) to 5,000 m (for certain types of carrot).

In order to facilitate the management of isolations, the sector has acquired a computerized mapping tool. It allows the remote declaration of crops before they are planted, with the precise location of the plots on an IGN (National Geographic Institute) map. These locations, which can be consulted by stakeholders in the sector via an internet interface, are validated, after verification of the isolation distances between plots, during regional meetings attended by representatives of companies and farmer-multipliers. After validation, the plots can be planted. This tool, which is appreciated by the sector, currently concerns 23 species, representing more than 3,000 plots mapped on the territory and a dozen regional meetings per year to validate the locations.

Varieties and seeds more respectful of human health and of environment

Since 1980, seed companies have been marketing old varieties or varieties derived from them, which are of interest to gardeners and growers targeting direct distribution: consumers are rediscovering tastes and textures from a wider genetic diversity.

A national brainstorming is ongoing since 2000, and action strategies have been initiated to lead to vegetable and grain production practices that are more respectful of human health and environment, particularly with regard to nutritional quality and biodiversity preservation. At the same time, the criterion of uniformity becomes less of a priority, and thanks to the short food circuits that are progressing at the same time (particularly for vegetables), the notion of conservation and resistance to transport hazards is becoming less important.

Economic and agronomic models are also reviewed, particularly with regard to selection methods (participatory selection, farm-saved seed production) and their efficiency. Contextual questioning is taken into account: for example, would a too strong varietal uniformity limit adaptability? What is the cost/benefit ratio of hybrids compared to populations? Is the cost of biotechnology in research consistent with its agronomic and social utility? Participatory breeding programs, inserted in European networks, take up such questioning, such as the *Brassica* programme at INRA Rennes (Chable et al., 2020).

Some seed companies have taken the turn, by adopting these stakes. They contribute to the development of seed production systems that respect the OA specifications, and/or they deliver a greater genetic diversity on the seed market. This is the case of Sativa and Zollinger in Switzerland, KulturSaat and Bingenheimer Saatgut in Germany, and Agrosemens, Germinance, Graines Del Pais, le Biau Germe, Essem Bio as well as some twenty seed craftsmen in the French regions. The Farmers' Seed Network (Réseau Semences Paysannes) coordinates actions in this direction. Industrial seed companies are also developing OA seed production to target a market that in 2019 corresponded to 8% of French sales (5% in 2015).

The released varieties are phenotypically diversified, and depending on market segments, they are:

- modern varieties, hybrids or not, intended for intensive OA,
- old known or "forgotten" varieties, including those from other continents (e.g., Seed Savers in the USA),
- varieties specifically created for the OA context (e.g., Sativa, KulturSaat), such as populations (Box 6).

In short, agricultural concepts and production systems are evolving, thanks to the growing consideration of agro-ecological and sanitary principles. Meanwhile, new actors (e.g., towns, regions) are taking up food-related issues in territories such as localized food systems, food sovereignty and security, nutrition and health that need to be taken into consideration in both seed systems and breeding strategies. A number of priorities can be defined that address such agricultural and food global challenges:

- Maintain farmer's and researcher's access to genetic variability and biodiversity in a globally recognized system of exchange with equitable benefit sharing,
- Strengthen the eco-systemic sustainability of vegetable production, including the development of crops where varieties and food systems are reasoned in an integrated manner,
- Encourage production systems that promote innovation both upstream and downstream and reward genetic progress according to new selection criteria including sustainability.

Conclusion

Since the 1960s, the context of vegetable species selection has undergone profound changes: vegetable production became more specialized and technologically advanced; it became deseasonalized and was developed on new territories in France (metropolitan and overseas) as well as in the Mediterranean region. Crop intensification has led to a strong development of sanitary constraints. In response to these background changes, specific organization and research on varieties, seed technology and production systems have evolved. Scale changes occurred: breeding teams have acquired expensive biotechnological tools, which necessary profitability has led breeding companies i) to strengthen their collaboration with public research, ii) to grow up through purchase of, or fusion with competitors, and iii) to internationalize their commercial activities.

By means of its efficient public research and of a strong national organization of the vegetable sector, the French State has created the conditions that led to the development of a dynamic and conquering French seed industry. The area of influence of the economic players of the vegetable sector has extended worldwide. Asia, which has the largest vegetable cultivation area in the world, and Africa, whose domestic market has not yet been fully explored, are the next key partners in research and training as well as for industrial and commercial developments. This potential partnership will be brainstormed at the XXXI International Horticultural Congress in Angers, France (www.ihc2022.org), by addressing the major challenges of food crop quality, nutritional security and health to worldwide representatives of the vegetables sector. So far, breeding has only partly met these challenges in a context of production intensification that has reached its limits. Socio-cultural considerations now need to be linked to environmental challenges (climate change and biodiversity loss) for developing rapidly agro-ecological production systems and "alternative" seeds and varieties adapted to resilient and sustainable food systems.

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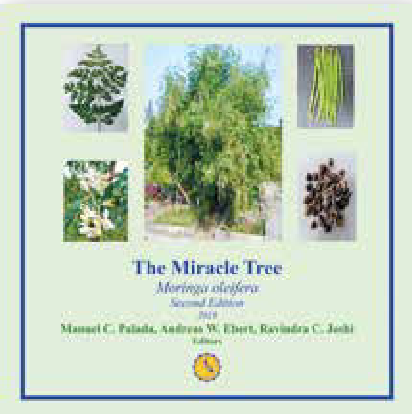
New Books
Websites

› New books, websites

Book reviews

The books listed below are non-ISHS-publications. For ISHS publications covering these or other subjects, visit the ISHS website www.ishs.org or the *Acta Horticulturae* website www.actahort.org



Palada, M.C., Ebert, A.W., and Joshi, R.C., eds. (2019). The Miracle Tree - Moringa oleifera, 2nd edn (Bloomington, IN, USA: Xlibris), pp.494. ISBN 978-1-7960-4454-6 (softcover) / 978-1-7960-4453-9 (e-book). $241.99 (softcover) / $5.95 (e-book). www.xlibris.com

Acquiring information and scientific knowledge is one of human's characteristics. This is achieved through personal communications and library resources. In this book, the distinguished editors, along with 46 eminent authors, provide readers with the latest references and a comprehensive collection of information on the various aspects of moringa. The book is useful for the growing moringa industry. This book covers four main areas: a) botany, genetic resources and cropping systems, b) nutritional quality, medicinal potential and benefits, harvesting, postharvest technology and agro-industry, c) insect, mite pests and diseases, and d) global perspective. The authors provide readers with both basic and applied research findings and the necessary background to enrich and enlighten the understanding of moringa cultivation and agro-industry. Most chapters end with a summary, conclusions, future prospects providing readers with specific web links and the latest literature.

The first chapter focuses on informative introduction and why moringa is considered as a "Miracle Tree". It provides readers with information about why moringa trees have great potential in combating extreme poverty and hunger. Detailed botanical information is given in chapters 2 and 3. The authors then provide information on the economic aspects of moringa. Then information on the climate, soil, and cultivation are discussed along with high density (HD) planting cropping systems, and several methods and practices involved in harvesting, postharvest technology, and processing of moringa. Chapter 9 provides a comprehensive overview of the insect and mite pests and pollinators and their management. Diseases of moringa and their management are next. Genetic resources, diversity, and moringa crop improvement with an insight into nutritional quality and health benefits of moringa follow. The medicinal potential and health benefits encompassing traditional and modern medicine are described followed by the potential of moringa for livestock production. The agricultural and industrial potentials of moringa, the account of moringa leaf extract as a natural bio-stimulant, and the benefits of moringa as an active ingredient for the cosmetics industry are summarized. The readers are provided with detailed information on farmer participatory and community livelihood projects in different parts of Africa. Finally, the book provides a comprehensive review of the potential of moringa with regard to climate change, sustainable livelihoods, and food security. This book provides a global perspective of moringa around the world and gives a future outlook on the challenges ahead.

Reviewed by Mahmoud A. Sharafeldin, Chair ISHS Working Group Moringa

› Medicinal plants, aromatic herbs and fragrance plants in France: a small but thriving sector with a strong traditional base and a dynamic research network

Annabelle Bergoënd and Joséphine Piasentin

In France, medicinal and aromatic plants (MAP) or herbal, medicinal and aromatic plants (HMAP) industries[1] traditionally refer to culinary herbs, medicinal plants, and plants cultivated for the fragrance and perfume industries. This agricultural sector encompasses several hundred plant species, as compared with field crops, such as cereals, which may include single species grains. The organic production for these crops is significantly larger than traditional crops of global French agriculture. Wild harvest of HMAP continues and is key for a successful economy in rural areas. These relatively small production areas are undergoing fast-paced growth. This production is very diverse and dynamic, leaning on strong traditional skills and benefiting from new techniques and high value processing. With a growing demand for natural products and unfolding opportunities for new markets, HMAP is facing exciting prospects.

Characteristics of French HMAP

Farm features and production are geographically diverse

The complexity of the production sector for HMAP is difficult to comprehend (FranceAgriMer, 2018). Production fields are often small areas. Many producers reserve some areas as a side crop for their main production. Many of the plants are not referenced in the European common agricultural policy (CAP) nomenclature. About 75% of the producers cultivate HMAPs to diversify their production. The largest amount of land is occupied by fragrance plants, then medicinal plants. Aromatic herbs account for less than 10% of the HMAP cultivated area. In 2018, the estimated average farm was 4 ha for MAP production and 17 ha for perfume plants. If the sector remains relatively well known in continental France, the overseas territories still lack organised bodies to represent producers and structure the market. Mostly in the tropics, farmers grow or gather completely different HMAP species. Many tropical MAP species are extensively used locally in traditional cuisine and medicine. The whole sector continues to develop very professional protocols. For example, about twenty medicinal plants endemic to Reunion Island have been newly registered in the French Pharmacopeia since 2013 (Armeflhor, 2019).

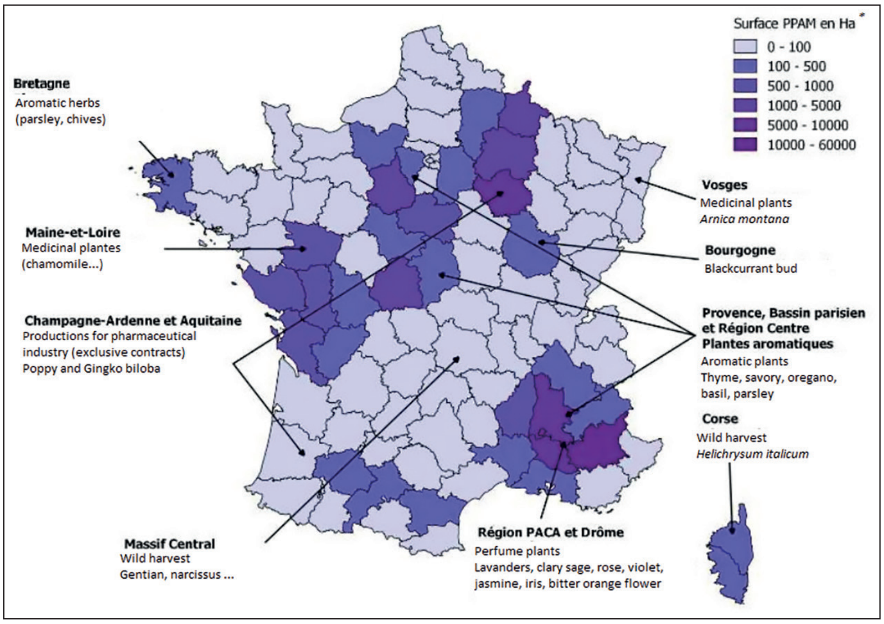


Figure 1. Surface distribution of HMAPs in continental France in 2018. ©FranceAgriMer (adapted). *1 Ha = 0.01 km².

Plants for perfume and fragrance

This cultivated production includes several species: lavenders (true lavender, *Lavandula angustifolia* Mill.; lavandin, *L.* x *intermedia* Emeric ex Loisel; and spike lavender, *L. latifolia* Medik.) and clary sage (*Salvia sclarea* L.) are the most economically important. In 2018, more than 29,600 ha was cultivated. Traditionally the majority of the production occurs in the southeast (Provence and surroundings), but new areas are being planted towards the north (Figures 1 and 2).

[1]In French, the acronym PPAM (for Perfume, Aromatic and Medicinal Plants) is used at official level.

Producers are mainly structured in cooperatives. This activity enjoys a strong *terroir* effect both at home and globally. Most of the production is internationally exported; 80% of lavandin essential oil, for example, is exported to Europe, the United States, and Asia. The production value generates a turnover of around €40 million. Even though the international essential oil market is highly competitive, France remains the world leader for perfume plant production. The cultivated area for lavenders alone increased by 29% between 2014 and 2018.

Figure 2. Lavandin field in the southeast (*L.* x *intermedia* Emeric ex Loisel). ©Iteipmai. More than 300 species are cultivated; however, two of them represent 70% of HMAP cultivated areas: lavender and opium poppy (*Papaver somniferum* L.); these crops account for 60% of total revenue.

Aromatic herbs and medicinal plants

National production occurs throughout, on 23,600 ha. The major areas are noted (Figure 1). Southwest of the Loire River has included a tradition of horticulture and medicinal plants (chamomile) from at least the 19th century. The southeast area is not restricted to lavenders (*Herbes de Provence*, parsley, basil). Aromatic herbs are produced in Brittany, while various areas in the east and north specialize in medicinal plants. Two large areas are dedicated to mono-production of opium poppy (*Papaver somniferum* L.) and *Ginkgo biloba* L. for the pharmaceutical industry. Opium poppy alone accounts for 70% of the medicinal plants' production region.

Producers of MAP are private agricultural companies or organized in cooperatives. A great many different species are cultivated. Basil, thyme, coriander, and green mint are the main production for aromatic plants; lemon balm, chestnut, or mountain arnica are the main crops produced for medicinal plants. Sage generates the most important economic value in this case. Production turnover totals €110 million. Overall volumes of MAP production decreased between 2014 and 2018. However, during the same period, both medicinal and aromatic cultivated surfaces increased. In Reunion Island, the aromatic sector is dominated by cultivated scented-rose geranium (*Pelargonium* sp.) and vetiver (*Chrysopogon zizanioides*). Harvest from wild stands is the predominant procedure to obtain medicinal plants (Association Réunionnaise pour la Modernisation de l'Economie Fruitière, Légumière et HORticole (Armeflhor), http://www.armeflhor.fr).

Processing: downstream economy determines the cultivation strategies

The usual segmentation in medicinal, aromatic and perfume plants is only a functional one related to the product destination. Fennel, for instance, may be cultivated for medicinal or culinary usage. However, industrial applications, production techniques, buyers, prices, etc. are very different, which determines producers' strategies.

HMAPs are present in more than a thousand different products. Perfume plants provide essential oils and extracts for the fragrance and perfume industry, cosmetics, aromatherapy, cleanliness industry, etc. Aromatic plants provide essential oils and extracts, dry and frozen products for food industry, herbal teas industry, aromatherapy, food supplements and nutraceutical industry, etc. Medicinal plants provide essential oils and extracts, dry and frozen products for herbal medicine, homeopathy, aromatherapy, pharmaceutical industry, cosmetics, herbal tea industry, food and feed supplement and nutraceutical industry. The whole industrial sector reaches a turnover of €5 billion.

The emergence of new markets during the past few years is significant: animal welfare (decreasing stress level and enhancing immune system with plant extracts in a context of antibiotics' reduction regulations), antioxidants, crop elicitation (help protect crops from diseases and stress) and biological control (using plant extracts as deterrent against pests or as attraction agent of pest predators and parasitoids), wine industry (alternatives to sulfites' addition), etc.

Ninety percent of the overall production is dedicated to plant extracts. HMAP production can hence be considered as a production of secondary metabolites (this is less true for aromatic plants) (Box 1). Quality and quantity of essential oils and other active compounds are critical factors to ensure a good harvest for the producer.

The impact of social demands

There is a strong and rapidly growing social demand for natural products. This is true for many industrial sectors. Therefore, the panel of potential usage has increased for HMAPs in recent years. There is also a tendency for consumers at a global level to be willing to pay more for better quality and for natural-based products (The Nielsen Company, 2015). The selling price is already rising on the organic market of aromatic plants and especially for whole plant products certified by a French or European quality sign, e.g. protected designation of origin (PDO), protected geographical indication (PGI), traditional specialities guaranteed (Marecaux and Sauvage, 2019). As an example, the PGI *Thym de Provence* (thyme), obtained in 2018 in Provence, recorded a 9 t sales increase in the first year; likewise, *Herbes de Provence* "Label Rouge" sales increased 33% between 2017 and 2018 (FranceAgriMer, 2018).

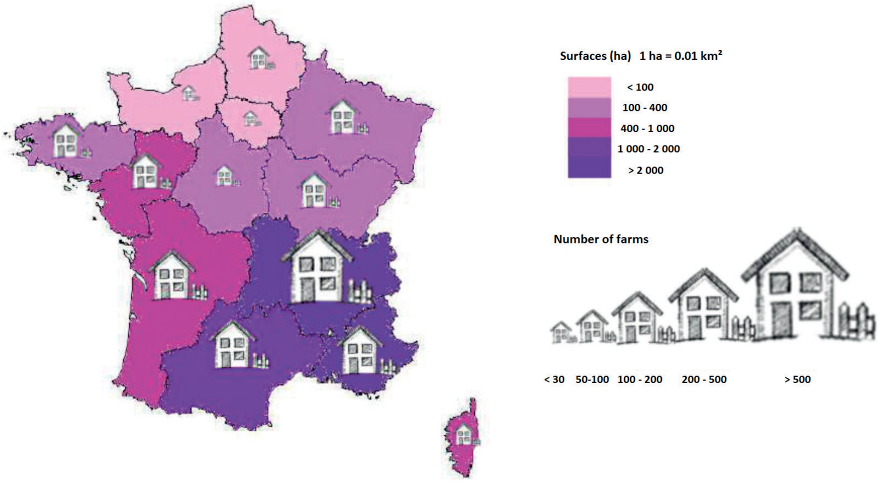
A tendency to relocate the production to the national territory can already be noticed:

Box 1. Secondary metabolites

Secondary metabolites are compounds that play no role in the basic biological mechanisms (the primary metabolism) but provide organisms an adaptational advantage. They are produced at some cost to the plant and often under biotic or abiotic stress. For example, inflammable volatile compounds synthetized by Mediterranean subshrubs help vegetation to cool down and make them less palatable to herbivores. Some secondary metabolites are protective against diseases, others are deterrents against herbivores, attract beneficial organisms or are a medium of infra-species communication.

Tens of thousands of molecules are produced this way; they can be separated into large chemical families, such as polyphenols, terpenes and sterols, alkaloids, etc. Their concentration in plants is extremely low (frequently inside specific storage cells or organs). Therefore, production competitiveness relies on active substance proportion in plants. This may be enhanced by plant breeding and the selection of chemotypes, i.e. clones of fixed and well-known chemical composition.

■ Figure 3. Mountain arnica (*Arnica montana* L.). ©Tela Botanica - JJ Houdré. This medicinal species grows spontaneously in mountainous meadows. Experiments for its cultivation are being attempted by the HMAP applied research network to help protect the natural resource.



■ Figure 4. Number and area of farms (organic certified and in conversion) per region in 2018. ©FranceAgriMer; Figures from AgenceBio.

some leading companies in the pharmaceutical, nutraceutical and perfume industry are taking up the challenge. They expect to meet the consumers' concern and enhance their image. It also reveals a commitment to ensure the regularity in quantity and quality of the supply. Consumers value increasingly traditional products and local production (Iteipmai, 2017).

Perspectives for sustainable production

An important activity for mountains

The HMAP sector remains of small economic importance with low employment levels and low social impact. Lavender cultivation is mostly located in dry mountainous areas without many other economic alternatives. Thus, in some parts of France, lavender fields sustain the economy of whole regions. The activity provides direct resources from essential oil extraction (usually carried out locally) and flower sales. Lavender fields also provide substantial revenue from the tourism industry that beneficiate to larger areas. Finally, income generated from lavender honey is equivalent to that of lavender essential oil trade. More generally, one third of HMAP production takes place in disadvantaged mountain areas.

What's more, some areas are dedicated to wild harvest and gathering, especially in the mountains (e.g. Massif Central, Vosges) and inside natural parks. Plants are picked up for the pharmaceutical, cosmetics or herbal/infusions industries (Figure 3). The positive social impact is difficult to estimate; some wild harvesters are farmers harvesting wild plants for extra revenue, others rely entirely on this niche activity.

Low impact agriculture: an asset towards sustainable development

The negative impact of the production activity on the environment is also low. Few chemical inputs are used, partly because high bioactive compound quality is favoured over high biomass yield. Furthermore, the rate of organic farming is high (Figure 4). In 2018, 16.5% of HMAP production was organic (7.5% of overall agriculture in France). Between 2008-2018, organic-cultivated surfaces (certified and in conversion) increased by 173% while the number of organic farms increased by 280% (FranceAgriMer, 2018). Some plants are almost entirely organically produced, such as saffron (*Crocus sativus* L.). Furthermore, HMAP cultivation frequently combines cultivated fields of different plants on the same farm and grows a great many melliferous species. Hence, HMAP agriculture provides positive externalities for biodiversity and the environment in general.

Applied research and field experimentation

A network of associations is dedicated to meet the needs of the HMAP sector, from production to active compound extraction: the national repository of HMAP seeds, CNPMAI (https://www.cnpmai.net/fr), a centre for field experimentation, Crieppam (http://crieppam.fr) and a technical institute for the sector's development, Iteipmai (https://www.iteipmai.fr/en). Among the many activities undertaken by this network, improving technical and agronomical schemes is an important element. Each crop has entirely different agronomic and processing needs, and the network strives to provide farmers with valuable experience and information out of field experimentation. Plant breeding is at the centre of applied research. The genetic diversity of HMAP species is very high. Furthermore, desirable traits are often heritable. Therefore, many projects have resulted in a doubling of the active compound content. This level of improvement is usually far more difficult to achieve when working on other production factors. Therefore, creation of tailor-made varieties is the preferred way to increase bioactive productivity, to adapt to changing environmental conditions and disease and pest pressure, as well as to better satisfy the market. This process allows the producers access to good-performing seeds or cuttings. It also provides the industry with stable extracts, both in terms of quantity expectations and of phytochemical content. Development of selected plant material presenting the best agronomic, industrial and economic interest is critical to ensure a sustainable and profitable activity for the producers as well as to provide the industry with high-quality ingredients that can be turned into innovative, safe and efficient products.

How applied research can successfully sustain horticulture

A multi-approach project to fight basil downy mildew

The value of basil production amounts to more than €20 million for open field plantations. It is also a flagship container plant product and offers diversification opportunities for flower producers. Basil downy mildew, a fungal disease that emerged in the 2000s with a worldwide dispersion, can spread and destroy a whole field in only a few days (Cohen et al., 2017). Iteipmai, in partnership with several technical and scientific organizations (Bureau Horticole Regional (BHR), http://bhr-vegetal.com; Vegenov, https://vegenov.com; Variety and Seed Study and Control Group (GEVES), https://www.geves.fr/geves; Technical Institute for Horticulture (Astredhor), https://www.astredhor.fr) has launched a project to come up with a set of turnkey solutions. This project, called "Basimil", was awarded a special prize (Acta Ita'Innov, https://www.acta-itainnov.com/) for its original concept.

Control: lower pathogen pressure instead of seeking eradication

Studies show that infection originates in the seed. The Basimil project thus aims to disinfect seed stock to lower the inoculum pressure. Different approaches are tested:

conventional, using biocontrol, and thermal treatment methods. Meanwhile, a new test has been developed by GEVES to confidently determine the infestation level of seed batches.

Selection

95% of the market is dominated by a cultivar known as 'Grand vert'. The challenge is to create a resistant cultivar able to meet this market's very specific requirements. After a first series of hybrid cultivars showed tolerance to the disease, one was selected and promoted. A repeated backcross of the initial cultivar's parents was carried out with 'Grand vert' to combine the market organoleptic and yield characteristics with the resistance trait. These transitional cultivars are already successfully tested in the field by producers.

Systemic approach

The development of a decision support system through a prediction model tool based on meteorological conditions helps the producers to anticipate the risk. This goes with adapted agronomic practices designed to optimise in-field and container density.

Using genomic tools for the French lavender sector

So far, lavender populations have been obtained with mass selection by collecting the best wild individuals and populations. However, the new environmental challenges, drought, biotic stress (mainly lavender decline caused by *Candidatus* Phytoplasma solani), underlined the need to select new cultivars adapted to these stresses, while keeping good essential oil yields and a quality up to the standards of the market (Iteipmai, CNPMAI, and Crieppam, 2019). In this context, genomic-assisted selection methods appear to be the right way to improve the efficiency and accuracy of breeding programs.

That is why, Iteipmai in partnership with Crieppam, Inra Etude du Polymorphisme des Génomes Végétaux (EPGV) – INRAE (https://www.inrae.fr/en) and Vegepolys Valley (https://www.vegepolys-valley.eu/en/) carried out a project named "Genoparfum" between 2015 and 2017, to study the genetics of lavender populations.

The purpose of the project was to develop lavender genomic resources and to discover single nucleotide polymorphism (SNP) to set bases for genomics in lavender. The work was carried out on the heterozygous lavender 'Maillette'. This clone was used as a reference for DNA and RNA sequencing. From these data, the complete gene sequences were reconstructed. The research team obtained a cleaned reference of 8,000 genes involved in various biological processes, including the response of the plants to biotic and abiotic stress (Fopa Fomeju et al., 2018). Finally, the team used these resources for SNP mining within a collection of 16 commercial lavender clones and tested the SNP within the scope of a phylogeny analysis.

The results from this project were used to launch the "Genolavande" project. This second project was carried out from 2018 by Iteipmai, in partnership with Inra EPGV, Crieppam and the Drôme Chamber of Agriculture (Chambre d'agriculture de la Drôme, https://extranet-drome.chambres-agriculture.fr).

Now, the purpose of the Genolavande project is to develop a genotyping tool from the SNP detected in Genoparfum and to set up new marker-assisted breeding strategies for *Lavandula angustifolia* Mill. This project is ongoing, but a genotyping tool based on 3,000 SNP has been built and is being tested.

Both projects are mainly granted by the French Ministry of Agriculture through *Casdar funds*. The results of these projects will be presented and their impacts will be discussed at the IHC2022 in Angers.

› Annabelle Bergoënd

› Joséphine Piasentin

› About the authors

Annabelle Bergoënd is a librarian professional and a botanist. Joséphine Piasentin is a librarian professional and an agricultural engineer. They run the Iteipmai's resource and documentation centre, which gathers highly specialised information about HMAPs, both scientific and technical. The Iteipmai's resource centre has been gathering valuable documents and information for more than 30 years, which makes it the reference for the sector at the European level. E-mail: annabelle.bergoend@iteipmai.fr, josephine.piasentin@iteipmai.fr. Scientific contact: philippe.gallois@iteipmai.fr

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› Conservation of horticultural genetic resources in France

IHC 2022
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Michel Roux-Cuvelier, Michel Grisoni, Arnaud Bellec, Emmanuel Bloquel, Carine Charron, Magalie Delalande, Marine Delmas, Audrey Didier, Charles-Eric Durel, Charles-Henry Duval, Florence Esnault, Laurence Feugey, Emmanuel Geoffriau, Bouchaïb Khadari, Sandra Lepers-Andrzejewski, François Luro, Cécile Marchal, Alix Pernet, Jérémy Salinier, Marc Seguin, Rebecca Stevens, Bernice van Issum-Groyer and Rémi Kahane

The conservation of biodiversity, and particularly of cultivated biodiversity or agro-biodiversity, is an issue of growing importance, particularly due to the acceleration of global change that is affecting the planet, human health, and nutrition. This article presents the strategy and the diversity of conservation actions of horticultural genetic resources as currently practiced in France. It also emphasizes the international horticultural connections of the French Republic, which include temperate, Mediterranean, as well as tropical environments, particularly considering overseas departments and territories.

The role of Biological Resource Centers

Plant genetic resources are the basis for varietal innovation in agriculture. They are an important source of diversity for the evolution of food systems and the development of agro-ecological cropping systems designed for sustainability and resilience. The evolution of regulations on biodiversity management by States and the implementation of the access and benefit sharing (ABS) regime have reinforced the strategic importance of agricultural plant genetic resources (PGR), and particularly of *ex situ* collections. Horticultural genetic resources are a subset of the agro-biodiversity that allows the improvement and development of horticultural value chains in the world. Conservation and valorization of these resources make agriculture more resilient to biotic and abiotic pressures, climate change, and are essential today for the food and nutritional security of the human population. They are also a matter of food sovereignty, which has become exceedingly apparent during the COVID-19 pandemic crisis.

The term "Biological Resource Center" (BRC) was coined in 1999, following work carried out by the Organization for Economic Cooperation and Development (OECD). It refers to any structure holding biological samples and their associated data from the different kingdoms of life: human, animal, plant and micro-organisms.

BRCs and gene banks are dedicated to the collection, management, characterization, conservation, enrichment and distribution of biological samples. To do this, BRCs implement procedures, techniques and databases according to standardized and optimized quality assurance and certification approaches.

They are operated under the responsibility of public research organizations. Their role is essential for research and development of horticulture. They also play an important social and cultural role through the conservation of heritage resources and traditional knowledge.

Infrastructures and organizations servicing BRCs

GIS IBiSA

The Scientific Interest Group GIS IBiSA (Infrastructure in Biology, Health and Agronomy, https://www.ibisa.net/) is a public instrument for the facilities maintained by the French life science establishments, including the BRCs. It carries out national policies for labeling and funding biology, health and agronomy platforms as well as BRCs. It promotes the organization and pooling of resources and equipment necessary for life sciences. The GIS IBiSA labels BRCs according to criteria of openness to all users, implementation of a quality management system, technological evolution and training.

RARe, a French agronomic BRC infrastructure

In France, in the field of agronomic and environmental research, BRCs are organized into networks (Mougin et al., 2018). The infrastructure AgroBRC RARe (Agronomic Resources for Research) brings together five networks of BRCs that conserve genetic, genomic, and biological resources:

- Microbial biological resources (https://doi.org/10.15454/1.5613788897481968E12);
- Crop resources and plant genomics – BRC4Plants (https://www.agrobrc-rare.org/agrobrc-rare_eng/Presentation/Plant-pillar);
- Forest resources (https://doi.org/10.15454/1.5613761929199846E12);
- Genomic or reproductive animal resources (https://doi.org/10.15454/1.5613785622827378e12);
- Resources associated with an environmental matrix (https://doi.org/10.15454/TRBJTB).

The AgroBRC RARe aims to pool skills, harmonize practices, encourage comparative biology projects and offers a single-entry web portal to facilitate access to well-documented samples. These objectives take into account the regulatory context that varies with the biological nature of the resources, both for sanitary and legal aspects. AgroBRC RARe provides organizational support to its members in the implementation of the Convention on Biological Diversity (CBD) in 1993, the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGR) in 2004, and the Nagoya Protocol in 2010. France has implemented the rules of access to genetic resources and the fair and equitable sharing of benefits arising from their utilization through the European regulation N° 511/2014 and French law No. 2016-1087 for the recovery of biodiversity, nature and landscapes.

The BRCs are under the responsibility of French research organizations working in the field of agronomy and biology: Research Institute for Agriculture, Food and Environment (INRAE), Research Centre for International Development (CIRAD), Research Institute for Sustainable Development (IRD), National Centre for Scientific Research (CNRS), and their partners – the technical institutes and higher education institutions. The BRC4Plants includes 47 living collections of species or groups of species shared between 18 BRCs.

Box 1. Plant collections, a window on viral biodiversity. Contributions of the Safe PGR project - EraNet Netbiome Program (2012-2015)[1]

Vegetatively propagated crops are prone to the accumulation of viruses because they do not benefit from viral sanitation following reproduction by seed. On the other hand, Biological Resource Centers (BRCs) bring together a large number of species and varieties from diverse geographical origins.

The general objective of the Safe PGR project was to improve the knowledge of the diversity of viruses infecting the crops addressed by the partners' BRCs, to develop or optimize diagnostic techniques. Ultimately, it aimed to limit the risk of spreading viral diseases through the exchange of tropical plant germplasm.

To reach its objective, the BRC partners from Guadeloupe, Madeira, Azores, and Reunion, combined classical molecular biology and next generation sequencing (NGS) approaches, leading to unprecedented virus discovery in the targeted crops (banana and plantain, sugarcane, yam, sweet potato, garlic and vanilla).

A total of 21 new virus species were discovered (1 in banana, 3 in garlic, 3 in sweet potato, 4 in sugarcane, 3 in vanilla and 7 in yam) and their molecular diversity was explored. This gave the possibility of setting up diagnostic methods for these new agents as well as the optimization of methods for 10 already known viruses. Thus, the knowledge of the viral status of the germplasm collections was improved, which helps to prevent the spread or emergence of diseases.

[1]For more information, see Pavis (2015).

In total, more than 103,000 accessions are conserved in the French plant BRCs, of which about 57,000 are horticultural resources belonging to 62 genera.

This organization of the plant BRCs into a network makes it possible to think about and carry out research projects around common issues specific to the BRCs such as genetic diversity and plant genome analysis or viral diversity of vegetatively propagated species (Box 1) or, more generally, the application of national and international phytosanitary regulations.

The French national coordination for plant genetic resources: safeguarding "orphan species"

The national coordination works towards the official recognition of collection curators and the identification of plant resources of cultivated species and their wild relatives (other than forest trees) that are relevant for France. Set up by the Ministry of Agriculture, the coordination is composed of a national support structure (SCN) hosted within the GEVES (Group for the Study and Control of Varieties and Seeds), and a Cross Section of the CTPS (Permanent Technical Selection Committee) bringing together a diversity of stakeholders (47 members) involved in the conservation and development of these resources.

In this context, the SCN acts to safeguard species, which are relevant for French agriculture. It focuses in particular on the conservation of "orphan" species, species without an identified collection or with a collection for which the regeneration or characterization are not carried out: for example, beans (*Phaseolus* sp.), grass pea (*Lathyrus* sp.), lentils (*Lens culinaris*) and onions (*Allium cepa*). Research has been carried out on existing collections, inviting other stakeholders who are interested in getting involved in the management of these species. For beans and onions, public and private cooperation networks are in the process of being created. For grass pea and lentils, the approach was unsuccessful due to an insufficient number of stakeholders. Nevertheless, discussions are being held with international centers to identify potential solutions for safeguarding these collections. Other species will be studied, such as buckwheat (*Fagopyrum esculentum*), radish (*Raphanus sativus*) or asparagus (*Asparagus officinalis*).

Involvement of French BRCs at European level

Though genetic resources management is organized mainly in crop-oriented networks and BRCs in France, centralized multi-species gene banks prevail in Europe. The cooperation on PGR in Europe is organized though ECPGR (The European Cooperative Programme for Plant Genetic Resources, https://www.ecpgr.cgiar.org/) with 33 member-countries and 23 working groups with several addressing horticultural crops: *Allium*, berries, *Brassica*, cucurbits, leafy vegetables, *Malus*/*Pyrus*, medicinal and aromatic plants, potato, *Prunus*, *Solanaceae*, umbellifer crops and *Vitis*. French BRCs actively participate to ECPGR. Genetic resources in Europe covering 43 countries, 400 institutes and 2 million accessions can be found in the Eurisco database (https://eurisco.ipk-gatersleben.de).

Biological Resource Centers in France for horticultural plants

Within the BRC4Plants, eleven BRCs manage horticultural living collections (Figure 1; Table 1). An additional BRC, the CNRGV (French Plant Genomic Resources Center), is specifically dedicated to genomic resources (Box 2). A French specificity within the European space is to have several ultramarine territories, called RUP (ultra-peripheral region) at the European level or DROM-COM (overseas departments and regions - overseas collectivities) at the French level. These territories are mainly located in tropical environments. They are home to significant biodiversity and host many collections of tropical horticultural genetic resources organized in BRCs.

The Florilège portal (http://florilege.arcad-project.org/fr/collections) provides a focal point for web entry into the biological resources of plants for agriculture conserved in France (metropolitan and overseas). In its

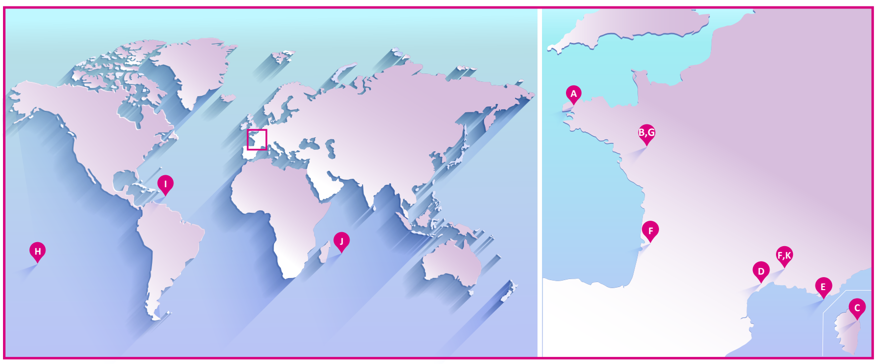


Figure 1. Localization of the 11 French Biological Resource Centers (BRCs) around the globe. Left: overseas BRCs, right: mainland France and Corsica BRCs. A = BrACySol, B = Carrot and other vegetable *Apiaceae*, C = Citrus, D = Grapevine, E = Olive trees, F = *Prunus-Juglans*, G = Rose-Pom, H = Tahitian vanilla, I = Tropical plants, J = Vatel, K = Vegetables. (Figure designed by M. Duportal, CIRAD).

Box 2. The French Plant Genomic Resources Centre (CNRGV)[2]

The CNRGV is a national infrastructure within the National Research Institute for Agriculture, Food and Environment (INRAE). Settled in Toulouse (France) in 2004, it is both a Biological Resource Centre (BRC) dedicated to plant genomic libraries and a service provider for plant genomics projects. A genomic library consists of collection of DNA fragments cloned into bacteria (so called BAC clones) that, altogether, represent the complete genome of a plant. The BAC clones are easy to conserve, to screen for genes of interest, to isolate DNA from and to sequence.

The missions of the CNRGV are to produce, conserve, characterize, and distribute genomic resources to, ultimately, understand the organization of plant genomes or to link biological functions or agronomical traits to the DNA sequences that govern their expressions. To fulfil these objectives, the CNRGV can either screen the genomic libraries to isolate the BAC clones of interest and sequence them, directly target and sequence large DNA fragments, using internally developed CATCH methods, or produce an assembled genome sequence of a genotype of interest in collaboration with sequencing facilities.

To date, the CNRGV conserves 392 genomic libraries corresponding to 45 plant species including 20 vegetable and horticultural species. Through collaborations on these particular species, the CNRGV has implemented various projects representative of the services available. They include the production of preliminary genomic data for species not or scarcely characterized (parsnip, passion fruit), the characterization of regions governing resistances to biotic (resistance to viruses in pepper) and abiotic (frost tolerance in pea) stresses, the production of reference genome sequences (tomato, vanilla). Recently, the CNRGV has developed tools to characterize intraspecific variations in chromosome structure (apricot).

In the future, the CNRGV aims to help to better characterize the genetic resources at the genomic level.

[2]For more information, see https://cnrgv.toulouse.inrae.fr/

current configuration, it represents the network of plant BRCs managed by INRA, CIRAD and IRD members of the national infrastructure AgroBRC RARe. It should soon be interconnected with the European portal Eurisco (https://www.ecpgr.cgiar.org/resources/germplasm-databases/eurisco-catalogue).

The Inter-TROP portal (http://crb-tropicaux.com/Portail) is dedicated to the biological resources of tropical plants for agriculture, maintained by the plant BRCs attached to French research organizations in tropical areas.

Biological Resource Center BrACySol (Figure 1A)

The BRC BrACySol preserves and characterizes collections of genetic resources of different cultivated genera: *Brassica* (cabbage, turnip, rape and mustard), *Allium* (shallot and garlic), *Cynara* (artichoke) and *Solanum* (potato and related species). It is supported by two INRAE units: the Joint Research Unit Institute of Genetics, Environment and Plant Protection (IGEPP) and the Experimental Unit Genetic Resources in Oceanic Conditions (RGCO), and is based in Ploudaniel in Brittany. The BRC BrACySol is involved in various European (H2020 G2P-Sol; Prima Bras Explor) or national (PIA Rapsodyn; CASDAR Brassidel, PoTStaR, GeCoNem) projects, and projects funded by professional partners (Promosol, GIE Colza, Association des Créateurs de Variétés Nouvelles de Pomme de Terre, Fédération Nationale des Producteurs de Plants de Pomme de Terre). The objectives of these projects are i) to explore, describe, and structure genetic diversity, ii) to develop core collections, iii) to carry out genetic association analyses to identify the regions of the genome involved in resistance traits to different pests or abiotic constraints, iv) to introduce this diversity into pre-selection material by exploiting recombination, and v) to develop markers that can be used in marker-assisted selection.

The *Brassica* collection includes 1,200 accessions of vegetable crucifers, which are populations collected from farmers before their disappearance in favor of hybrid varieties, and 2,200 accessions of oilseed crucifers including lineage varieties representing world variability. It also includes original scientific material presenting traits of agronomic importance such as resistance to different pests, or seed quality. The accessions of this collection are stored as seeds in freezers (-18 °C) or in cryopreservation containers (-196 °C). The seed lots are regenerated every 10 to 15 years, depending on the evolution of their germination faculty.

The *Solanum* collection includes 12,000 accessions. It is composed of i) clones of potato-related species originating from South America and characterized for a certain number of traits of interest, ii) varieties representing world variability, including heritage ones that are not maintained in any other European BRC, and iii) original scientific material presenting traits of agronomic importance such as resistance to different pests, or related to the technological quality of tubers. These accessions are maintained by vegetative propagation in the form of tubers, in vitro plantlets or cryopreserved meristems. The maintenance of related species in the form of characterized clones constitutes a specificity of this collection.

The *Allium* collection includes 120 garlic accessions and 300 shallot accessions. It is composed of populations collected in France before the opening of the catalog in 1991, old and new varieties and original scientific material for the selection of agronomic characteristics such as disease resistance or dry matter content of bulbs. The accessions are maintained by vegetative multiplication in the form of bulbs and planted in the field every year.

The *Cynara* collection includes 20 artichoke accessions. It is composed of French varieties and varieties used as reference in the trials. The accessions are maintained in the form of plants in the greenhouse.

The BrACySol BRC coordinates three national networks for the conservation of plant

Figure 1A. A. Diversity of potato varieties. Credit: C. Maitre, INRAE. B. Diversity of cabbage populations. Credit: N. Quéré, INRAE.

■ Table 1. Detailed list of French Biological Resource Centers dealing with horticultural collections.

Code	BRC name	Town (region)	Affiliation	Contact	Family
A	BrACySol	Ploudaniel (Brittany)	INRAE	Bracysol@inrae.fr	*Brassicaceae* *Alliaceae* *Asteraceae* *Solanaceae*
B	Carrot and other vegetable *Apiaceae*	Angers (Pays de la Loire)	Agrocampus Ouest	crbcarotte@agrocampus-ouest.fr	*Apiaceae*
C	Citrus	San Giuliano (Corsica)	INRAE-CIRAD	emmanuel.bloquel@inrae.fr	*Rutaceae*
D	Grapevine	Montpellier (Occitania)	INRAE	cecile.marchal@inrae.fr	*Vitaceae*
E	Olive tree	Porquerolles (French Riviera)	CBN Med/INRAE	b.khadari@cbnmed.fr magalie.delalande@inrae.fr	*Oleaceae*
F	*Prunus-Juglans*	Avignon (Provence), Bordeaux (Aquitaine)	INRAE	marine.delmas@inrae.fr	*Rosaceae*
G	Pome fruits and roses (RosePom)	Beaucouzé (Pays de la Loire)	INRAE	Alix.Pernet@inrae.fr Laurence.Feugey@inrae.fr	*Rosaceae*
H	Tahitian vanilla	Raiatea (French Polynesia)	EVT	sandra.lepers@vanilledetahiti.pf	*Orchidaceae*
I	Tropical plants	Petit Bourg (Guadeloupe), Le Lamentin (Martinique)	CIRAD/INRAE	crb.plantes-tropicales@cirad.fr	*Musaceae* *Bromeliaceae* *Poaceae* *Anacardiaceae* *Dioscoreaceae*
J	Vatel	Saint Pierre (Reunion Island)	CIRAD	carine.charron@cirad.fr marc.seguin@cirad.fr	*Orchidaceae* *Amaryllidaceae* *Araceae*, *Euphorbiaceae*, *Dioscoreaceae*, *Convolvulaceae* *Fabaceae* *Cucurbitaceae*
K	Vegetables (Leg)	Avignon (Provence)	INRAE	rebecca.stevens@inrae.fr	*Solanaceae* *Cucurbitaceae* *Asteraceae*

genetic resources: the "vegetable crucifers" network, the "oilseed crucifers" network and the "potato" network, and it participates in the Cynara network. In addition, the BRC BrACySol is part of the European network ECP/GR and is a member of the *Brassica*, *Allium* and Potato working groups. The collections maintained within the BRC BrACySol are visible on the French portal Florilège. The BRC BrACySol is engaged in a certification process according to the ISO 9001-2015 standard.

BRC Carrot and other vegetable *Apiaceae* (Figure 1B)

Based on genetic resources research and management activity initiated in 1996, the BRC "Carrot and other vegetable *Apiaceae*" was re-established in 2011. This BRC is supported by the Institut Agro | Agrocampus-Ouest, with joint research with IRHS (Institute of Research on Horticulture and Seeds). The related activities involve carrot and wild relatives genetic diversity and evolution, the genetic determinants of compounds involved in quality and resistance to diseases in carrot, and the effect of environment,

Main genus/ species	Common names	Number of accessions preserved	Number of accessions released (2019)	Selected scientific references
Brassica *Allium* *Cynara* *Solanum tuberosum*	Cabbage, rape seed Garlic, shallot Artichoke Potato	3,400 420 20 12,000	1,310	Aissiou et al. (2018) Esnault et al. (2014, 2016)
Daucus *Chaerophyllum* Other *Apiaceae*	Carrot Tuberous rooted Chervil, parsnip, fennel, etc.	4,376 706 37	5	Chevalier et al. (2021) Geoffriau (2020) Martinez Flores et al. (2019)
Citrus	Citrus	1,100	420	Ahmed et al. (2019) Curk et al. (2016) Luro et al. (2017)
Vitis	Table grape Grape	2,262 5,738	500	Bonhomme et al. (2020) Candresse et al. (2020) Dumas et al. (2020)
Olea	Olive	63	0	El Bakkali et al. (2019) Khadari and El Bakkali (2018) Khadari et al. (2019)
Prunus sp. *Juglans*	Apricot, almond, peach, cherry, plum Walnut	2960 400	NA	Bernard et al. (2020) Cirilli et al. (2020)
Malus *Pyrus* *Cydonia* *Rosa*	Apple Pear Quince Rose	4,917 2,474 59 2,518	638	Lassois et al. (2016) Liorzou et al. (2016) Lopez Arias et al. (2020) Muranty et al. (2020)
Vanilla	Vanilla	321	2	Lepers-Andrzejewski et al. (2012) Lubinsky et al. (2008)
Musa *Ananas* *Saccharum* *Mangifera* *Dioscorea*	Banana Pineapple Sugarcane Mango Yam	403 467 335 120 430	600	Arnau et al. (2017) Martin et al. (2020) Umber et al. (2020)
Vanilla Tropical garlic Roots and tubers Neglected vegetables	Vanilla Garlic Taro, Cassava, Yam, Sweet potato, etc. Beans, peas, etc. Luffa, snake gourd, etc.	700 33 82 103	300	Andriamihaja et al. (2020) Bouétard et al. (2010) Roux-Cuvelier (2017)
Solanum melongena *Capsicum* *Solanum lycopersicum* *Cucumis melo* *Lactuca*	Eggplant Pepper Tomato Melon Lettuce	2,333 2,173 3,378 2,332 948	1,595 (distribution out of the research unit)	Daunay et al. (2011) Salinier et al. (2019a, b)

practices and genetic interactions on quality and resistance. The BRC collaborates internationally (e.g., with European and Tunisian gene banks, ECPGR, University of Wisconsin). This BRC focuses on carrot genetic resources with 1,376 patrimonial accessions (among which 350 wild relatives) and nearly 3,000 scientific accessions resulting from research activities (inbreds, segregating populations, intercrossing populations). It holds a unique collection of tuberous-rooted chervil (23 patrimonial and 683 scientific accessions) and a few accessions of other *Apiaceae* crops. The BRC Carrot and other vegetable *Apiaceae* coordinates the national network of carrots and other *Daucus* genetic resources (including 7 companies and 3 professional organizations), hosts and manages the network collection. It provides expertise and resources in the CTPS (variety registration and maintenance controls). This BRC runs projects in partnership with seed companies, and provides scientific support to participatory breeding process of organic vegetable growers. Knowledge management of wild carrot populations is done in collaboration with national botanical conservatories (e.g.,

■ Figure 1B. A. Diversity of carrot root color. Credit: E. Geoffriau. B. Wild carrot umbels for seed regeneration. Credit: E. Geoffriau.

Bailleul, Porquerolles, Corsica) and a taxonomy expert (Via Apia). At European level, the BRC Carrot and other vegetable *Apiaceae* is the French representative on the ECPGR working group *Umbelliferae* (coordination 2008-2013), and is involved in ECPGR Carrot Diverse and EVA carrot projects. It coordinates collecting missions.

The national patrimonial carrot collection can be accessed through https://crb-carotte-cn.agrocampus-ouest.fr/. The BRC Carrot and other vegetable *Apiaceae* is engaged towards ISO 9001-2015 certification.

BRC Citrus (Figure 1C)

In 1959, the BRC Citrus was created by the introduction of material initially from the Mediterranean area, then from other growing areas such as Southeast Asia, the region of origin of citrus. It is located in Corsica, on the INRAE station of San Giuliano, and managed jointly by INRAE and CIRAD. Today, the Citrus BRC has more than 1,100 accessions from more than 50 countries, which constitutes one of the five most important citrus collections in the world. All groups or cultivated species are represented but the group of mandarins and their hybrids are a specialty core collection (about ¼ of the BRC). Citrus is conserved in the form of grafted trees (3 or 4 trees per accession) planted in orchards on 14 ha in total. Today, about 25% of the collection is duplicated and maintained in an insect-proof greenhouse. More secure forms of conservation are being studied such as cryopreservation of polyembryonic seeds (apomictic multiplication by somatic embryo). From 2014 to 2020, the Citrus BRC was certified according to the NFS 96-900 standard. In 2020, this was switched to the international quality system ISO 9001-2015. A management software has been developed and consists of modules dedicated to each major activity: introduction, conservation,

Box 3. The origin of citrus fruit – F. Curk (INRAE) and P. Ollitrault (CIRAD)

Citrus ancestors first diversified in different regions from the southern Himalayas to Oceania. This so-called allopatric evolution differentiated a number of taxa, of which four (*C. maxima* (Burm.) Merr [pummelos], *C. reticulata* Blanco [mandarins], *C. medica* L. [citrons] and *C. micrantha* Wester [papedas]) are at the origin of the main horticultural groups (Figure 2). Hybridization between these ancestral taxa has occurred as a result of overlapping geographical ranges, certainly linked to major climatic changes. These hybridizations have generated new species, some of which modern man has inherited after identification and selection by humans over millennia. Recent phylogenetic studies have uncovered and confirmed this history.

We now know that the sour orange (*Citrus aurantium* L.) is a direct hybrid between a pummelo and a wild mandarin tree. The orange (*Citrus sinensis* L. (Osb.)) merged from a more complex combination of *C. maxima* and *C. reticulata* genomes. Lemon (*C. limon* (L.) Burm.) is a hybrid between a sour orange and a citron. The citron is the male parent of all acidic citrus, including the Mexican lime (*C. aurantiifolia* (Christm.) Swing.), a direct hybrid between *C. micrantha* and *C. medica*. The most recent results have highlighted the complex origin of the Tahitian lime (*C. latifolia* Tan.), which has a complex mosaic genome derived from the four ancestral taxa. This lime is, in fact, a hybrid between the Mexican lime and the Mediterranean lemon.

In addition to identifying the ancestral species at the origin of cultivated citrus, this information opens the way to new strategies for breeding based on a wide exploitation of the genetic resources of the species complex to generate the genotypes of tomorrow.

■ Figure 1C. A. Citrus field collection. Credit: F. Luro, BRC Citrus. B. Greenhouse citrus collection. Credit: E. Bloquel, BRC Citrus.

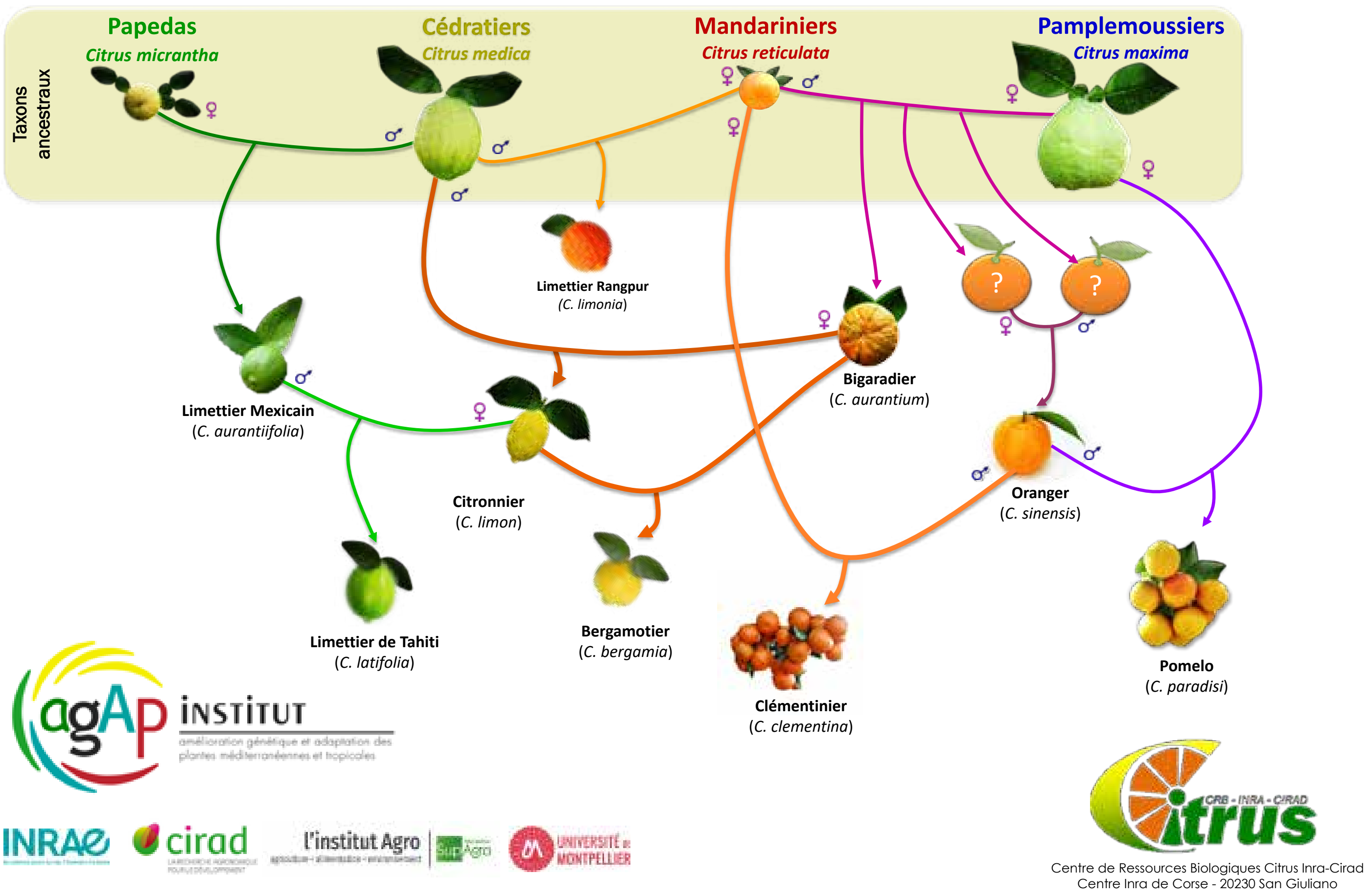


Figure 2. Genetic origin of the main citrus sub-groups.

characterization, and dissemination of plant material.

Until 1999, the conservatory had its own quarantine strategy. Thermotherapy and regeneration by somatic embryogenesis were used, in the beginning, to guarantee the sanitary status of the introduced material. Then, from 1981, apex micrografting was applied and opened the possibilities of introduction to all varieties of all geographical origins. Since the beginning of the 21st century, the National Agency of Sanitary Safety of Food, Environment and Work (ANSES) of Clermont-Ferrand (mainland France) ensures the quarantine services. Corsica has low pest pressure for citrus. Then, the regular controls enable this BRC to be one of the rare locations where all outdoor trees remain healthy.

Nearly 32% of the accessions are available for distribution through shipment of budwood or seeds (about 170 accessions each year). These forms are available for research on plants, leaves, fruits, and flowers (about 250 accessions per year). The collection supports numerous genetic, agronomic, physiological or biochemical studies, and varietal development by selection for hybridization. The important varietal diversity of mandarins, lemons, limes, and citrons has been exploited to develop phylogenetic studies and to analyze the structure of genomes (Box 3).

BRC Grapevine (Figure 1D)

The Vassal-Montpellier Grapevine BRC is the oldest and richest ampelographic conservatory in the world, both in number and diversity of accessions. The conservatory was created in 1876 at the Montpellier School of Agriculture (now the Institut Agro | Montpellier SupAgro). During the phylloxera crisis in 1949, INRAE began managing the collection at the Domaine de Vassal site. Under the scientific aegis of the research team on vine genetics in Montpellier (now the AGAP Institute (Genetic Improvement and Adaptation of Mediterranean and Tropical Plants research unit, team “Diversity, Adaptation and Improvement of the Grapevine”), the collection has been studied and enriched continuously. The documentation of the collection and associated data are also of great importance.

Today, the collection consists of over 8,000 accessions of cultivated vines, rootstocks, and wild relatives from 54 countries. The collection conserves 2,262 accessions of table grapes, representing 1,187 different varieties, of which 243 are considered “dual purpose” for wine and table.

The accessions are cultivated in the vineyard on five rootstocks. They are characterized for morphological, phenological, agronomic, technological, sanitary, genetic, and bibliographical traits. In recent years, the emphasis has been placed on behavior in the face of the main pathogens, in particular through the Vitirama project (https://www6.montpellier.inrae.fr/vassal/Activites/Projets/Vitirama), to support the use and creation of varieties requiring less phytosanitary treatment. Each year, an average of 500 varieties are distributed as cuttings-graft or fresh material (leaves, berries), to professionals in the sector, amateurs, or French and foreign researchers. The research topics in which the BRC Grapevine is involved are very diverse, from archaeobotany to virology, including physiology and adaptation to climate change.

The documentary collection is a resource in its own right and is being digitized thanks to a sponsorship program. It is used in particular in projects with historians, such as the historical ampelographic atlas of France (CepAtlas, http://citeres.univ-tours.fr/spip.php?article3174).

In addition, the BRC Grapevine collaborates with the French Wine and Vine Institute and the French Network of Vine Conservatories,

Figure 1D. A. Domaine de Vassal, field collection. Credit: C. Cruells. B. 'Italia Rubi' cultivar. Credit: BRC Grapevine. C. 'Malaga' cultivar. Credit: BRC Grapevine.

which brings together 36 professional partners from all wine-producing regions. The common database for this network is https://bioweb.supagro.inra.fr/collections_vigne/Home.php.

BRC Olive trees (Figure 1E)

The olive tree (*Olea europaea*) is one of the emblematic species of the Mediterranean. It is cultivated for the production of edible oil and table olive on a surface area of over 10 million hectares worldwide. It is an "immortal" tree, particularly because of its ability to regenerate after extreme weather events. *Olea* includes six subspecies, but only the olive tree *Olea europaea* subsp. *europaea* was domesticated about 6,000 years ago. This subspecies is present throughout the Mediterranean, both in its wild (var. *sylvestris*) and cultivated (var. *europaea*) forms. Domestication *sensu stricto* began with the vegetative multiplication of wild trees selected for traits probably related to fruit size and oil content. The BRC Olive trees is supported by the National Mediterranean Botanical Conservatory (CNBMed), based in Hyères-les-Palmiers in PACA (Provence-Alpes-Côte d'Azur) region, and managed jointly by INRAE, within the framework of the AGAP Institute in Montpellier.

The BRC focuses on the national olive tree collection, hosted by the Port-Cros National Park on the Porquerolles Island (PACA region). The core collection is composed of French heritage varieties and those from other Mediterranean countries. In partnership with the olive-growing professional organization (France-Olive), a French national collection has been established, constituted by 63 formally identified accessions and considered as reference of French olive varieties. This has been possible following a huge identification work based on morphological (tree, leaf, fruit, kernel), molecular (microsatellite markers) and bibliographical (validation of names) information and according to the opinions of the France-Olive stakeholders. This identification work continues to remove any ambiguities about certain varieties for which the reference genotype has not yet been validated.

The BRC Olive trees is based on a collection located on an island within a national park, following an organic cropping system. Moreover, its management takes into account a national level through local collections managed in partnership with France-Olive stakeholders, and an international level through world collections managed within the genetic resources network of the International Olive Oil Council (IOC). BRC Olive trees organization ensures a safeguarding of French genetic resources *ex situ* in local (France-Olive network) and worldwide collections (IOC network), as well as *in situ* through trees geo-located by France-Olive in orchards.

The BRC Olive trees is considered an innovative research tool on adaptation to climate change conducted by the AGAP Institute in collaboration with national and international partners mainly in Morocco and Spain (OliveMed project funded by Agropolis Foundation, 2021-2025). Two research topics are currently implemented within this framework: i) understanding the flowering processes in relation to the cold requirements of varieties, and ii) investigating the variability of functional traits related to drought resistance in olive trees (https://umr-agap.cirad.fr/en/research/main-projects/olivemed). These research lines are linked to NGS (next generation sequencing) analyses in order to identify adaptive genomic variants.

BRC *Prunus-Juglans* (Figure 1F)

The BRC *Prunus-Juglans* is managed by INRAE, in orchards or in sheltered containers of fruit and related species belonging to the genera *Prunus* (stone fruit) and *Juglans* (walnut). A large part of this material is composed of traditional and modern varieties of agronomic interest. Another part is made of accessions of scientific interest, mainly resulting from INRAE research work. Related species are also included in the collections: some are of interest as rootstocks, others may carry genes of interest such as disease resistance ones. Japanese cherry (*Prunus serrulata*), highly prized for its abundant flowering, and myrobolan (*Prunus cerasifera*), widely used as rootstock for plum, apricot or almond trees, are among the best-known species of the *Prunus* collections. These trees are grown and observed in two production regions in France:

- In Provence-Alpes-Côte d'Azur (south-east of France) the INRAE-GAFL (Genetics and Breeding of Fruit and Vegetables) research unit manages exclusively stone fruit trees: apricot (600 accessions), almond (250 accessions) and related species;
- In Nouvelle-Aquitaine (south-west of France), the Fruit tree Experiment unit of INRAE manages both *Prunus* and *Juglans* trees: cherry (3 species, 500 accessions), peach (1 species, 500 accessions), plum (1 species, 350 accessions), and related *Prunus* species (30 species, 70 accessions); and walnut (15 species, 40 accessions).

The *Prunus* collections are used by research units of the "Biology and Plant Breeding" department of INRAE, involved in varietal innovation or stress resistance. This is illustrated by the CASDAR-funded project "Caress *Prunus*" (Characterization of *Prunus* genetic resources for biotic and abiotic stresses). This project characterized the available genetic resources through a multi-criteria approach targeting phenology (dormancy, flowering, maturity and senescence) and sensitivity to pests and diseases. The *Juglans* collections are used both for breeding purposes in a partnership with the Interprofessional Fruit and Vegetable Technical Centre (CTIFL), and for research purposes, particularly in animal

Figure 1E. A. Turning color olives of ‘Petit Ribier’ cultivar. Credit: J.-P. Roger, CBNMed. B. Organic clay treatment against the fly *Bactrocera olea* in the French national collection located in the Parc National de Port-Cros Porquerolles. Credit: M. Delalande, INRAE.

Figure 1F. A. Flowering *Prunus* from the Rose-pom collection. Credit: BRC Rose-pom. B. Flowering of walnut in new plantation. Credit BRC *Prunus-Juglans*.

physiology in a research project developing plant hormonal compounds in goat breeding.

BRC Pome fruits and roses (RosePom) (Figure 1G)

The BRC “Pome fruits and roses” (BRC RosePom) is hosted by INRAE near Angers, in the region Pays de la Loire, on two main sites: Beaucouzé and La Rétuzière. It is managed by the joint research unit Research Institute in Horticulture and Seeds (IRHS), and by the experimental unit Horti. It includes collections of i) apple, pear, and quince accessions, mostly in the field and as DNA samples, and ii) rose accessions. Scientific accessions of the *Rosa* genus are preserved in the field and as DNA samples, whereas patrimonial accessions are mostly as DNA samples, the heirloom field roses being preserved by different private and public rose gardens in France.

The missions of the BRC RosePom include:

- The preservation of biological resources of pome fruit and roses, including improvement and rationalization of the collections;
- The phenotypic and genotypic characterizations of these resources, to be able to supply samples and data for research and breeding purposes, mainly in the framework of collaborative projects;
- The provision of expertise and available materials from the pome fruit collections for distinctness, uniformity and stability (DUS) testing;
- Data analyses associated with these resources in collaboration with research teams and external germplasm managers.

BRC RosePom also leads or contributes to pome fruit and rose genetic resources networks at national, European and international levels.

The BRC RosePom currently preserves nearly 10,000 accessions in the field (4,917 *Malus*, 2,474 *Pyrus*, 59 *Cydonia*, and 2,518 *Rosa*) and several thousand additional accessions as DNA samples only. To efficiently store all associated data, a database is under construction and should soon be available. This resource, whether patrimonial or scientific, is the basis of many research projects. For example, the CorePom project funded by the Foundation for Research on Biodiversity produced an unprecedented increase in knowledge about the accession identity and uniqueness/duplicate status of the French apple germplasm genotyped with SSR. The genetic diversity and structure were analyzed and helped in constructing core collections. A first parentage analysis was also performed. In the EU-funded FruitBreedomics project (https://cordis.europa.eu/project/id/265582), more than 2,400 accessions from 14 European collections, including that of the BRC RosePom, were further analyzed and revealed a prominent gene flow in apple at the European level. The same accession set was also used in a genome-wide association study on flowering and ripening periods and for the reconstruction of an extra-large, multi-generation, highly-connected pedigree. For rose, the DNA stored in the BRC of French cultivars of the 19th century allowed the FlorHiGe project (2013-2016) to show introgression of the European genetic background by the Asian one. Rose mapping prog-

Figure 1G. A. An overview of the different colors and fruit shapes of the apple varieties conserved in the BRC RosePom. Credit: L. Feugey, INRAE. B. Scientific genetic resource collection of *Rosa* at INRAE, Beaucouzé, France. Credit: Thouroude, INRAE.

enies present in the BRC RosePom fields are the support of several quantitative trait loci studies on different traits, including scent of roses, prickle and disease resistance. Other projects on rose diversity such as those on *Rosa gallica*, or the RosesMonde project (2015-2019) highly contributed to enrich the DNA collection of the BRC RosePom.

BRC Tahitian vanilla (Figure 1H)

The Tahitian vanilla BRC is located on the island of Raiatea, in French Polynesia. It is managed by the Etablissement Vanille de Tahiti (EVT) and was labelled by the GIS IBiSA in 2015. Its quality management system is based on the ISO 9001 standard.

This BRC includes 71 vanilla accessions (*Vanilla × tahitensis, V. planifolia, V. pompona* and hybrids) conserved in two shaded greenhouses, plus 250 varietal creations conserved in vitro. Out of these 321 accessions, 316 are only present at the BRC Tahitian vanilla (Polynesian vanillas and hybrids created by the EVT). Five accessions are also present in the BRC Vatel: *V. planifolia, V. pompona* and *V. × tahitensis* 'Haapape'.

The analysis of the genetic diversity of the vanilla plants in the collection has provided insight into the secondary diversification of vanilla plants in French Polynesia and unraveled their hybrid origin. Moreover, genetic analyses have shown that the majority of varieties found in Polynesian plantations result from spontaneous germination of seeds of the 'Tahiti' cultivar, or by natural polyploidisation (doubling of the number of chromosomes) for the 'Haapape' and 'Tiarei' cultivars, for example. These elements highlight the specificity of Polynesian vanilla plants. They have made it possible to define protection and development strategies such as local regulations and the PDO certification process currently underway.

The most widely grown cultivar in French Polynesia is *V. × tahitensis* 'Haapape', which is vigorous but not very floriferous and of average aromatic quality. In the Tahitian vanilla BRC, various vanilla varieties have been evaluated as part of a program to select better performing varieties, i.e., which are better adapted to climatic hazards and emerging diseases. The selection is made by monitoring agronomic traits in the EVT greenhouse, at Polynesian producers' farms, and in laboratory by in vitro tests of susceptibility to fusariosis. Some accessions selected in this way are now offered to producers. These are varieties with excellent aromatic quality and high flowering capacity, or more tolerant to fusariosis.

Figure 1H. A. Cured beans of Tahitian vanilla. Credit: T. McKenna. B. Tahitian vanilla flower. Credit: EVT.

BRC Tropical plants (Figure 1I)

In Guadeloupe and Martinique, the French Caribbean Islands, CIRAD and INRAE have been building up large collections of tropical crop genetic resources for several decades. In 2010, the two organizations joined forces to create the Biological Resource Center "Tropical Plants-Antilles" (BRC-TP). Four collections of vegetatively propagated horticultural species, conserved in the field, make up the BRC: banana, mango, pineapple and yam. These collections are managed under quality assurance, BRC being certified according to the NF-S 96 900 standard and in the process of being certified for the ISO 9001-2015 standard. The BRC also hosts the Guadeloupe Herbarium, which contains more than 12,000 botanical plates. It actively participates in the BRC4Plants networking activities at national level.

The banana collection comprises 403 accessions representing a significant proportion of the world's banana diversity. It is maintained in the field and secured in vitro for the most fragile accessions. The following types of banana are represented: plantain, cooking, dessert, ornamental and wild bananas, including *Musa acuminata* and *Musa balbisiana*, the ancestral relatives of cultivated banana. This collection is part of the Musa-LAC (Latin America and Carribean) network supported by Bioversity International. It is involved in numerous research projects in genetics and banana breeding. It is one of the most important banana field collections in the world in terms of the genetic diversity and number of accessions conserved.

The yam collection, managed by INRAE, is composed of 430 accessions conserved in vitro, part of which is renewed in the field each year. The main species represented are *Dioscorea alata, D. trifida, D. cayenensis-rotundata, D. bulbifera* and *D. esculenta*. Virology research is conducted on this collection, which is also used in international projects (e.g., RTBfoods, https://rtbfoods.cirad.fr/; Africayam, http://africayam.org/).

The mango collection is a historical CIRAD collection. It comprises 120 accessions kept in the field, mainly of the *Mangifera indicae*

Figure 1I. A. Pineapple field collection in Martinique. Credit: M. Roux-Cuvelier. B. Diversity of banana fruit. Credit: BRC Tropical Plants. C. In vitro plantlet (yam collection). Credit: M. Roux-Cuvelier. D. Diversity of mango fruit. Credit: BRC Tropical Plants.

species. Seventy percent of the genotypes come from Africa. Recently enriched with heritage varieties from the French Caribbean Islands, this collection is used to diversify mango production.

The pineapple collection, located in Martinique, includes 467 wild and cultivated accessions representative of the diversity of the genus and of the Amazon Basin, the pineapple area of origin. The pineapple collection is currently conserved in the field, but should be secured by cryopreservation in a near future. It is one of the most important pineapple collections in the world.

The BRC is responsible for the development of OLGA software (local accession management tool), a computer tool used by many BRCs in France to manage stocks of genetic resources and associated data. The collections maintained within the BRC are listed on the Florilège web portal.

BRC Vatel (Figure 1J)

The BRC Vatel (vanilla, garlic, tubers and vegetables) is located on Reunion Island, in the Indian Ocean. It is managed by CIRAD as part of the Peuplements Végétaux et Bioagresseurs en Milieu Tropical research unit (CIRAD/University of Reunion Island). Four collections of agricultural plant genetic resources are conserved in the BRC Vatel:

- Vanilla: 700 accessions, 25 species of the genus *Vanilla* (*Orchidaceae*);
- Tropical garlic: 33 varieties of *Allium sativum* (*Amaryllidaceae*);
- Root and tuber vegetables: 82 accessions, 11 species (cassava, taro, yam, sweet potato, etc.), 7 families (e.g., *Euphorbiaceae*, *Araceae*, *Dioscoreaceae*, and *Convolvulaceae*);
- Seed vegetables: 103 accessions, 30 species (including squashes, pigeon peas, cowpeas), 9 families (mainly *Cucurbitaceae* and *Fabaceae*).

The vanilla collection includes accessions of the three cultivated species (*Vanilla planifolia, V. pompona* and *V. × tahitensis*) as well as 25 wild relatives and interspecific hybrids. It is one of the most important collections worldwide for the genus *Vanilla*. In recent years, the BRC has contributed to major work on the genetic diversity and evolution of cultivated and wild vanillas, on the elucidation of the mechanisms of biosynthesis and storage of aromatic compounds in the fruits, and on resistance to fusariosis. It is also involved in the creation and selection of improved vanilla genotypes. Since 2018, the BRC Vatel has been coordinating the VaniSeq project carried out by a French public-private consortium to decipher the genome of the main cultivated vanilla species *V. planifolia*.

The three collections of garlic and vegetables are made up of traditional varieties from the southwestern Indian Ocean region, most of which were collected in Reunion Island. These collections meet the challenge of conserving an agricultural and cultural heritage ("legume lontan"), but are also of interest in terms of food diversification in the region.

The BRC Vatel is using four CIRAD facilities in Reunion Island: the laboratories of the Plant Protection Platform and three field stations. The accessions are kept in the form of living collections cultivated in the field or in greenhouses (vanilla, garlic, root and tuber vegetables) or seed collections in cold storage (seed vegetables). Part of the accessions are duplicated by in vitro tissue culture for vanilla, cassava, yam and sweet potato.

Of the 918 living accessions conserved at the BRC Vatel, about 200 are available for distribution. Seed samples (seeds, lianas, bulbs or tubers depending on the species) can be ordered online on the portal of the French tropical BRC network http://intertrop.antilles.inra.fr/Portail/pages/crb-vatel. On average each year, 300 accessions are distributed to around 30 clients, for agricultural, educational, research or recreational use.

The Vatel BRC has been awarded BRC by the GIS IBiSA label since 2009. The collections are managed according to a quality assurance approach and certified under the French standard NFS 96-900 since 2016, then ISO 9001-2015 standard since 2019.

BRC Vegetables (Figure 1K)

The Centre for Vegetable Germplasm (BRC-Leg) is part of the INRAE-GAFL research unit situated in Avignon, Provence (PACA region) (https://www6.paca.inrae.fr/gafl_eng/Vegetable-Germplasm-Centre). It maintains over 10,000 accessions spread across five collections, as follows:

- Eggplant (*Solanum melongena* and relatives, 2,333 accessions): the national collection is part of the multilateral system since the species is contained in Annex 1 of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA);
- Pepper (*Capsicum annuum* and related species, 2,173 accessions);
- Tomato (*Solanum lycopersicum* and related species, 3,778 accessions);
- Melon (*Cucumis melo*, 2,332 accessions);
- Lettuce (*Lactuca* spp., 948 accessions).

The genetic resources held by the BRC-Leg are mostly used by French public institutions (research and development), and by breeders of seed companies, who actively collaborate with each other. The accessions are regenerated and described by network associations of public and private partnerships. For each crop, collections are split into two parts: i) the freely available national collection, and ii) the networking collection, access to which is subject to specific conditions. The BRC-Leg coordinates three networks: *Solanaceae* (three crops), melon, and *Lactuca*. It also provides free samples to researchers from foreign public institutions, growers, NGOs and other bona fide users who request the acces-

Figure 1J. A. Field maintenance of the garlic collection at a farm in Petite Ile (Reunion Island). Credit: M. Seguin, CRB Vatel. B. Display of the diversity of vegetable seeds for educational purposes. Credit: C. Charron, CRB Vatel. C. Maintenance of the vanilla collection under insect-proof shade-house. Credit: M. Grisoni, CRB Vatel.

Figure 1K. A. An example of the fruit diversity of *Solanum melongena* (eggplant) and related species maintained at the "CRB-Leg". Credit: CRB-Leg. B. A pepper (*Capsicum*) flower from one of the accessions of the *Capsicum* collection maintained by the BRC "CRB-Leg". Credit: CRB-Leg. C. An example of melon (*Cucurbitaceae*) fruit diversity in the collections of the "CRB-Leg". Credit: CRB-Leg.

sions through the INRAE database (https://urgi.versailles.inra.fr/siregal/siregal/grc.do). This database contains passport data and descriptions of each accession. It is linked to other databases such as Florilège (national database) and Eurisco (European database).

The duty of the BRC-Leg is to carry out morphological descriptions in the open field or in greenhouse. Historically, this activity has mostly included traits related to the harvested product (fruit or leaves). Evaluation has so far typically focused on resistance to pathogens and fruit quality. GAFL scientists are developing research programs to include root traits in the plant descriptions. Both the patrimonial collections and the scientific genetic resources (segregating populations, mutants, etc.) of the BRC-Leg are used for research topics currently including: salt resistance in tomato (ERA-NET root project, https://www.suscrop.eu/projects-first-call/root), or *Bremia* resistance in lettuce (https://www.ecpgr.cgiar.org/european-evaluation-network-eva/eva-networks/lettuce). The BRC-Leg genetic resources are part of the European G2PSol project on biodiversity in the *Solanaceae* (www.g2p-sol.eu).

All seeds are conserved at 5 °C under controlled humidity, and the daily work includes the transfer of the collections to -20 °C for long-term storage. The BRC-Leg is also currently moving towards ISO 9001 quality certification.

Conclusion

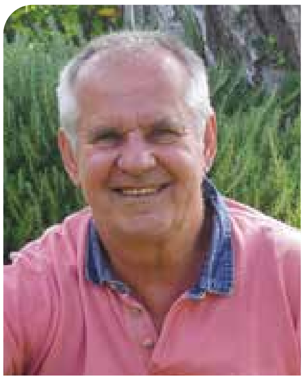
In recent years, and more particularly since the implementation of the CBD, the ITPGR, and the Nagoya Protocol, the holders of genetic resources in France have organized themselves around the constitution of networks allowing for the global consideration of common problems and the easy sharing of information.

The management of French horticultural genetic resources has benefited from recent technological advances that have enabled the acquisition of mass data, particularly in the fields of genotyping and phenotyping, thus enriching the intrinsic value of conserved genetic resources. The horticultural BRCs and collections now play an essential role in French agronomic research, particularly for the preservation and enhancement of agrobiodiversity and the agro-ecological transition of agriculture.

Like most agricultural genetic resources, public funding for the conservation of horticultural diversity is often precarious. However, it has tended to gain in sustainability in recent years thanks to a growing institutional awareness of its crucial importance for the food of tomorrow.

The horticultural genetic resources conserved by the French BRCs are under the responsibility of national public organizations that use them for agricultural research and development. They are also widely used in breeding and varietal improvement programs conducted by the private seed and plant sector. The French horticultural BRCs have made particularly significant contributions to the development of banana, clementine, apple and vegetable *Solanaceae* and *Apiaceae* by several seed companies.

Finally, the French BRCs located in tropical environments in the French overseas departments and territories, play a critical role in the preservation of tropical agricultural genetic resources. They contribute to the food security and sovereignty of territories that are particularly threatened by climate change and the standardization of eating habits. This point will be debated during the United Nations Food Systems Summit in October 2021, and also discussed during the 31st International Horticultural Congress (www.ihc2022.org) to be held in Angers (France) from 14 to 20 August 2022.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IHC2022: a lively Congress to reconnect with communities of horticulture and beyond

IHC 2022
INTERNATIONAL HORTICULTURAL CONGRESS
ANGERS – FRANCE
www.ihc2022.org

Experience the French "art de vivre" during IHC2022!

You all know about the next International Horticultural Congress to be held in Angers, France, on 14-20 August 2022 (www.ihc2022.org). However, you probably do not know yet how much horticulture in France is highly developed, diversified, and competitive. France is the third largest producer of fruits and vegetables in the European Union, behind Italy and Spain. All kinds of horticultural crops are present in France, from apple to banana, from artichoke to chayote, from lily of the valley to bird of paradise, and from lavender to vanilla, thanks to its temperate and tropical territories. This very diverse sector is dynamic, and can rely on numerous official signs and quality procedures, in food as well as in ornamentals or landscaping production. It is a great source of inspiration for French artists, whether chefs, dress makers, or painters: it is a cultural way of life, continuously studied and reinvented by scientists and professionals.

The host destination of IHC2022 is Angers, a human size city compared with the former hosts of IHC: Istanbul, Brisbane, Lisbon or Seoul. Located in the Loire Valley, a UNESCO World Heritage site, Angers is incontestably the French capital of horticulture, remarkable for its richness and diversity, from tradition to innovation and, from urban to nature. It is France's greenest city and top for quality of life, combining a dynamic economy, and a preserved environment. The region has everything it takes to be a world attraction: nature, history, wines and fine gastronomy (Figure 1).

The diversity and the link research-education-industry will be at the core of the congress as well as at the heart of the city: the venue is organized around the botanical garden "Jardin des Plantes", with the renovated Congress Center and the University of Angers, both served by the tramway. Moreover, the entire city will sound and vibrate under the topics of horticulture, with the support and technical touch of the Angers City Council.

Figure 1. Corniche Angevine (©Sébastien Gaudard).

A scientific programme with cross cutting topics

The organizers realize that IHC2022 will combine the tourist appeal of Angers and the region with the high quality of the presentations, scientific, professional, educational or emotional. In particular, a number of international invitees with various backgrounds will open each day of the congress with their views on the major issues of our time: climate change, the defense of biodiversity, the agro-ecological transition and the sustainability of food systems. The programme of the congress will proceed during the course of five days (Figure 2). Symposia and workshops occur each day in a preferentially on-site status, to stimulate exchanges and interactions, all that was missing during the pandemic, despite all kinds of virtual events. Half a day of a wide array of technical local tours are scheduled. Attendees will relax and benefit from the exceptional number of magnificent sites, well worth the visit.

The main scientific part of the congress is comprised of 25 symposia (Table 1), whose topics have been relevantly discussed and formulated thanks to the IHC2022 Scientific Committee, the ISHS Executive Committee (Division and Commission Chairs), and the respective conveners and scientific committees of each symposium. Each symposium is organized in sessions with keynotes, oral and e-poster presentations, and welcomes academic and applied communications. The topics will stimulate cross cutting exchanges between disciplines, crops and actors. In particular, issues such as climate change, and exchange of experience between South and North, shall be integrated into each symposium. The call for abstracts is open, you are already invited to submit your contributions (https://www.ihc2022.org/submission-registration/abstract-submission/)! A series of workshops will be offered to encourage dynamic exchanges between participants around stimulating questions (see examples at https://www.ihc2022.org/scientific-program/workshops/).

■ Table 1. IHC2022 symposia (see details at www.ihc2022.org/scientific-program/symposia).

Topics	Conveners
S1 - Breeding and Effective Use of Biotechnology and Molecular Tools in Horticultural Crops	Vincent Bus (New Zealand) Mathilde Causse (France)
S2 - Conservation and Sustainable Use of Horticultural Genetic Resources	Tiziana Ulian (UK) Raphaël Morillon (France)
S3 - Quality Seeds and Transplants for Horticultural Crops and Restorative Species	Daniel Leskovar (USA) Olivier Leprince (France)
S4 - In Vitro Technology and Micropropagated Plants	Sandra Correia (Portugal) Stefaan Werbrouck (Belgium)
S5 - Innovations in Ornamentals: from Breeding to Market	Johan Van Huylenbroeck (Belgium) Fabrice Foucher (France)
S6 - Innovative Technologies and Production Strategies for Sustainable Controlled Environment Horticulture	Youssef Rouphael (Italy) Jean-Charles Michel (France)
S7 - II International Symposium on Greener Cities: Improving Ecosystem Services in a Climate-Changing World (GreenCities2022)	Vivian Loges (Brazil) Philippe Faucon (France)
S8 - Advances in Vertical Farming	Eri Hayashi (Japan) Leo Marcelis (The Netherlands)
S9 - Urban Horticulture for Sustainable Food Security (UrbanFood2022)	Kathrin Specht (Germany) Kevin Morel (France)
S10 - Value Adding and Innovation Management in the Horticultural Sector	David Neven (Italy) Syndhia Mathé (Cameroon)
S11 - Adaptation of Horticultural Plants to Abiotic Stresses	Fulai Liu (Denmark) Bénédicte Wenden (France)
S12 - Water: a Worldwide Challenge for Horticulture!	Brunella Morandi (Italy) Marcel Kuper (France)
S13 - Plant Nutrition, Fertilization, Soil Management	Lee Kalcsits (USA) Patrice Cannavo (France)
S14 - Sustainable Control of Pests and Diseases	Lucia Zappalà (Italy) Michel Peterschmitt (France)
S15 - Agroecology and System Approach for Sustainable and Resilient Horticultural Production	Maria Claudia Dussi (Argentina) Sylvaine Simon (France)
S16 - Innovative Perennial Crops Management	Sara Serra (USA) Pierre-Eric Lauri (France)
S17 - Integrative Approaches to Product Quality in Fruits and Vegetables	Alyson Mitchell (USA) Nadia Bertin (France)
S18 - III International Symposium on Mechanization, Precision Horticulture, and Robotics: Precision and Digital Horticulture in Field Environments	Sindhuja Sankaran (USA) David Rousseau (France)
S19 - Advances in Berry Crops	Susan McCallum (UK) Béatrice Denoyes (France)
S20 - The Vitivinicultural Sector: Which Tools to Face Current Challenges?	Ahmet Altindisli (Turkey) Benjamin Bois (France)
S21 - XII International Symposium on Banana: Celebrating Banana Organic Production	Walter Ocimati (Uganda) Thierry Lescot (France)
S22 - Natural Colorants from Plants	Riikka Räisänen (Finland) Anne de la Sayette (France)
S23 - Postharvest Technologies to Reduce Food Losses	Gustavo Teixeira (Brazil) Florence Charles (France)
S24 - IX International Symposium on Human Health Effects of Fruits and Vegetables (FAVHEALTH2022)	Kaleab Baye (Ethiopia) Marie-Jo Amiot-Carlin (France)
S25 - Medicinal and Aromatic Plants: Domestication, Breeding, Cultivation and New Perspectives	Christoph Carlen (Switzerland) Guillaume Frémondière (France)

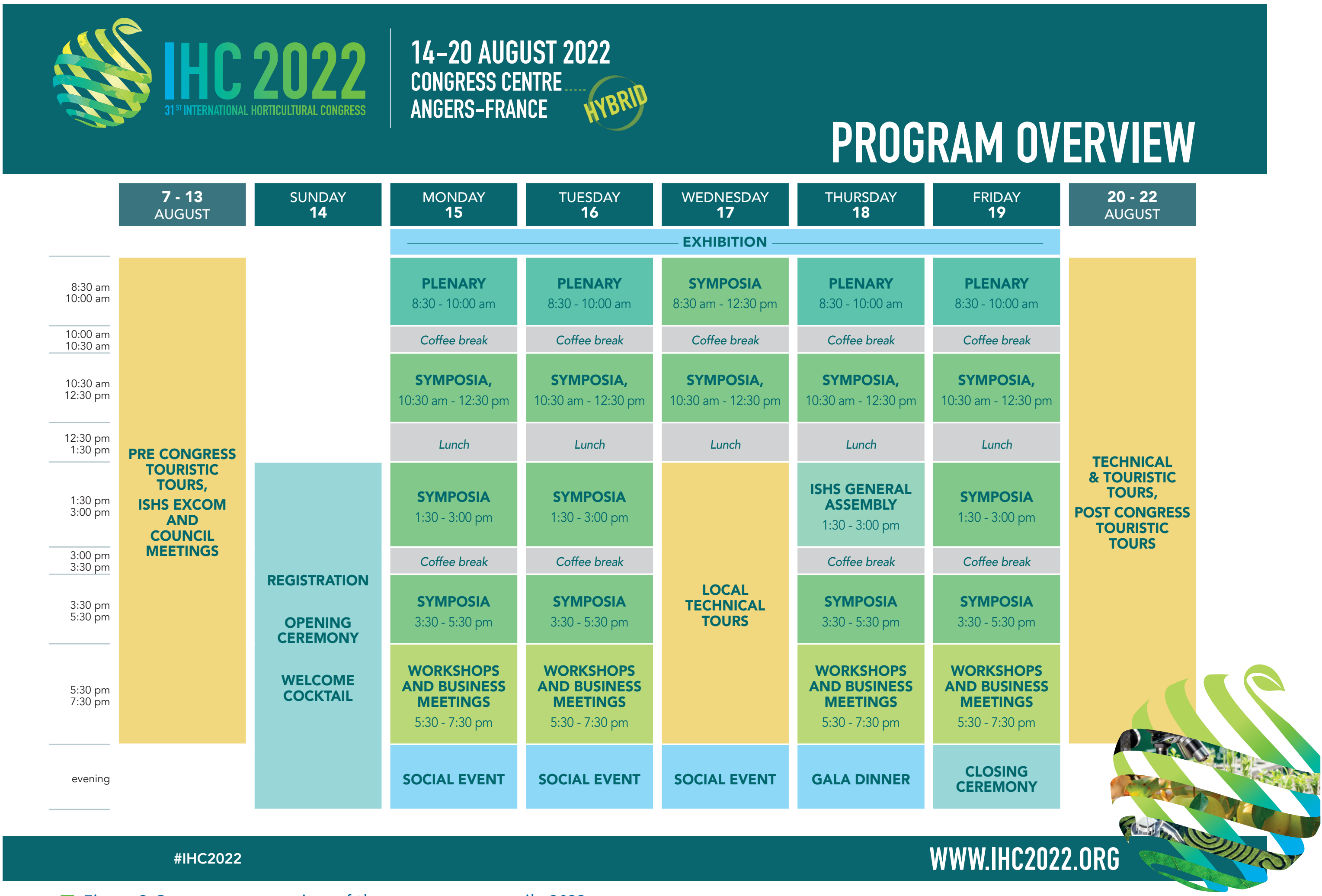

Figure 2. Programme overview of the congress – www.ihc2022.org.

In order to diversify and enlarge the audience and allow more people to benefit from IHC, the organizers have decided to open the symposia to remote attendance in a hybrid format. People who register for attendance at distance can benefit from plenary sessions and symposia presentations and propose e-posters. However, only those participants on-site will be allowed to make an oral presentation.

IHC2022 seen from an industry point of view

One of the objectives of the IHC2022 is to enlarge the audience and facilitate linkages and exchanges between researchers and companies (from producers to R&D services). It seems essential that companies are aware of the latest knowledge in the world, and that researchers listen to companies' needs. The congress plans various activities to stimulate relationships between scientists and entrepreneurs.
First, the content of the programme is open to industry topics. Thus, companies can participate in various events: the exhibition fair, symposia, workshops, and attend meetings. They can present results of a whole project or a single experiment. For each symposium, conveners will organize, if relevant, a dedicated session for professionals. When necessary, these sessions will be translated into French to facilitate access to producers. Companies are already associated in the scientific committee of symposia, more are expected to join the committees of workshops.

Figure 3. Château d'Angers exterior and gardens (©Dorothée Mouraud).

UNDER THE AUSPICES

ISHS

UNDER THE HIGH PATRONAGE OF

CONVENING INSTITUTIONS

PUBLIC SUPPORTS

Figure 4. People behind the IHC2022 organization, with two key contacts for science and for sponsoring.

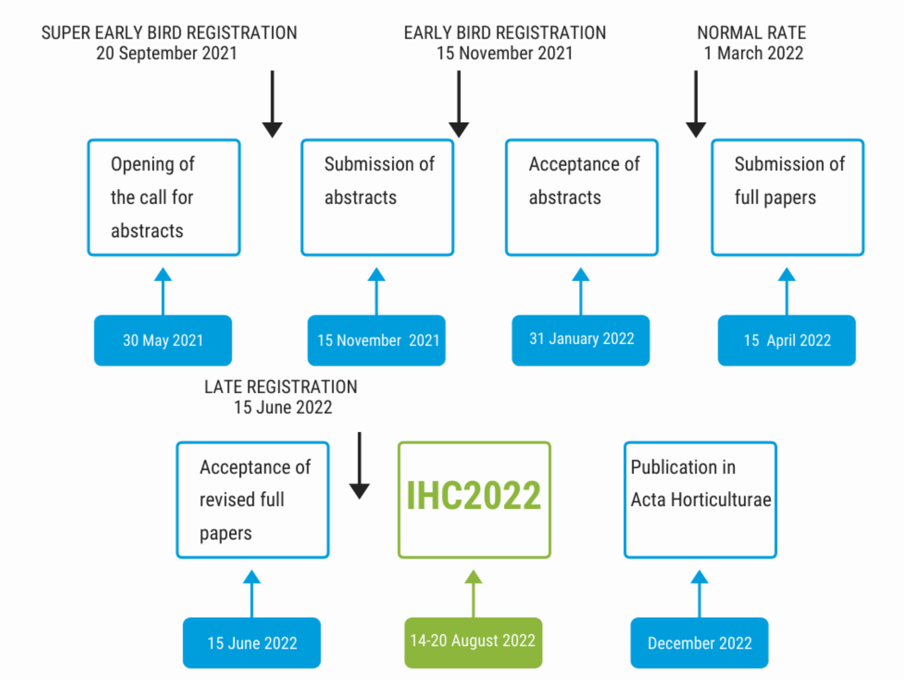

Figure 5. Key dates for the scientific production and registration to IHC2022.

Secondly, the congress will benefit from professionals who share their issues to the global scientific community. A challenge for scientists will be open in the fall. Professionals could share their problems on the website. A committee will guide the answers via a symposium, a dedicated workshop, a meeting, or a face-to-face meeting.

An attractive event for youth

With the aim of promoting stronger interaction between research, training and innovation before, during and after the IHC2022, several activities are proposed to i) involve students and young researchers in horticulture and enhance their scientific and professional skills within IHC2022, ii) promote training and pedagogical innovation in horticulture, and iii) enhance and promote IHC in training and educational institutions.

- The ISHS young minds programme will run in each symposium involving also those who have won national competitions with the exhibition of their achievements before and during IHC2022.
- The first international competition for recently graduated PhD students is inspired by the academic "Three-minute thesis" and will involve an international pre-selection of candidates from their national competition or selection.
- An original workshop on innovation in learning methods will specially focus on e-learning.
- Summer schools or research schools/ workshops before or during the congress on the main themes of IHC2022 will be promoted.
- Networking between PhD and young scientists' associations across the world will be stimulated through BtoB meetings between students and scientists or professionals.

The main argument for attracting young people and encouraging the mixing of generations remains a proactive policy of accessible prices and accommodation: this is a priority set by the organizing committee, that invites all ISHS members to encourage students and young scientists and professionals to register and get their first international experience at IHC2022.

A high quality congress for science... and more

As the congress will be hosted and embedded in the heart of Angers, history, art, and gastronomy will always accompany the participants (Figure 3). Angers will look and sound like horticulture for a full week! The evening social programme will be plentiful and at walking distance, the excursion programme in the region will be attractive and diverse, and opportunities to combine science with tourism will be numerous, from the half-day technical tours to the pre- and post-congress tours in the Loire Valley, in Brittany, or even in Occitanie (south of France). The congress will be a relaxing interlude, reason for attending the place to taste wines, discover art exhibitions, develop friendships during cocktails at botanical sites and at a memorable gala dinner.

A dedicated team for you

The organising committee is made up of men and women of science and experience of public events. The members of the steering committee are each responsible for a specific committee gathering eminent experts in each field. Getting in touch with them is made easy through the generic email addresses (Figure 4).

One of the main challenges of the organizing team is to ensure a high participation level together with a smooth scientific submission process. A simplified road map with few key dates is set up, that offers opportunities of unbeatable registration fees (Figure 5). For a world in transition, let us show that horticulture is central, addressing most of the UN Sustainable Development Goals. Horticultural science is essential to adapt to and mitigate climate change, contribute to nutrition security and human health, and develop attractive and decent jobs in a sustainable and gender equitable environment. We look forward to meeting again and to welcoming all of you next year in Angers for a safe and unforgettable event!

› Rose selection in France: a long and beautiful history

Jérémy Clotault, Fabrice Foucher, Agnès Grapin,
Laurence Hibrand-Saint Oyant, Valéry Malécot, Sophie Paillard,
Alix Pernet, Vanessa Soufflet-Freslon and Cristiana Oghina-Pavie

Introduction

A multitude of species provide ornamental plants for the embellishment of public spaces, gardens, balconies and homes and for the production of cut flowers. The genus *Rosa,* due to its popularity, history, and incredible diversity of traits (from flower shape, colour, scent, to architecture) is considered as the "queen of the flowers." Its diversity of usage (cut flower, miniature indoor pot plant, garden shrub, climbing plant, but also perfume and some culinary tradition) can explain its high economic value which has earned it the title of the world's favourite flower.

The genus *Rosa,* comprised of 150-200 species (Wissemann and Ritz, 2007) well distributed circumpolar boreal, presents a complex evolutionary history. At least 30,000 cultivars have been listed (Roberts et al., 2003), and many of them have a French origin (Figure 1). In France, the rose industry involves many actors, including private (breeders, producers) and public (research teams and horticultural technical institutes) entities.

The rose in France

Indigenous French species

Slightly less than 20 wild *Rosa* species are endemic in France, with the addition of the highly complex *Rosa canina* aggregate in which taxon delimitation is particularly complex. These species belong to subgenus *Rosa*, and are grouped predominantly in section *Caninae*, though some are members of sections *Rosa* or *Gallicanae*. A few ornamental taxa have escaped from cultivation, particularly *Rosa banksiae* W.T.Aiton and *Rosa rugosa* Thunb., and the most characteristic species is *Rosa gallica* L., protected at the national level but also source of numerous cultivars and old cultivated hybrids.

Roses are probably more numerous in France as a result of human practices.

Figure 1. A) 'Aimée Vibert' (1824, Vibert), B) 'Belvédère' (1829, Jacques), C) 'Safrano' (1839, Beauregard), D) 'Triomphe de l'Exposition' (1855, Margottin), E) 'La France' (1867, Guillot), F) 'Etoile Luisante' (1918, Turbat), G) 'Raymond Privat' (1935, Privat), H) 'Papa Meilland' (MEIcesar, 1963, Meilland), I) 'Paul Bocuse' (MASpaujeu, 1997, Massad), J) 'Red intuition' (DELstriro, 1999, Delbard), K) 'Brocéliande' (ADAterhuit 2000, Adam), L) 'Jardin de Grandville' (EVanrat, 2010, André Eve) (Credit: 1A) Cristiana Oghina-Pavie, UA, 1B-L) Agnès Grapin, Institut Agro).

Consumption

Roses are by far the leading ornamental product in France. More than half of the money spent on cut flowers by the French is for roses (€376.3 million in 2018). It is the leading flower for Mother's Day, Valentine's Day, as well as for Christmas. The rose is also the leading plant purchased for gardens, with a value of €50.2 million in 2018. This represents almost 5 million rosebushes bought by private individuals, to which must be added roses for landscaping by local authorities (around 2 million). Miniature roses are in the top 3 of the indoor plants (2.8 million pots for €23.2 million) (https://www.valhor.fr/

etudes-statistiques/etudes-de-marche-et-dopinion/infographies-vegetaux/). These demands are insufficiently covered by the French production. Actually, the balance of trade is strongly in deficit: approximately -€122 million for cut flowers and -€10 million for rose plants per year these three last years (https://comtrade.un.org/data/).

Production

The production of garden roses dominates and represents approximately 800 ha in France, with a large area of production in Doué-en-Anjou, close to Angers (Box 1). Cut flower production, estimated at 190 million stems in 2007, is essentially concentrated on the Mediterranean coast. The French Interprofession of ornamental horticulture, floristry and landscaping (Val'Hor) is a professional organisation, recognised by the French State, uniting all the companies in the ornamental sector. It allows the financing of collective actions that contribute to the dynamism of the sector. In 2015, the 'Label Rouge' approach (guaranteeing a higher level of quality than that of other comparable products) was introduced for sale of rosebushes. About fifty cultivars are deemed eligible for the label. The introduction of the 'Fleurs de France' label in 2017 makes it possible to certify the origin and the eco-responsible process of production, responding to the development of a 'slow flower' movement.

The production of rose in France would be incomplete without at least mentioning the cultivation of *Rosa* × *centifolia* for luxury perfumery, which is part of the skills related to perfume in the Pays de Grasse (Côte d'Azur), recognised as Intangible Cultural Heritage of Humanity by Unesco.

Selection

Rose breeding is particularly dynamic in France. Currently, some 20 breeders/creation companies are listed (https://societe-francaisedesroses.asso.fr/fr/filiere_roses/obtenteurs.htm), with diverse profiles. Some of them are direct (Ducher) or indirect successors (via takeovers, e.g., Guillot with Sirphe company) from rose-growing families of the 19th or early 20th century (Box 2). Others, already well-known, have obtained their first creations over the last 30 years (Adam, Félix, Lebrun, for example). Rose plant breeding activities can be partially monitored by studying the number of Plant Variety Right (PVR) applications present in the CPVO Variety Finder database (Community Plant Variety Office, headquarters in Angers, France). Since 2001, an average of 20 French PVR has been registered for *Rosa* sp. per year,

Box 1. Production in Doué-en-Anjou, a production basin of garden roses for more than two centuries

Doué-en-Anjou (between Angers and Saumur) is the leader in France. In 2011, about 80 producers (500 ha) produced nearly 5 million rosebushes per year corresponding to around 15% of the European garden rose production. The Doué production benefits from a local terroir and a particular know-how in the grafted roses production on *Rosa multiflora* and on *Rosa* 'Laxa' rootstocks. The quality of the roses grown in the region is particularly adapted for the production of garden roses in pots. The varietal choice approaches the thousands of different varieties grown in the region. Research into new varieties and new cultivation techniques is ongoing to adapt to new market requirements: naturally resistant varieties grown with respect to the environment. In 2018, a collective of seven rose producers (Bardet, Bon Temps, Chastel, Harpin, La Saulaie, Leroi and Oriot) created the publishing company 'Select Roses SAS' to ensure the promotion of varieties of roses that will be exclusive 'Douessines'.

› Christophe Travers, manager of Les Pépinières de la Saulaie, receiving the participants of the VII International Symposium on Rose Research and Cultivation in 2017 (credit A. Grapin).

› Producers words: "I have been managing Chastel Nurseries since 2015. I am committed to modernising the company's production while maintaining the quality that has made its reputation for nearly 30 years. At Chastel Nurseries, we grow more than 600 varieties and maintain an expertise in the production of stem and weeping roses. Everything is done to ensure quality production from the best varieties, with an adapted cultivation itinerary that is constantly evolving to reduce our environmental impact." Jean-Loup Pohu, www.pepinieres-chastel.com (credit Chastel Nursery).

Box 2. Two well-known rose breeding companies in France

Malicorne, in the centre of France, is the location where the rose varieties are created by Georges Delbard nursery. Each year, more than 30,000 flowers are manually pollinated between April and June to create a total of 80,000 new genotypes of roses for cut flowers and 60,000 for garden roses. This is followed by a period of 8 to 10 years during which the roses will be carefully observed in different soil and climatic conditions and selected to result in a dozen varieties that will be marketed. Since 1935, Georges Delbard company is at the origin of many successful varieties. Some of them have won national and international awards, such as Château de Cheverny® Deljaupar, winner of the SNHF Grand Prix for roses in all categories in 2017 and elected 'Rose of the year 2021' by the prestigious Royal Horticulture Society. As part of its ongoing drive for innovation and continuous improvement, Georges Delbard company maintains a close relationship with public research. In particular, by collaborating on research projects, the company aims to achieve more sustainable management of pathogens (Robio project) or to gain precision in its varietal innovation programme by using modern molecular marker technologies with the scientific support of INRAE.

The rose is the emblematic flower of the Meilland Group. For six generations, they have been working with passion on colours, fragrances, shapes, resistance, etc., to make the rose ever more seductive. In the center in Le Cannet des Maures (France), research teams elaborate every year breeding programmes to improve the qualities of varieties. They rely on a long experience, a great expertise and an exceptional pool of genitors. Each year, between April and the end of July, 20,000 to 30,000 flowers are manually fertilised corresponding to 2,000 and 2,500 crosses. The harvested fruits allow to obtain about 150,000 to 200,000 seedlings. The plants obtained are then tested in about 15 test stations, in different climatic conditions. In the end, only ten or so varieties are marketed: an extremely demanding process that is rewarded by the fact that Meilland creations win prestigious prizes in international competitions every year. In order to value and secure investments in research, and thus continue to innovate, they take care to protect their creations. Meilland's varieties are the subject of patents, Plant Variety Certificates and trademarks to ensure their promotion in more than 40 countries. To date, Meilland holds more than 1,000 protection titles and a portfolio of 500 trademarks.

› Chateau de Cheverny® Deljaupar, 2014 (credit: Georges Delbard Pépinières et Roseraies).

› 'Line Renaud' MEIclusif, 2005 (credit: Meilland Roses & Creation).

› Arnauld Delbard, founder's grandson (credit: Georges Delbard Pépinières et Roseraies).

› Selection meeting in a test field in 2019 (credit: Meilland Roses & Creation).

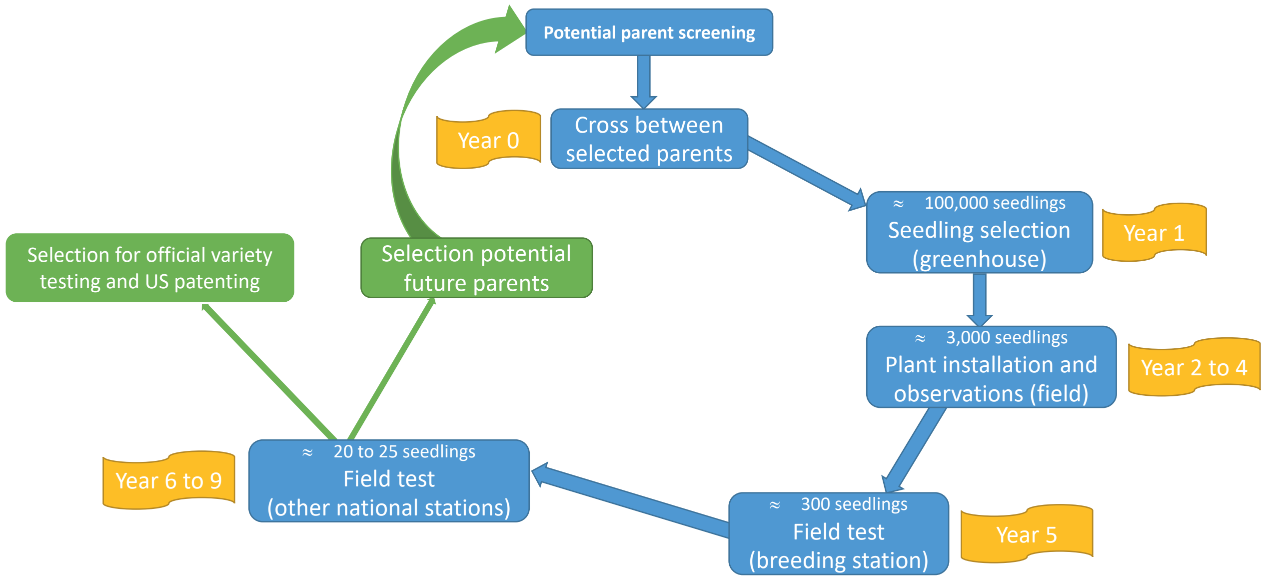

Figure 2. Garden rose breeding scheme (French breeder recommendations).

representing 15% of the world's PVR of CPVO. France is thus the fourth leading breeder country, after the Netherlands, Germany and Denmark, with a very strong specialisation in garden rose breeding (Widehem and Plottu, 2020).

Rose breeding is a long process that can require as much as ten years (usually between 8 to 9 years) from the first hybridisation to the commercialisation of a new variety (Figure 2). Rose breeding programmes are divided into two phases: 1) selection among a large number of seedlings in the greenhouse during the first two years, and 2) performance testing and selection in the field for garden roses from the third year on. During the first year, breeders select against weak growth, for innovative traits that are not found in the released varieties, and for floral traits like colour attractiveness and longevity, wilted flowers that do fall properly and bloom shape (Zlesak et al., 2017). In the following years, the breeders focus on floral traits, plant development and adaptability, disease and pest resistance, tolerance to diverse abiotic stresses and multiplication capacity. Today, breeding for garden roses is mainly focused on pest resistant plants. Black spot is a major pest causing foliage damages thus reducing the aesthetics of the plant (Leus et al., 2018).

Wild endemic genetic resources of roses are preserved in France by "Conservatoires botaniques nationaux" (i.e., national botanic conservatories). Varieties are preserved by public or private rose gardens, as Roseraie du Val de Marne in l'Haÿ-les-Roses near Paris, Roseraie Loubert in Gennes-Val de Loire, 30 km far from Angers, Roseraie du parc floral de la Beaujoire in Nantes, and Roseraie du jardin botanique de la ville de Lyon. Scientific resources like families for QTL mapping, and DNA of all types of accessions (wild, cultivated, scientific) are preserved by the BRC "Pip fruit and roses" described by Roux-Cuvelier et al. (2021).

Rose gardens, in addition to preserve patrimonial genetic resources, also participate to the breeding process by organising competitions between new selections proposed by the breeders. Each competition has its own specificities. Competitions may be distinguished according to the number of locations where they take place and according to the season of the main rating. One-site competitions are organised by the rose gardens of Paris (Bagatelle, Figure 3), Lyon, Nantes and Orléans. In all cases, plants are rated by a specialised commission at different times over two years. The first three towns organise in June the final rating by a grand jury (Bagatelle and Lyon) or by a jury of perfumers (Nantes). Orléans invites in September a grand jury for the final rating, as a consequence, this competition especially distinguishes reblooming varieties. A multisite competition is organised by SNHF (Société Nationale d'Horticulture de France). New rose accessions are planted in seven different rose gardens throughout France, reflecting different types of climatic conditions. Only new varieties commercialised for less than five years may be presented by the breeders. Plants are rated during all seasons over the course of two years by specialists.

Figure 3. Bagatelle (Paris) in June 2021 during the Concours International de Roses Nouvelles. It is the oldest international rose competition, first edition being in 1907 (credit Tatiana Thouroude, INRAE).

Research on rose genetics and selection in Angers

In France, many public and private players are working on research and development as in Lyon (on genomics and flower development) and in Saint-Etienne (on the metabolic pathways controlling scent production), as well as in Strasbourg with the experimental garden of the Erlen in Colmar. Angers is home to several of them.

For 20 years, the Research Institute of Horticulture and Seeds (IRHS) (https://www6.angers-nantes.inrae.fr/irhs) has developed with the GDO team (Genetics and Diversity of Ornamentals) a genetic project to study the impacts of evolutionary history, natural selection and human activities on *Rosa* diversity and to understand genetic determinism of traits of interest.

The genus *Rosa*: a complex genus for systematists and geneticists

The genus *Rosa* has more than 150 described species. Among these 150 species, about ten would have contributed to the cultivated roses that we find in our gardens or at our florists. Due to complex genetic processes (polyploidisation and interspecific hybridisation), the evolutionary history of the genus *Rosa* is still very poorly known. Using a phylogenomic approach and a step-by-step method, we were able to reconstruct a robust nuclear and plastid phylogeny of the genus, and to highlight interspecific hybridisation events and polyploidisation that generate its current diversity. We have thus resolved most of the evolutionary relationships between subgenera, sections and some species of the genus *Rosa*. For some species, such as *R. gallica*, *R.* × *damascena* or *R. canina*, we have proposed hybridisation scenarios using large genomic data (Debray et al., 2021)

Historically, roses from the *Gallicanae* section were cultivated mainly for their therapeutic interests, in areas such as Provins, near Paris. Diversification of the *Rosa gallica* varieties increasingly developed in the first half of the 19th century and led to numerous varieties well phenotypically and genetically separated from wild accessions of French populations (see section below on rose selection during the 19th century). Questions regarding the origin of these French wild populations and more generally on the genesis (this is a putative allotetraploid) and diversity of the *Rosa gallica* species, as well as on the evolution of the relationship between the wild and the cultivated compartments through breeders' work are under investigation with C. Pawula PhD thesis (2020-2023).

Rose diversity and selection: a multidisciplinary approach

This history of rose breeding in France in the 19th century has been widely documented during the time of its protagonists (monographs, catalogues, etc.). Many roses obtained during this period are still preserved in rose gardens. This twofold observation is the starting point for the interdisciplinary approach that unites historians (TEMOS, https://temos.cnrs.fr/) and biologists (IRHS/GDO) to study together the creation of rose varieties over time. This began with the

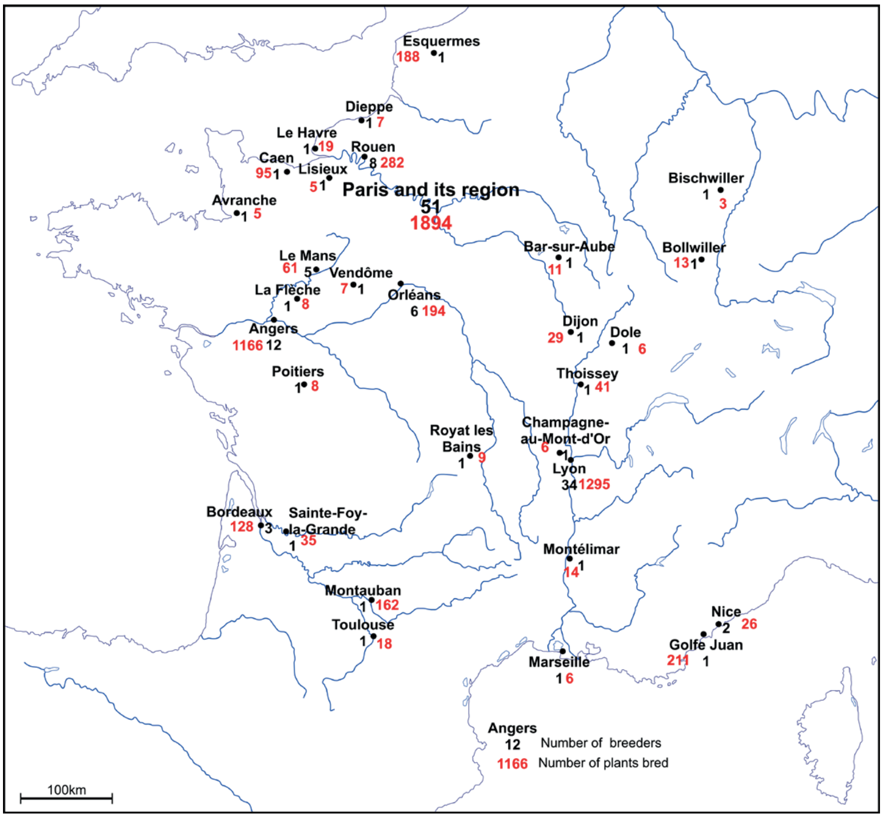

Figure 4. Geographical distribution of breeders (in black) / number of varieties (in red) in France during the 19th century, according to Léon Simon and Pierre Cochet (1906). Cartography by Aurélie Hess.

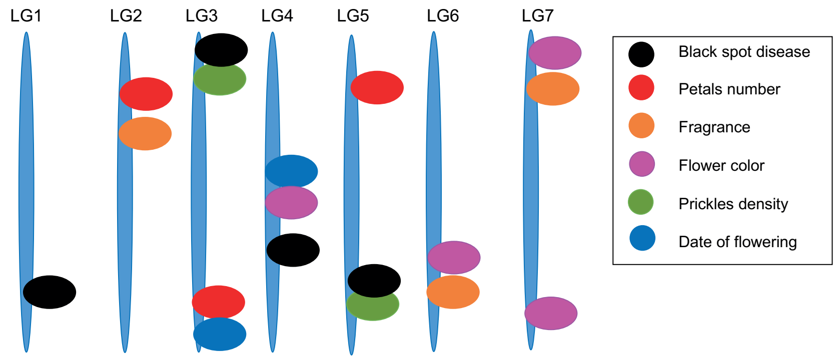

Figure 5. Schematic representation of the seven rose linkage groups and the localisation of genes involved in major traits studied by the IRHS team.

FloRHiGe project (funded by the Pays de la Loire French Region) dedicated to the 19th century in France. Although roses have been cultivated since Antiquity, a strong interest in their diversification only emerged around 1800. The famous collection of roses gathered by Joséphine de Beauharnais in Malmaison in 1804-1815 (Joyaux, 2005), as well as gardening treatises, botanical writings and illustrated monographs, including the luxurious edition of *Les Roses* by Redouté and Thory (1817-1824), have fostered a new perception of the diversity of the genus *Rosa* and its horticultural potential. The popularity of roses quickly went beyond the elite's taste for collecting plants and turned into a broad economic and cultural phenomenon: French rosomania. Initially supported by the Dutch nurserymen, rose breeding took on an unrivalled breadth in France throughout the 19th century. French breeders did not have a "type profile". The most renowned were nurserymen (Descemet, Vibert (Box 3), Jacques, Noisette, Laffay, Verdier, Schwartz, Pernet-Ducher, Guillot) or head gardeners (Hardy), but many successful varieties were due to amateurs: landowners, lawyers, retired officers, etc. The connoisseurs, both breeders and judges of novelties in horticultural shows, formed an almost exclusively male society.

Box 3. Jean-Pierre Vibert, a French breeder in the 19th century

Jean-Pierre Vibert (1777-1866) was the first French nurseryman specialised in the exclusive cultivation of roses. Former soldier in the Napoleonic army and hardware merchant (Joyaux, 2001), he acquired in 1814 and 1815 a part of Jacques-Louis Descemet's collection, consisting of 250 different kinds of roses and 10,000 seedlings. Vibert became a skilled and successful rose grower and the most prolific rose breeder, with more than 500 varieties bred and named by him, despite the misfortunes caused by the infestation of his collection by cockchafer grubs, which forced him to move his nursery in several locations near Paris. In 1839, he moved to Angers, before handing over his nursery to his head gardener, Robert, in 1851. Vibert also managed to describe his observations and practice as a breeder in some of the most informative pages of the rich literature on roses in the 19th century.

Vibert's words

"Oh, how happy was the one who first, having incidentally or intentionally placed seeds into soil, realised that nature could still vary and improve its production; but how much time one must have employed to achieve from this discovery some results less uncertain than those which mere chance would allow him! Modern worldly men, for whom the expectation of a dinner can occupy eight whole days, who only avoid boredom in the midst of the whirlwind of the great world, no, you will never conceive of such enjoyments, never will you believe that such simple pleasures can be bought by years of assiduous care. Too fortunate still if, as a price for such sustained zeal, nature does not refuse our efforts the only reward we seek! At the sight of so many marvels, how many ideas come to mind! What an astonishing spectacle offer to the good observer all these games, these variations of nature and this inexhaustible fecundity, provoked by industry, the limits of which cannot be assigned!" (our translation from Vibert, 1824).

› 'Aimée Vibert' bred by Jean-Pierre Vibert, 1828. Drawing by Annica Bricogne in Hippolyte Jamain, Eugène Forney, *Les Roses. Histoire, culture, description*, Rothschild, Paris, 1873, pl. 59, Bibliothèque Nationale de France- Gallica.

Few women-breeders received a real recognition for their merit. They were widows who ran horticultural establishments after the death of their husbands, like Marie Ducher and Marie-Louise Schwartz. The geographical distribution of French breeders (Figure 4) has evolved during the 19th century. Paris and its region constantly concentrate a high number of breeders. The North was a more active area in the first half of the century, while the South only became so after 1860. Angers was already an important centre in the 1820s, still active but surpassed by Lyon in the second half of the century.

The FloRHiGe project also highlighted the changes in horticulturists' aims and practices over the century and the path towards the quest for novelty by obtaining new rose varieties. The increase in the technical mastery of the practice of hybridisation (from hazard seedlings in the 1800s to controlled hybridisations at the end of the century) and, above all, the use of new genetic resources with innovative traits have resulted in major modifications to the phenotype of roses and a profound change in their genotypes. It has been shown that the genetic background of European hybrid roses has gradually shifted from a genetic background close to that of ancient European roses (Gallic, Damask) to a genetic background close to that of Chinese roses, which notably gave the modern rose its perpetual blooming (Liorzou et al., 2016). Another experience of interdisciplinarity allowed the development with mathematicians from LAREMA of an approach to reconstruct pedigrees, in the context of roses with variable ploidy levels (Proïa et al., 2019), during the PedRo project, conducted in the framework of the regional programme "Objectif Végétal, Research, Education and Innovation in Pays de la Loire".

RosesMonde, a recent interdisciplinary project (geography, history, sociology, economics, biology), funded by the French National Research Agency, has enabled us to broaden our understanding of the history of rose breeding and, more broadly, of the world of the rose, for the contemporary period of the 20th and 21st centuries. In addition to rose cultivars, the study also focused on places and actors, in a context of market segmentation according to rose use, globalisation and standardisation of rose production and, more recently, heritage/patrimonial rose trend. The genetic work has led to an understanding of how segmentation by use and breeding time frame have structured the diversity of roses of this period.

Genetic determinism and French collaborations to understand rose black spot disease resistance

Using F_1 progeny and more recently a genome-wide association approach, several genetic studies were carried out to localise major genes and QTLs on the seven chromosomes of the rose genome, which are involved in the determinism of number of petals (Hibrand Saint-Oyant et al., 2018; Roman et al., 2015), seasonality of flowering (Iwata et al., 2012; Randoux et al., 2014; Soufflet-Freslon et al., 2021), flowering time (Kawamura et al., 2011, 2015; Roman et al., 2015), flower architecture (Kawamura et al.,

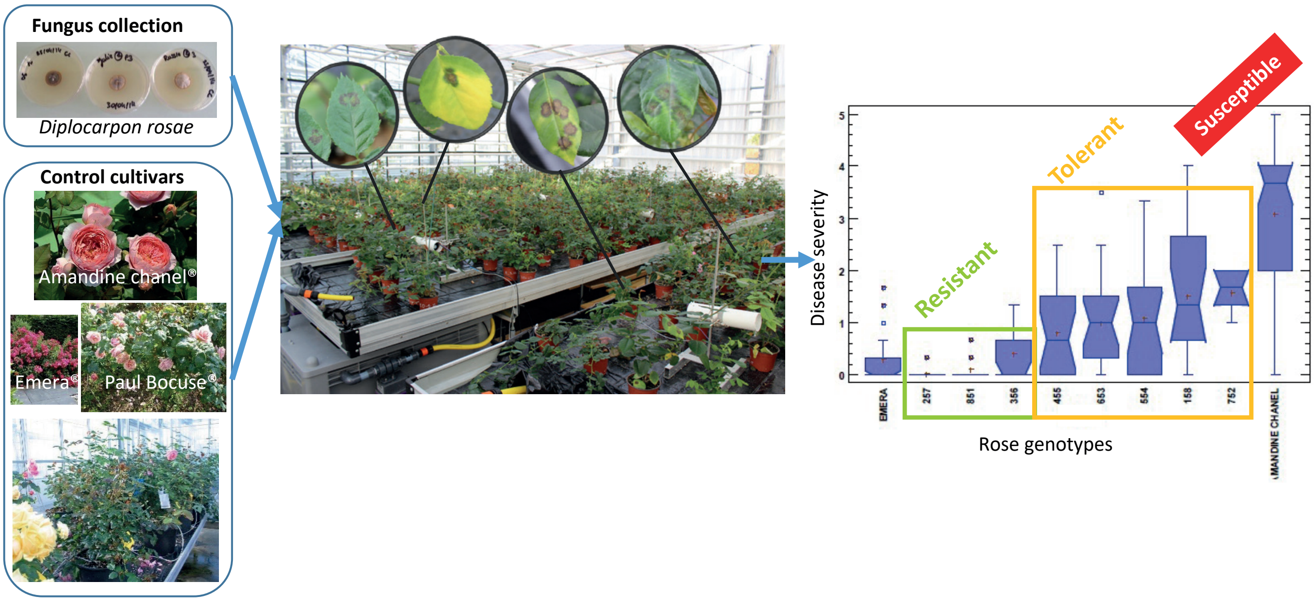

Figure 6. Whole plant assay in semi-controlled conditions (greenhouse) to assess the resistance of rose genotypes (Soufflet-Freslon et al., 2019; Marolleau et al., 2020).

2011), plant architecture (Li-Marchetti et al., 2017), fragrance in collaboration with the university of St Etienne (S. Baudino team at the BvPAM) (Hibrand-Saint Oyant et al., 2019; Magnard et al., 2015; Sun et al., 2020), prickles (Zhou et al., 2020) and black spot disease resistance (Lopez Arias et al., 2020) (Figure 5).
Moreover, the IRHS team coordinated a large international effort to obtain the first rose genome sequence of *Rosa chinensis* 'Old blush' (Hibrand Saint-Oyant et al., 2018), a strategic resource that will accelerate genetic research (identification of new genes, study of genome evolution).
For several years, rose breeders have considered disease resistance to be one of the major traits that requires improvement in new cultivars. The need for resistant cultivars is strengthened by the need to reduce chemicals in the environment (Ecophyto plan). Many have been prohibited in France since 2017, for landscape professionals (towns, landscape architects, public forest, roads and highways) and since 2019, for home-gardeners (Labbé, 2014).
Several collaborations between French breeders, French producers, Astredhor technical institute, Vegepolys Valley (https://www.vegepolys-valley.eu/), IRHS-GDO and IRHS-Ecofun research teams helped to develop knowledge on black spot disease, one of the most important diseases of garden roses during several successive projects frequently supported by the French Ministry for Agriculture and Food.
The "Rosa fortissima" project (2011-2013) allowed an investigation on the genetic determinism of black spot disease on F_1 cross-populations in different environments and during several years. These data were used during the PhD of D. Lopez-Arias (2017-2020) to localise QTLs (common or specific year or environment). Notably, a meta-analysis (Biomercator, http://moulon.inrae.fr/logiciels/biomercator/) revealed two meta-QTLs located on linkage groups 3 and 5 (Lopez Arias et al., 2020).
Another project ("Belarosa", 2015-2016) allowed the establishment of a greenhouse assay to characterise the resistance level of rose cultivars against black spot disease. This pathotest was first realised on a few rose cultivars, known to be susceptible or resistant, and then performed on new varieties under registration (Soufflet-Freslon et al., 2019; Marolleau et al., 2020) (Figure 6). This assay in semi-controlled conditions was compared to the behaviour of rose genotypes to disease in field, which showed a good correlation between the greenhouse and the field observations (Marolleau et al., 2020). A fungal collection project ("DIRO", 2014-2015) contributed to create a collection of 77 strains of *Diplocarpon rosae* (the fungus responsible for black spot disease), sampled from cultivated and wild roses mainly from Asia and Europe (Figure 7). Two of these strains were sequenced and allowed us to develop a microsatellite set to characterise the fungus genetic diversity (Marolleau et al., 2020) (Figure 6).
The studies on black spot disease continue with the PhD of L. Lambelin (2021-2024), which identified candidate genes and mechanisms for the resistance QTLs identified by D. Lopez-Arias during her PhD, and a current research project on the development of biocontrol products ("ROBIO", 2021-2024) and conducted in collaboration with French producers, breeders, Astredhor and Vegenov (https://www.vegenov.com/).

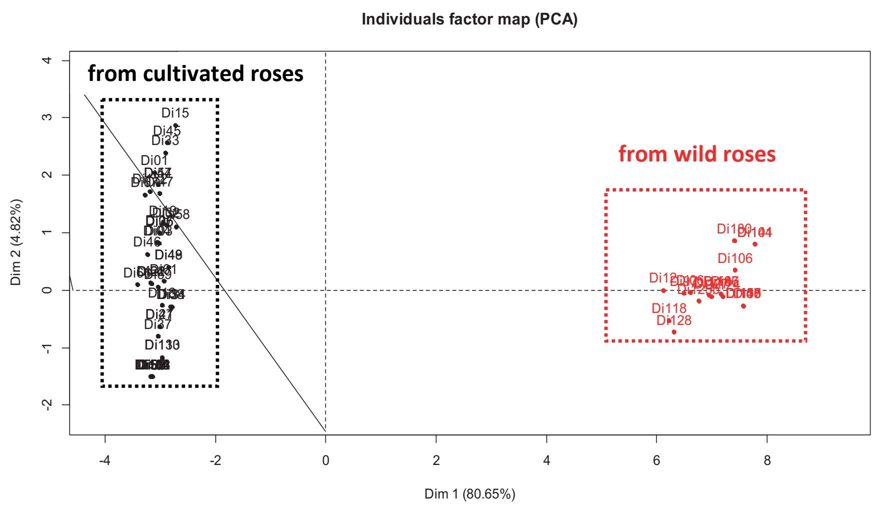

Figure 7. Genetic diversity of 77 strains of *Diplocarpon rosae* isolated from cultivated or wild rose species in Europe and Asia. ACP was carried out using the data obtained with 27 microsatellite markers (Soufflet-Freslon et al., 2019).

Conclusions

Some important issues in research cannot be addressed in the usual model plants (e.g., *Arabidopsis*). Rose is an interesting model to investigate ornamental traits (such as seasonality of blooming or floral scent), durable resistance to diseases in vegetatively propagated shrubs, and to explore plant evolution (human and natural selections) in the framework of interdisciplinary approaches (as history and genetics).

The challenge regarding foliar diseases is to develop durable resistance by obtaining pathogen resistant plants to limit the use of pesticides and developing alternatives to these (as biocontrol products, genetic resistance). These projects aim to produce fundamental knowledge on the diversification of rose genetic resources as well as on resources on plant-pathogen interactions, but also some operational knowledge for rose garden curators, producers, gardeners and breeders thanks to the strong collaborations with different actors of the rose sector (rose gardens, technical institute, producers and breeders).

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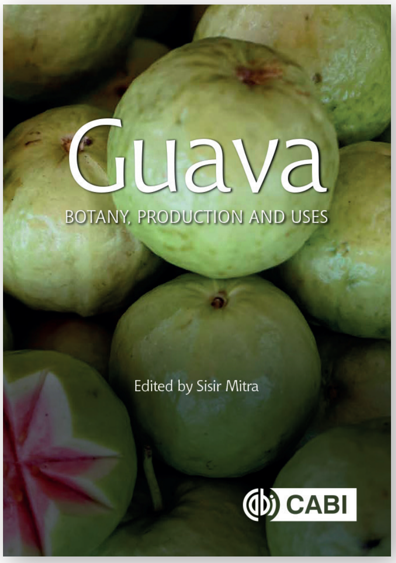


Mitra, S., ed. (2021). Guava: Botany, Production and Uses (Wallingford, Oxfordshire, UK; Boston, MA, USA: CAB International), pp.380. ISBN 9781789247022 (hardback). £135.00 / €155.00 / $180.00.

A 25% discount will be received by entering the code “CCISHS25” when ordering through https://www.cabi.org/bookshop/book/9781789247022/

Guava is commercially grown in more than 70 tropical and subtropical countries and is the most important “minor tropical fruit,” ahead of lychee and longan. The world production of guava increased during the last decade and was estimated at 6.75 Mt in 2017. Simultaneously, the global trade in fresh and processed guavas is experiencing promising growth, in relation to the greater attention paid to this fruit by consumers.

Despite this importance, there was a lack of publication compiling knowledge on guava biology and cultivation. The book edited by Prof. Sisir Mitra, published in 2021, in the series “Botany, production and uses” of CAB International, finally comes to meet this need. Thirty-two authors, recognized for their experience on guava and working in seven producing countries, wrote this comprehensive book covering the different aspects of guava biology, cultivation, production, and trade. The book contains sixteen chapters. Each chapter presents a comprehensive review of current knowledge, outlines future research directions, and provides a useful extensive list of old and recent references.

Chapters 1 to 3 describe the taxonomy, possible origin, and relative species of the guava,

Challenges and opportunities of the French apple chain

Jean-Luc Regnard, Claude Coureau, Vincent Mathieu, Benjamin Gandubert, Jennifer Lussan, Frédéric Aubert, Xavier Le Clanche, Sandrine Gaborieau, Vincent Guérin and François Laurens

Apple production in France has been marked by a centuries-old tradition and numerous successes. Its recent evolution is underpinned by the diversity of the geographical and market contexts in which it takes place. The impact of globalization now represents a permanent challenge for the actors of the apple industry, in search of economic, social, and environmental sustainability, recently reinforced by sanitary constraints and climate change. The present overview, while not exhaustive, develops the main economic aspects of the apple sector, its territorial reality, some main lines of technical progress, and outlines some ways to face the major current challenges.

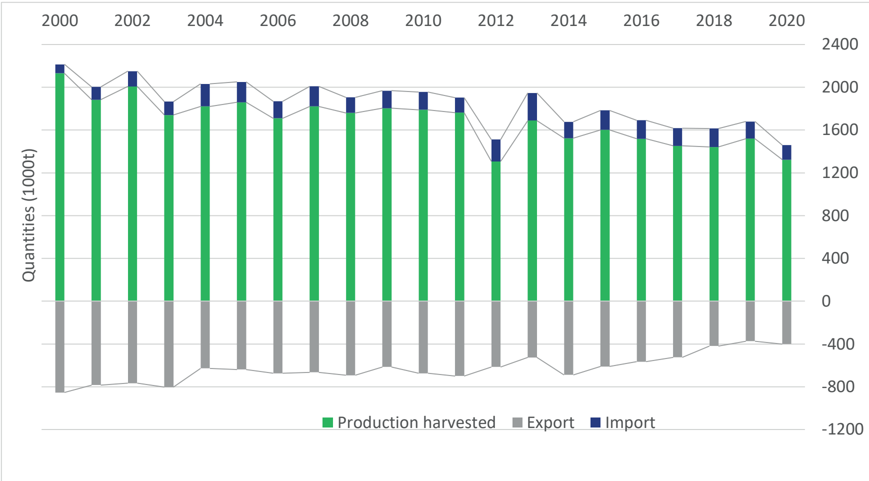


Figure 1. Apple production, imports and exports in France (fresh market). By convention, the quantities exported are indicated in negative values. Source: French Agreste statistics and customs.

The apple industry in France: excellence in the face of international challenges

Key figures on production and trade

Apple production for the fresh market is one of the pillars of French fruit economy, which it tries to maintain in the current context of globalization. Between the years 2000 and 2015, the area of commercial apple orchards steadily decreased from 53,000 to 36,500 ha, before it stabilized around 37,500 ha. There are about 3,500 apple farms, with an average orchard area of about 11 ha. This average masks strong disparities: more than 88% of French apple orchards are located in specialized fruit farms, about 1,100, where the average orchard size exceeds 30 ha. In contrast, there are also multi-purpose production farms with smaller orchards, and small family farms producing apples for niche markets (e.g., in the suburban context). The size of apple orchards that are certified for organic production or in conversion, approached 9,000 ha in 2020, which is nearly 25% of the total production area.

The potential of the national apple production has globally decreased, from 2 million tons (Mt) in the 2000s to 1.75 Mt in the early 2010s. It has stabilized at a threshold of 1.5-1.65 Mt since 2014, making France the 3rd largest European apple producer behind Poland and Italy. However, this production potential can be adversely affected by climate. The frequency of climate events has increased over the last decade (particularly in 2012, 2020, and 2021) (Figure 1). Affected by spring frost, the 2021 harvest is estimated at 1.36 Mt. On this basis, an average yield of about 40 t ha^{-1} can be calculated, for all apple orchards combined (extensive and intensive, young and mature, conventional and organic). This is a respectable performance, and very stable since the 2000s, masking much higher yields per ha in the most specialized farms.

In terms of trade, France was the world leader in apple exports for the fresh market until 2003, with an average volume shipped close to 0.80 Mt. Outclassed by other exporting countries (China, Chile, Italy) from 2004 onwards, and more recently by Poland, France is ranked 7th largest exporter, with annual exports of 0.40-0.50 Mt (Figure 1), close to amounts shipped by New Zealand and Iran. In France, apples remain the leading exported fruit in volume and value. The main client countries are Great Britain and some European Union countries (Spain, Germany, The Netherlands) for 4/5th of the French apples shipped (Figure 2). The other destinations (1/5th: Middle East, Asia) are more irregular, or disputed by other suppliers, notably on price. The number of client countries nevertheless remains very high, at more than 100. For imports (0.15-0.20 Mt) (Figure 1), France is an open market, with 50% of its suppliers European (Italy, Belgium, Spain, Poland), and others located in the southern hemisphere (Chile, New Zealand). A significant part of apple imports counted as fresh, actually goes to processing.

In 2019, 21% of the French apple harvested production (0.38 Mt) was dedicated to processing, of which 80% was delivered to the compote industry (FranceAgriMer, 2020). For this product, France is the European leader and net exporter (about 30,000 t $year^{-1}$). Domestic consumption of compote is increasing, especially among children, with a high-end positioning and a growing share of no-sugar-added products (42% of manufacturing in 2019). Industrial processing is an important outlet for the use of sorting residues (small sizes, and damaged fruits). These fruits which are unsuitable for fresh market also contribute to the fight against food waste. For processed French apples,

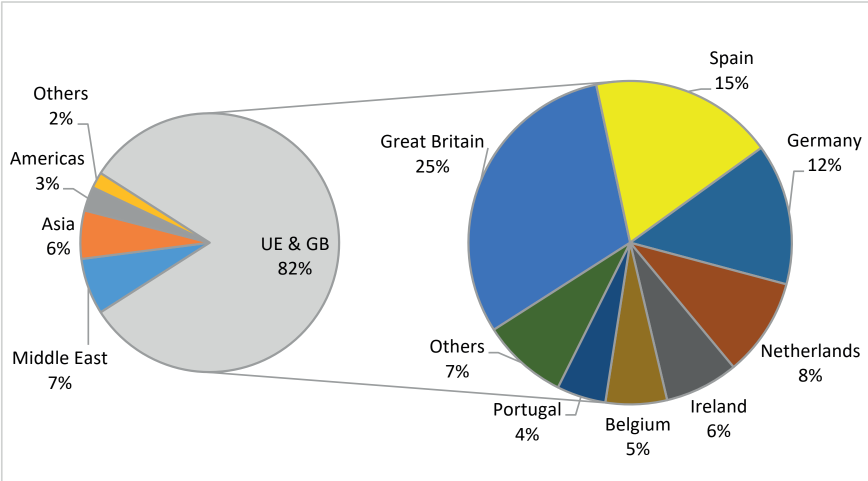


Figure 2. Destinations of apple exports from France (2020-21 season, Agreste and customs data).

industrial supplies are the subject of contracts within AFIDEM (French Interprofessional Association for Multipurpose Fruits and Vegetables). The fruit for cider, calvados, and the cider brandy sector (0.20-0.25 Mt of apples for cider or juice year^{-1}; 950,000 hL of cider year^{-1}), based on a dedicated orchard of about 9,000 ha, is not covered by this report.

A steady consumption, with an attentive and demanding consumer

The evolution of apple consumption in France (fresh market) is based on data from Kantar Worldpanel, in particular via the indicator of the family purchases for home use. This indicator is representative of 65% of total consumption (source: Inter-professional Technical Center for Fruit and Vegetables, CTIFL), even if the share of fruit consumed outside the home is trending in increasing, except for the recent pandemic period. The analysis of the 2019 data (FranceAgriMer, 2021a) shows that apple remains the leading fruit purchased by households (16 kg year^{-1}), i.e., a level equivalent to 13 kg per capita. There has been a downward trend in apple volume purchased, -1.6% per year since 2011, offset in terms of sum spent (+1.5% per year) thanks to higher sales prices. Apple has a good image (taste quality, health, and convenience) and shows a penetration rate of 88% and a satisfaction rate exceeding 90%. In terms of value, apple purchases represent 15-17% of the money spent in the fresh fruit shelf. The share of pre-packed fruit in this amount has increased to almost 40% (last two campaigns), while many consumers continue to prefer bulk (markets, direct sales). As a new French regulation (since January 1, 2022) prohibits the use of plastic bags for batches of less than 1.5 kg, one can expect a higher part of presentation in cardboard or wooden sales units for lots of 4-6 fruits (Figure 3), at least for mass distribution.
French consumers can name between two and eight different varieties, while they consume an average of five (Cavard-Vibert, 2020). Their first criteria of choice in 2019 were variety, price, origin, freshness, and production method. The French supply of organic apples is becoming surplus to the needs of the domestic market (20% of families are buyers, for 10-15% of volumes). This makes some organic produce return to the conventional market.
The analysis of apple sales by distribution channel indicates that hypermarkets, supermarkets, and hard discounters represent 60% of the quantity purchased. This marks a slight decrease, while an increase in sales is noted for the drive-through formats (2%). It has been encouraged by the Covid-19 pandemic, as well as supermarkets specialized in fresh produce (4%) and organic stores (2%). Premier stores and markets, and direct sales, have a market share close to 23%.

Figure 3. Presentation of apples in pre-packed units at the retail stage. A) Plastic bags of 1.5-3.0 kg used for small sizes and 2nd choice (packaging discontinued for lots of less than 1.5 kg). B) Cardboard trays of 4 or 6 fruits, sometimes with an assortment of apples. These fruit shelves reflect the diversity of the French varietal offer, particularly present in the large-scale fresh produce specialists (©J.-L. Regnard).

Collective approaches aiming at excellence and meeting societal expectations

The French apple sector is highly structured. Upstream, collective strategies, based on recognized producers' organizations, are connected within the French Apple and Pear Association (ANPP). This association brings nearly 1,400 apple producers together and represents about 70% of the surface area and tonnage for this product. It has set up a charter of good arboricultural practices, through the "Eco-friendly orchards" label (Figure 4A), recognized by the Ministry of Agriculture. It actively communicates on this approach specific to French production through various audiovisual channels and "open-orchard days". The Eco-friendly orchard label has made strong progress with French consumers both in terms of awareness (more than 50% of buyers in 2020) and confidence (77%), which is in line with societal expectations for respect of the environment. The ANPP also synthesizes the knowledge of the national and export markets to elaborate strategies of sector, develop products, and support and encourage consumption near the consumers.
About fifteen professional families of the fresh fruit and vegetable sector are grouped together within Interfel, a private law and initiative inter-professional organization recognized by the European Union. Among its actions, Interfel participates in the governance of CTIFL, particularly in its research and development orientations. Interfel also guides the actions of the Agency for Research and Information in Fruit and Vegetables (Aprifel), which gathers and disseminates knowledge on the links between fruit and vegetable consumption and health to promote their consumption. At the end of 2017, the French fresh and processed fruit and vegetables interprofessions submitted a sector plan to the public authorities. Its

Figure 4. A) The Eco-friendly orchards label applies to fruit from the French apple producers' quality charter. Officially approved, this label certifies that the production comes from orchards affiliated to the ANPP, committed to the production of healthy, tasty, and quality fruit, according to integrated fruit production methods that respect the environment and biodiversity, as well as the economic sustainability of the farms. The addition of the tricolor banner is a response to the French consumer's expectations of local products. B) The French high environmental value label is relative to farms strongly involved in environmental objectives. This high level of certification, not specific to fruit production, but complementary to the previous one, is awarded after external control of procedures and result indicators.

Table 1. Breakdown of apple production in France by variety (registered trademark ®, cultivar denomination and plant breeder right $_{pbr}$), for the average of the 2018-20 campaigns (in 1,000 t and %, source ANPP). For many varieties (*), mutants are available, with either a modified precocity, fewer cosmetic defects, or more intense skin color.

Varieties	2018-20 (1,000 t)	%
Golden Delicious*	403	27.1
Gala*	297	20.0
Granny Smith*	141	9.5
Fuji*	59	3.9
Braeburn*	59	4.0
Red Delicious*	52	3.5
Jonagold*	27	1.8
Elstar*	16	1.1
Sub-total international	**1,054**	**70.8**
Pink Lady® Cripps Pink$_{pbr}$*	163	11.0
Jazz® Scilate$_{pbr}$	24	1.6
Joya® Cripps Red$_{pbr}$	13	0.9
Honey Crunch® Honeycrisp$_{pbr}$	15	1.0
Juliet® Coop 43$_{pbr}$	13	0.9
Les Naturianes® Ariane$_{pbr}$	15	1.0
Choupette® Dalinette$_{pbr}$	5	0.3
Tentation® Delblush$_{pbr}$	6	0.4
Sub-total managed	**254**	**17.1**
Belchard® Chantecler$_{pbr}$	52	3.5
Canada	39	2.6
Boskoop*	8	0.6
Queen of the Pippin*	11	0.7
Goldrush® Coop 38$_{pbr}$	5	0.4
Rubinette® Rafzubin$_{pbr}$	5	0.3
Sub-total terroir	**120**	**8.0**
Idared	3	0.2
Others	58	3.9
TOTAL	**1,488**	**100.0**

main goal is aimed at strengthening competitiveness, supporting consumption, and reinforcing the place of products and companies internationally. These interprofessions have been privileged interlocutors of the French government for the elaboration of the national strategic plan (NSP) recently submitted to the European authorities. This is a prelude to the elaboration of the future Common Agricultural Policy (CAP 2023-2027), which will be ambitious in terms of environment and climate (European Green Deal).

Strengths and weaknesses of the French apple sector

France's place in the international apple industry is studied by a competitive intelligence published annually for the attention of the sector's actors, comparing the main apple-producing countries, on the basis of different criteria from production to consumer. The latest edition of this watch (FranceAgriMer, 2021b) shows that France was ranked 7th for competitiveness in 2019, thanks to certain assets: the diversity of its varietal offer, the satisfactory renewal rate of its orchards (4.3% on average), the technical skills of its producers, the dynamics of the organic sector, and a set of favorable natural factors (climate, water availability). French apple production remains handicapped by high production costs, the loss of orchard surface area (although stabilized since 2015), which limits the potential in volumes, and a contraction of exported quantities.

A rich production potential for diverse and demanding markets

Apple production in France is characterized by great diversity. This is the result of the varied soil and climatic conditions found in the different basins, but also of the great diversity of the varieties grown, reinforced by the active breeding programs and the renewal rate of the orchards. French apple production areas are mainly located in irrigated plains, but also in hillsides or in piedmont (Figure 5), or in green belt.
According to recent official statistics of the Ministry of Agriculture, the share of French regions for a normal apple harvest (without spring frost) shows the major origins of the volumes of fruit harvested: Provence-Alpes-Côte d'Azur (23%), Occitanie (21%), New Aquit-

■ Figure 5. Apple orchards in Limousin. The medium elevation (350-500 m), the contrast of day/night temperatures, the soils on a crystalline base, in association with the local know-how, contribute to the reputation of the 'Pomme du Limousin' protected designation of origin (PDO; AOP in French). The PDO specifications are a refractive index of at least 12.5 °Brix, a firmness of at least 5 kg cm^{-2} and an acidity of at least 3.7 g L^{-1} of malic acid (©F. Besse).

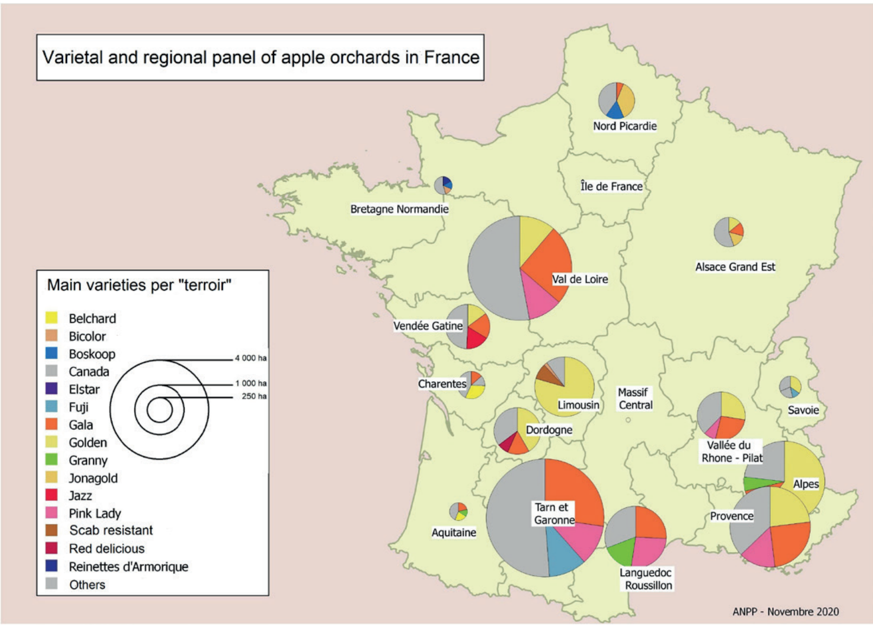
aine (20%) and Pays de la Loire (17%), whereas significant volumes come from the regions Auvergne Rhône-Alpes (7%) and Centre Val de Loire (5%).

The distribution of the main apple varieties in ANPP orchards is displayed in Figure 6. It shows the importance of 'Gala' (often 25%) in the Provence, Languedoc, Tarn-et-Garonne and Loire Valley basins, a high share of 'Granny Smith' and 'Pink Lady' in Languedoc-Roussillon, and some particularities such as the dominance of 'Golden Delicious' in the Alps and Limousin, the share of 'Belchard'® Chantecler$_{pbr}$ in Charentes and Aquitaine, and the presence of regional apples in Brittany and 'Boskoop' in the north. The regional growing of diverse apples is based on the analysis of the market need (national or export), local opportunities, and characteristics of the physical environment. A wide range of varieties can thus be accessed through French fresh food retail specialists.

French orchard production can be segmented into three major groups of varieties (Table 1): international varieties, intended for both the domestic and export markets (71% of the 2018-2020 quantities, slightly down), "club" varieties, aiming for a higher value on one or two of these two markets (17% of the volumes produced, i.e., before application of the specifications, slightly up), and the so-called "terroir" varieties (8%) rather suitable for the national or even regional market. Some apple productions also benefit from official quality signs: protected geographical indications (PGIs) 'Pommes et Poires de Savoie' (since 1996) and 'Pommes des Alpes de Haute-Durance' (since 2010), and protected designation of origin (PDO) 'Pomme du Limousin' (since 2007). These terroirs have made it possible to distinguish certain favorable characteristics acquired at 350-450 m elevation ('Golden Delicious', in particular). A red label can be associated with part of this production, for 'Golden Delicious' and 'Gala', with a minimum of 13.5 °Brix, harvested at an optimal stage of ripeness.

Following the example of 'Pink Lady'® apples ('Cripps Pink' and its mutants), some varietal innovations are launched and managed in "clubs" (Table 1), the varieties being more or less exclusive to a few marketers, who sell the fruit under an exclusive brand name, based on the typicity of the fruit (e.g., 'Jazz'®, 'Joya'®, 'Honeycrunch'®, 'Juliet'®, and 'Les Naturianes'®Ariane). In this context, red-fleshed varieties have recently been released ('Kissabel'® or 'Red Moon'® brands), also intended for exclusive sale. By contrast, the recent scab resistant varieties bred within the INRAE/NOVADI partnership ('Story'®Inored$_{pbr}$, 'Garance'®Lespin$_{pbr}$, 'Mandy'®Inolov$_{pbr}$, 'Lory'®Inogo$_{pbr}$, and 'Galy'®Inobi$_{pbr}$, see below) are not intended for exclusive distribution, but benefit from branding strategies aimed at increasing their market value and their visibility among consumers. An increasing number of recent varieties with good hardiness, resulting from resistance or tolerance to scab, are being planted (Table 2). Some of them are suitable for production according to organic principles and are adapted for niche markets or short circuits. Given the potential for scab to overcome genetic resistance due to the *Vf(Rvi6)* gene, some treatments are still needed for these varieties, targeted at the pathogen's peak infections. Active research is being conducted (INRAE and international partners, Laurens et al., 2018) to overcome this difficulty by the breeding for a durable resistance to this pathogen.

Since the 1980s, French producers have increasingly tended to plant apple varieties with sweeter and less acidic fruit that is medium size, with very firm flesh and good storage capacity (Collective, 2021). These decisions are supposed to meet the expectations of consumers, including the youngest, in terms of gustatory pleasure, or adaptation to nomadic consumption. But they must also answer the expectations of the supply chain distribution, in terms of tolerance to handling and transport. It is necessary for the apple sector to remain attentive to the great varietal diversity now available, without becoming counterproductive in terms



■ Figure 6. Varietal plantings in apple growing regions in France for orchards affiliated with ANPP. The pie chart surfaces are relative to the territorial importance, and indicate the share of the main varieties. Source: ANPP, November 2020.

A public-private partnership in apple breeding

For more than 25 years, NOVADI and INRAE have been running a breeding program, dedicated to the selection of apple varieties that naturally offer a high level of hardiness to bio-aggressors. The main objectives of the varietal selection include a set of favorable agronomic traits: resistance or tolerance to the common races of scab, to powdery mildew and fireblight, non-attractiveness to aphids, ease of tree management, regular yield of top-quality fruit (aroma, sugar/acid balance, juiciness, fine texture) reaching high pack-out percentages thanks to an attractive presentation, and having a long shelf-life. The different stages of the breeding process are carried out jointly, with a predominant involvement of public research in the upstream steps (pre-breeding, crossing schemes, advanced phenotyping) and a strong commitment of private partners for the agronomic evaluation. In particular, the end of the selection program consists of pursuing the observations of the best hybrids in a system close to the production conditions, with experimental orchards representative of various pedoclimatic contexts. This step of assessment of varietal behavior is based at the national level on the French variety evaluation system and at the European level on an international network composed of partners who evaluate the adaptation of the pre-selections to different pedoclimatic conditions. The NOVADI company (www.novadi.fr/en/), which groups thirteen French nurserymen producing apple material for professional producers, is the exclusive world editor/manager of the varieties resulting from this program.

■ Table 2. Main apple varieties adapted to organic production in France. The behavior against scab is mentioned, either resistance (*Vf(Rvi6)* gene), or tolerance, as well as the control of the variety distribution (managed = club) and the main market objectives (L/S = long and/or short circuit). Registered mark®, cultivar denomination and plant breeder right $_{pbr}$.

Maturity	Registrated mark	Denomination	Scab	Variety control	Distribution
Early	Antares®	Dalinbel$_{pbr}$	Resistance	Brand	L/S
Mid-early	Cœur de Reine®	Daliclass$_{pbr}$	Tolerance	Managed	L/S
Mid-early	Pixie Crunch®	Coop 33$_{pbr}$	Resistance	Brand	L/S
Mid-early	Crimson Crisp®	Coop 39$_{pbr}$	Resistance	Brand	S
Season	Les Naturianes®	Ariane$_{pbr}$	Resistance	Brand	L/S
Season	Evelina®	Roho 3615$_{pbr}$	Tolerance	Managed	L/S
Season	Opal®	UEB 32642$_{pbr}$	Resistance	Managed	S
Mid-late	Candine®	Regalyou$_{pbr}$	Resistance	Managed	L/S
Mid-late	Choupette®	Dalinette$_{pbr}$	Resistance	Managed	L/S
Mid-late	Story®	Inored$_{pbr}$	Resistance	Brands	L/S
Late	Juliet®	Coop 43$_{pbr}$	Resistance	Managed	L/S
Late	Swing®	Xeleven$_{pbr}$	Resistance	Managed	L/S
Late	Goldrush®	Coop 38$_{pbr}$	Resistance	Brands	S

of notoriety on the retail markets. It should be noted that this risk can be amplified by the various brands existing for a same apple, without forgetting the numerous labels qualifying the production methods.

Faced with abiotic and biotic threats, an orchard design aiming at a better resilience

Increasing attention is being paid to the areas where apple orchards are planted to avoid those most prone to spring frosts, wet situations (low-lying areas, poorly drained soils), or places where soils are too light or too alkaline. The issue of adaptation to climate change is on the growers' agenda, particularly by considering the choice of irrigable situations. As an example, apple trees in the Limousin region have been grown under natural rainfall for decades, while recent orchards in this area are now installed with the support of irrigation. Beyond this example, the creation of new orchards raises the crucial question of water resources. Indeed, outside of the existing collective irrigation networks, apple growers are confronted with administrative or regulatory difficulties to create surface water reservoirs, especially in the context of individual farms. In 2021, this issue was in the French spotlight, during the meetings of the 'Varenne de l'Eau'. The public authorities are in favor of the creation of new collective water resources, made necessary by climate change or hazard control, and they support the emergence of water management territory projects (PTGEs in French). However, these projects must be implemented in compliance with wetlands legislation, which may reveal oppositions between the stakeholders (e.g., farmers vs. environmentalists).

The anticipation of mild winters unfavorable to the chilling requirement of tree (i.e., to the release of bud dormancy) has led to the evaluation of low-chilling apple varieties, notably issued from Brazilian breeding. These trials have not led to implementation to date because these very early flowering varieties are exposed to frost. The fight against spring frosts is leading more and more fruit growers to equip the orchards with means of active control, by overhead irrigation, heaters, and wind machines. To protect plantations from damage and production losses due to hail, losses for which insurance is prohibitive or even impossible, most French orchards planted since the early 2000s are protected by hail-netting (Figure 7). This type of protection, which can cost more than 12,000 euro ha^{-1}, not including installation labor, requires an annual deployment just after flowering and folding after harvest. Anti-scab plastic rain-roofs can be combined with these nets.

Physical protection is also used for insect control. A growing number of orchards (especially organic) in the more exposed southern areas have adopted the 'AltCarpo' netting protection system to reduce codling moth damage. Netting can be placed directly on the tree row or installed as 'mono-parcel' (Figure 8). Some nets have a double action against hail and insects.

In most orchards, moreover, the search for the natural balances encourages the fruit tree growers to strengthen or set up agro-ecological infrastructures, source of biodiversity, which are often recommended or imposed by the specifications of production. Thus, the design of orchards is attentive to plant biodiversity with the implementation of grassing of the inter-row, up to 60% of the surfaces, the annual sowing of flowering fallows (Figure 9A), and the planting of windbreaks. These vegetal structures, especially when they are multi-species, can have a melliferous (honey producing) interest and host a useful fauna (predatory or parasitic auxiliaries, pollinating insects), which facilitates biological control by conservation. With the same objectives, various specifications also

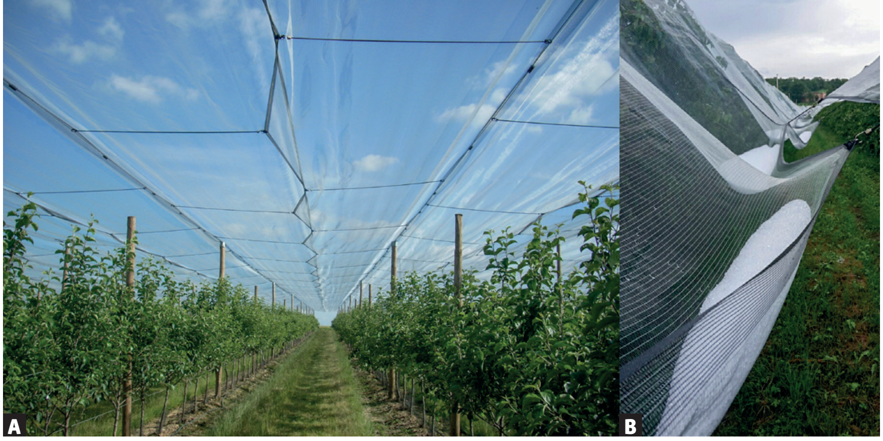


Figure 7. French apple orchards are predominantly protected by hail nets. Nets are stretched with bungee cords (A). In case of a hailstorm, the hailstones are retained by the structure (B) or fall into the inter-row, without damage to the vegetation (©Blue Whale).

Figure 8. A young organic apple orchard protected from codling moth attacks by an exclusion perimeter and cover netting ('mono-parcel' system). The mesh of the net, 5.5×2.2 mm, prevents the entry of the pest, and its egg-laying bites (©J.-L. Regnard).

recommend the installation of nesting boxes for insectivorous birds (e.g., tits) (Figure 9B), perches for birds of prey (vole predators), or even hedgehog shelters or insect hotels. These agroecological investments can be considered at the plot scale, or even at the supra-plot scale, by paying attention to interconnection corridors at the farm or landscape level.

The actions of prevention and passive control of climatic damages and biotic aggressions must be conceived from the very beginning of the orchard system, to contribute to its later efficiency aiming at a sustainable fruit production. Given their partial effects, they require complements in terms of annual direct control, as much as possible by means of biocontrol available (e.g., mating disruption or biological control).

Innovative technical management of the orchard

A continuous evolution driven by economic factors and supported by research and development

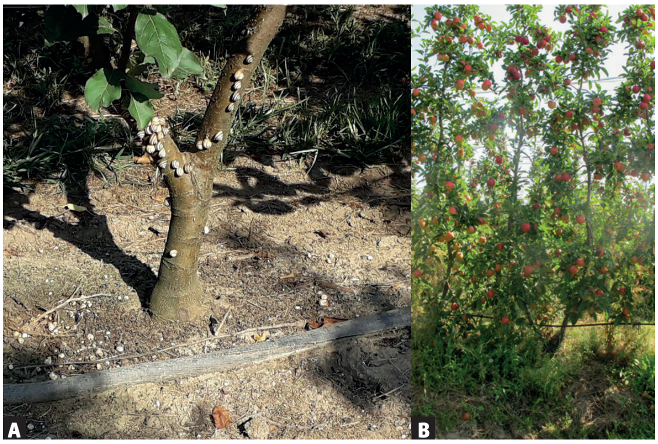
The technical management of apple orchards in France has undergone a constant evolution since the 1960s-70s. At that time, hedgerow systems were adopted as a standard adapted to intensification through mechanization of cultural operations (interventions made from the inter-rows, such as phytosanitary spraying) and assistance to manual operations by platforms (pruning, harvesting) (Figure 10). For economic reasons, high-density multiple row planting systems were then experimented (1970s-80s), followed by 'pedestrian' orchard concepts (1980s-90s). However, there has been no significant adoption, either because of excessive investment, or because of yield deficits at maturity. The objective of high-quality fruit production has also been more and more present, in response to markets' expectations. The first professional production charters date back to this period, especially for apples and pears. The initiatives of orchardists converged to lead to a National Charter of Integrated Fruit Production (1997), today known as Eco-friendly orchards, supported by the ANPP organization. These advances were made possible thanks to a systemic approach, consisting in synthesizing scientific and practical knowledge from research and development work in fruit production, carried out by INRAE, by CTIFL, and regional experiment stations, also fed by data from the networks of technical advisors, in close contact with orchardists.

Thus, in the mid-1990s, the work of the Mafcot group ("Maîtrise de la fructification concept et technique") co-animated by INRAE and technical advisors, disseminated innovative concepts of apple tree management based on knowledge of varietal behavior and tree physiology, stemming in part from field observations, and aimed at regulating the fruit load and increasing control of biennial bearing (Lauri et al., 2004; Lauri and Simon, 2019). Meanwhile, other experimental approaches were developed, notably by CTIFL, more focused on adapting to mechanization, including a 'fruit wall' concept based on annual mechanical pruning of tree hedges (Masseron, 2002).

Nowadays, the increasing difficulty of recruiting qualified permanent staff in fruit farms oriented towards international varieties and long circuits seems to favor a return to a very simplified management of orchards, with higher density plantings than in the 2000s, aiming at quickly reaching the performance of adult orchards (Roche, 2020), which contributes to improve the return on investment. A high yield is a divisor of expenses per kilogram of fruit produced, which makes it possible to contain production costs despite the heavy initial investments (more than 50 k€ ha^{-1}). In recent plantations, the row of apple tree forms a narrow geometry known as 2D, in which pruning is simplified and facilitated; the fruit hedges generate less internal light gradients, which favors fruit homogeneity and improves the harvesting rate. The alleyways, which were classically 4 m wide, tend to become narrower, with row spacings of 3.00-3.50 m. As a consequence, the planting density increases, and can reach or exceed 3,000 trees ha^{-1}, which in turn increases the investments. With this orchard design, the linear meterage of fruit hedges per ha is also increased, which has an impact on mechanical operation times. The objective of mechanization remains more than ever on the agenda, with for example the practice of mechanical thinning of trees as soon as they bloom (Darwin® or Eclairvale® tools, especially in organic farming). Different forms seem appropriate to establish these new apple orchards, for example the two-branch tree (Bibaum® or Ypsilon®) installed at planting (Figure 11), thanks to the pre-formation of apple trees in the nursery, or to multileader training (Figure 12). The adoption of

Figure 9. A) Flower strip sown around the orchard. B) Tit nesting box placed within an apple orchard (©Blue Whale).

■ Figure 10. A) Apple harvesting organized from the ground, with direct deposit of apples in paloxes (©Blue Whale). B) Harvesting assisted by a self-propelled platform, carrying pickers located at different heights (©J.-L. Regnard). The trellised fruit hedge system is essential to the efficient organization of harvest.



■ Figure 11. Two-branched apple trees. A) Detail of the branching initially obtained in the nursery (©J.-L. Regnard). B) An adult orchard in production based on this type of tree, showing the porosity of the fruit hedge (©CTIFL).

these management methods also induces a change in the range of rootstocks, the vigor of the G11 types being considered adequate, superior to that of the M9 types, which is insufficient, especially in replanting. As a result, the traditional M9 range is tending to be replaced by new rootstocks favorable to rapid fruiting, with tolerance to telluric bio-aggressors and better anchorage.

Specifications and fruit production

In the 1980s, mass distribution influenced fruit production, with each distributor subjecting suppliers to its own specifications, before the European distributors of the Euro-Retailer Produce Working Group established a common reference framework of good agricultural practices (Eurep-Gap, 1997). Their practices aimed at safer food, based on sustainable production methods especially for fruits, and social responsibility. In 2007, this reference system evolved to become Global Gap, an essential standard for collective organizations of apple producers wishing to access the national market or especially for export. Faced with the demands of distribution, the organized fruit producers are asserting their own rules and try to have them recognized. Thus, the National Production Charter (late 1990s) evolved into the afore mentioned Eco-friendly orchards approach (2011) subsequently accredited as level 2 environmental certification, at a level compatible with the distribution benchmarks. This progress approach, oriented towards environmental, economic, and social sustainability, aims very quickly to achieve, for half of the fruit farms, the official French label of high environmental value (HVE in French) (Figure 4B). Other standards can be superimposed to the production charter to specify an additional feature; one, focused on the promotion of citizen production with strong local roots, is represented by the 'Demain la Terre' (Tomorrow's Earth, from Nouveaux Champs collective) approach while the other, 'Bee friendly'®, aiming at protecting pollinating insects, has been adopted by various producers' organizations. These procedures are subject to self-controls, internal controls and independent controls by accredited third-party organizations.

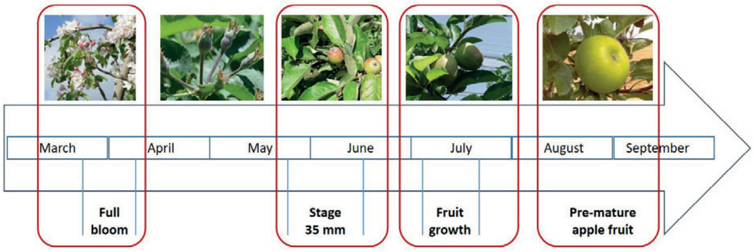
Reduction in the use of pesticides

For pest control, the French apple orchard had already assimilated the principles of integrated fruit protection by the end of the 1970s, to overcome the impasses of a protection based exclusively on chemistry. This evolution, consistent with the objectives of fruit quality, was extended to the concept of integrated fruit production (IFP, 1990s), leading to Eco-friendly orchards today, in accordance with the expectations of distributors and markets.
Apple growers in France are subject to a very demanding regulatory context in terms of plant health, as the marketing authorizations for plant protection products are often more restrictive than those of other European countries, despite the same registration of active substances (Regulation (EC) No 1107/2009). The conditions of application of plant protection products are also highly regulated since 2006 (e.g., weather conditions, untreated areas, and residue management). Following a national consultation on a policy for the environment ('Grenelle de l'Environnement', 2007), France implemented measures to reduce the use of pesticides, through the Ecophyto I and II plans (2008 and 2014, respectively), which are the national declination of the European directive EC 2009/128. These plans have also led to the emergence of the DEPHY networks for fruit production, with a "Farm" system based on volunteer farms for agroecological transitions, supported by network engineers, and an "Expé" system consisting of the exploration of innovative R&D systems. These actions have also stimulated the provision of decision support systems and dedicated tools, which allow the triggering of chemical interventions, the development of biocontrol methods, and more broadly alternative methods of regulating bio-aggressors. The French Fruits Scientific Interest Group (GIS Fruits) published a first summary of these methods for fruit producers and technicians (Laget et al., 2015).
The strict French regulation and the control plans that accredit its application are facilitators to reach the label zero pesticide residue, but the profession deplores that technical impasses appear when the arsenal of alternative methods to control orchard pests is insufficient and/or when the authorized products are too few or withdrawn (e.g., control of the rosy apple aphid, fruit flies, or new pests such as brown marmorated stink bug). Apple production, which aims at a more natural orchard pest control, is evolving towards more resilient orchard systems. These systems make room for varieties that show resistance or tolerance of bio-aggressors and are exploiting spatial inter- and intra-specific biodiversity (market garden orchard, or multi-specific orchard).

Precision agriculture to save resources and preserve the environment

For arboricultural practices, the time has come for the emergence of better reasoned and sized practices (e.g., adapting the volume of spray to the leaf surface deployed), which can be modulated within the framework of the plot, saving on inputs and energy, and thus bringing apple production into preci-

■ Figure 12. Multi-leader apple tree trial in France, established according to the Double Guyot training system (©CTIFL).



■ Figure 13. Annual cycle of the apple orchard showing four key periods for geo-localized image acquisition (visible or laser scanner) whose rapid interpretation is the basis for decision support for a cultural intervention and its modulation according to the maps obtained (©Blue Whale).

sion agriculture. One of the major French apple production groups (Blue Whale) has launched a project based on advances in precision imaging in the orchard to assist in decision-making. Based on four key periods for yield development (Figure 13), the current experiment consists of using mapped information at the plot level to help and/or adjust the farmer's decisions regarding thinning on blossoms or young fruit (end of March and June) as well as forecasting and preparing the harvest site (end of summer to fall).

Beyond the "orchard edge", French apple professionals wanted to assess their contribution to climate change, to minimize the negative impacts of production. Thus, as part of a framework program (Green Go) supported by ADEME (www.ademe.fr/en), various major players in the apple sector have committed to a two-year program (Peren, 2021-22) that aims to improve the environmental performance of the apple chain. This program, co-piloted by the ANPP, and concerning table apples and apple sauce, covers the orchard production, upstream, and the postharvest stages of the fruit from the fruit station to the consumer, downstream. A previous study has shown that the postharvest steps (including the movement of consumers to the shops) can account for more than 70% of greenhouse gas emissions. The environmental performance of apples is included at the production stage, with the Eco-friendly orchards charter aiming for de-carbonized production by 2024. The Peren project allows to deepen the results of a previous project on the impacts of agricultural and food products (Agribalyse), which led to the development of life cycle assessment tools (Means-InOut). The Peren project provides an inventory of the major types of orchards and postharvest chains and proposes to identify the priorities to work on, in a multi-criteria approach, to improve the environmental performance of apple. Different action levers must be evaluated at the orchard stage in terms of eco-design and carbon footprint (e.g., impact of disease-resistant varieties, fertilization management, reduction of the number of tractor and other machinery passes, and management of orchard biomass at the end of the cycle) but also at the packing station and in the supply chain. The technical and economic feasibility of the actions will be evaluated through multi-stakeholder workshops.

A dynamic fruit sector raising questions to better meet the challenge of sustainability

The sustainability of the apple sector is based on inseparable economic, social, and environmental pillars. At the economic level, the strong organization of the profession allows the sharing of the major challenges that it faces to prepare the campaigns and to implement performance strategies. The dynamic collective animation and the work in project groups aim to answer the economic challenges and technical stakes of the sector. Among the concerns of the moment, the attention of the professionals is focused on the evolutions of the distribution, the necessary control of the production costs despite the increase of energy prices (mechanical interventions, storage, transport), the very strict French regulation on packaging and use of stickers, and the behavior of a consumer marked by a search for ethics and ecology, still remaining sensitive to the price. The producers committed to the Eco-friendly orchards demonstrate their willingness to communicate with consumers, explaining their objectives and their production methods during "open orchard" actions allowing for transparent exchanges (Figure 14). Even if this communication mode seems to answer the search for a healthy and local product, the ambition of apple production in France continues to be access to the national and export markets. Technical choices in production are made according to commercial positioning.

A dominant trend is towards an intensive and high-yielding orchard, physically protected against hazards, designed to meet the challenges of international competition and low production costs. Its optimization is based on consistency between the parameters of initial design and increasing mecha-

■ Figure 14. Meeting between an apple producer committed to the Eco-friendly orchard charter and the public, during recent "open orchard" days (©ANPP).

nized management, seeking to compensate for the scarcity of labor, and offering an economically viable solution to increasing hourly labor costs. In contrast, more extensive orchard models are emerging, demonstrating a search for resilience. Based on new production paradigms, some of them are tested as prototypes (e.g., agroforestry orchard, or market garden orchard), giving a large place for interspecific diversity, ensuring natural pest regulation, thus minimizing the need for phytosanitary protection. In these orchards, economic profitability depends on a parsimonious use of resources (fertilizers, water, energy) and a better value for fruits pertaining to a mode of production explicitly agro-ecological, targeted on a qualitative niche, in short circuit. Meanwhile, agri-voltaic systems for carbon-neutral apple orchards are also being tested. Equipped with pivoting panels, these systems aim at offering a shelter mitigating the effects of summer heat waves, increasing the climate resilience, whereas ensuring a sustainable production of apples and a generation of solar power.

It should be noted that the distribution is likely to reference apples issued from one or the other production model, allowing a strongly segmented offer for this fruit. The choices of the fruit growers must, in any case, be in accordance with the production methods and the commercial targets. Indeed, the different choices when creating the orchard are multi-facetted, and raise the question of varietal choice for the future. For fruit type, in addition to bicolor apples, the emergence of new high quality varieties with yellow skin (e.g., 'Rubis Gold'®, 'Opal'®) should diversify an offer mainly occupied by 'Golden' in this segment. Market niches are also possible for breakthrough innovations: red-fleshed apples or snack size apples adapted to nomadic consumption (e.g., 'Rockit'®). Tolerance to biotic stresses is a strong trend (for example durable scab resistance to scab undertaken by INRAE), interesting for both conventional and organic production, which precedes the search for varieties that will be less sensitive to climatic hazards, showing good phenotypic plasticity, in a climate context marked by uncertainty. At the genetic level, traits of tree architecture, light interception efficiency, and response to abiotic stresses are largely independent. These traits are susceptible to recombination through selection (Coupel-Ledru et al., 2022). Among the current varietal issues, the evaluation of the efficient resource use is imperative. Will it be possible to select apple varieties for water-use and/or nitrogen-use efficiencies in the future? Already, increased attention is being paid to the "services" provided by orchards, not only in terms of agricultural production and employment, but also in terms of ecosystem services and landscape (Bopp et al., 2019).

Finally, it should be emphasized that solving the numerous technical questions posed by apple production will require, more than ever, the support of multidisciplinary research and development efforts, which may fall under public/private partnerships, such as those established in France. Thus, GIS Fruits, created in 2012 and led by INRAE, brings together 22 partner institutions in the sector, including applied research (e.g., CTIFL), higher education and professional organization. GIS Fruits works on the priority themes of the fruit sector, allowing the emergence of new research questions. It stimulates collaboration and the emergence of projects between French partners, accompanies innovations and the agroecological transition. It supports the writing of syntheses on fruits (e.g., Legave, 2022, on climate change), helps to disseminate results of R&D projects, and contributes to enlighten public decisions.

Following the example of this national collaboration between partners, international scientific meetings, such as IHC2022 (www.ihc2022.org), with its various thematic symposia, will be able to facilitate the emergence of projects and international and interdisciplinary collaborations contributing to the sustainability of fruit production, and, in particular, that of the apple.

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French Articles

Angers, hier. Le symposium GreenSys est l'occasion de préparer le Congrès mondial d'horticulture qui aura lieu en août 2022. PHOTO : CO - CHLOÉ BOSSARD

Angers en vert en 2022

Plus de 600 scientifiques et professionnels de l'horticulture phosphorent jusqu'à vendredi au Centre de congrès qui accueillera dans trois ans le congrès mondial de la filière.

Ils sont venus de France, mais aussi des Pays-Bas, de Corée, du Japon ou de Chine. Plus de 400 chercheurs et 200 professionnels de l'horticulture, issus de 39 pays différents, sont réunis depuis lundi et jusqu'à vendredi au Centre de congrès d'Angers, pour le symposium scientifique GreenSys. Les derniers travaux autour de la culture sous serre y sont présentés, à travers des conférences et expositions. « *On a voulu mettre l'accent sur les cultures en milieux confinés et l'utilisation de la lumière LED* », précise Pierre-Emmanuel Bournet, d'Agrocampus Ouest, qui coorganise l'événement avec le CTIFL et l'Inra.

La session d'aujourd'hui sera dédiée aux professionnels, avant deux jours consacrés à des visites d'entreprises. Les participants découvriront vendredi le fabricant de serres agricoles Richel, à Saint-Barthélemy et le producteur de plantes Barrault, à La Possonnière.

Associer entreprises du végétal et grand public

Mais GreenSys est surtout l'occasion pour les dirigeants de l'International Society for Horticultural Science (ISHS), qui chapeaute l'événement, de découvrir « *enfin* » Angers, qui accueillera en août 2022 son Congrès mondial d'horticulture (IHC). « *Nous sommes ravis d'être ici, de voir les équipements, le dynamisme de la filière locale et la beauté de la ville. Ça confirme le choix que nous avons fait il y a déjà cinq ans* », s'enthousiasme Yüksel Tüzel, présidente turque de la société savante.

L'occasion, aussi, de lever le voile sur les contours de ces « *Jeux Olympiques de l'horticulture* », selon l'expression de François Laurens, chercheur à l'Inra et président du comité d'organisation. Fin du suspense, le congrès se tiendra en centre-ville, contrairement à ce qui avait été envisagé jusqu'ici. « *Il y a deux mois, on pensait encore que l'IHC se déroulerait au Parc-Expo. Et puis, j'ai découvert le Centre de congrès rénové lors de son inauguration. J'ai été complètement conquis par sa configuration, son lien avec le Jardin des Plantes et sa position centrale* », défend le scientifique. La jauge du lieu, fixée à 3 500 personnes, correspond au nombre de participants attendus. Mais « *on recherche quand même des salles en dehors* », dit-il.

Côté programme, les enjeux écologiques seront mis en avant, avec des restitutions sur les thèmes de l'alimentation, de la santé et du bien-être, de la durabilité des systèmes de production et de l'adaptation au changement climatique. Les entreprises du végétal ne seront pas en reste, avec des interventions sur la compétitivité des filières, des temps réservés aux rencontres d'affaires, mais aussi des jobs datings. « *On veut faire un événement scientifique de haut niveau associant recherche, formation et industrie, tout en étant vraiment dans le concret* », explique François Laurens.

Le comité d'organisation travaille par ailleurs avec la Ville d'Angers autour d'une animation en direction du grand public, Angevins et touristes de passage. « *On pense peut-être à installer des jardins expérimentaux... On a des tas d'idées* », ajoute son président. Il reste encore trois ans pour leur donner vie.

Chloé BOSSARD

Jean-Marc Auffret, Benjamin Thomas, Serge Alloend-Bessand, Guy Ribrault, Jacky Rabin, Michel Marsault, Maxence Henry et Grégory Blanc..

En présence de nombreuses personnalités, Michel Marsault, le président du SCA, a célébré les 60 ans du club samedi au stade de la Baraterie.

À quelques encablures du stade Raymond-Kopa, dans l'ombre du bientôt centenaire SCO, le SCA a fêté un peu en avance ses 60 ans samedi dernier alors que son anniversaire officiel est le 23.

Michel Marsault, le président du club, avait convié de nombreuses personnalités parmi lesquelles on retrouvait Guy Ribrault, président du District de Maine-et-Loire et Maxence Henry, adjoint au maire d'Angers, en charge du quartier des Justices, Madeleine et Saint-Léonard.

C'est au cadet Benjamin Thomas (U17, moins de 17 ans), que revenait l'honneur de retracer 60 ans d'histoire de ce club de football. On y apprenait – ou se rappelait – qu'à sa naissance, le 11 avril 1956, le SCA s'appelait NGSA pour Nouvelles Galeries Sportives d'Anjou et qu'il ne devint Sporting Club Angevin que le 23 juin 1959. Alors qu'à l'origine, le club ne comptait que deux équipes seniors, le cap des 100 licenciés était passé lors de la saison 1980-1981.

Le SCA a joué son premier match officiel sur le terrain synthétique du stade de la Baraterie le 12 septembre 1993.

Pour la saison 2001, le club atteindra les 400 licenciés, puis 450 en 2016.

Sur le plan sportif, malgré une montée en PH en 2011, l'équipe première évolue maintenant en D2. Mais Michel Marsault, le président depuis deux ans, à l'issue d'un discours où il n'a pas manqué de rappeler l'histoire du SCA et citer quelques dirigeants historiques, a tenu à souligner la volonté des dirigeants de voir l'équipe fanion retrouver rapidement « *le niveau régional après plusieurs années de vaches maigres* ».

TENNIS DE TABLE

Le tournoi de l'AS Monplaisir n'a pas eu le succès escompté

INFOS SERVICE

TÉMOIGNAGE

« Un congrès scientifique international de l'horticulture ouvert aux professionnels »

ENTRETIEN AVEC

François Laurens

Ingénieur de recherche au centre Inrae Pays de la Loire et président du comité d'organisation du congrès international de l'horticulture 2022

• PROPOS RECUEILLIS PAR AUDE BRESSOLIER •


INRAE

Du 14 au 20 août 2022, la France, et particulièrement la ville d'Angers, accueillera le 31e congrès international d'horticulture, dont vous présidez le comité d'organisation. Pouvez-vous nous présenter plus en détail cet événement ?

François Laurens : Tout d'abord, il faut préciser ce qu'on entend par « horticulture » au sens international du terme. Il s'agit des productions autres que les grandes cultures : l'horticulture ornementale, mais aussi les fruits, les légumes, les plantes médicinales… avec des activités qui vont de l'amont à l'aval, de la génétique aux aspects marketing. Sous l'égide de l'ISHS[1], la plus grande société d'horticulture au monde, le congrès international de l'horticulture (IHC) est un évènement qui se déroule tous les quatre ans et qui entend réunir les acteurs de la science fondamentale et appliquée, pour ce qu'on a coutume d'appeler « les jeux olympiques de l'horticulture », toutes proportions gardées ! Cette 31e édition que nous accueillerons à Angers sera notamment construite autour de 4 sessions plénières, où de grands témoins (à l'image d'Ameenah Gurib-Fakim, ancienne présidente de la République de l'Île Maurice) viendront aborder 4 grands thèmes : la compétitivité, l'agroécologie, la sécurité alimentaire et le changement climatique. Nous avons construit un vaste programme de 25 symposiums sur des thématiques variées et transversales, comme la sélection variétale, les ressources génétiques, la gestion de l'eau et des stress abiotiques, la gestion du verger, l'agroécologie, la robotique et la culture de précision…

Combien de participants attendez-vous et quels sont leurs profils ? Exclusivement des chercheurs ?

F. L. : Nous attendons entre 2 000 et 3 000 participants : bien évidemment, des chercheurs du public et du privé, des enseignants-chercheurs, des étudiants… mais pas seulement ! Nous cherchons aussi à faire le lien avec les professionnels de la filière.

Ce congrès n'est pas un rendez-vous de scientifiques pour les scientifiques !
En s'appuyant sur la présence du pôle de compétitivité Végépolys Valley dans le comité d'organisation, nous avons d'ailleurs construit notre candidature autour du triptyque recherche/entreprises/formation et cela a joué en notre faveur quand nous avons été préférés à la ville de Pékin pour organiser l'événement.
Nous avons donc un important travail à fournir pour donner envie à ces professionnels, moins habitués à participer à ce type de rencontres scientifiques, de se joindre à nous au mois d'août. Nous serons d'ailleurs présents au Sival pour leur présenter les offres adaptées que nous avons mises en place : des sessions qui leur seront dédiées au sein de chaque symposium, des visites techniques, des « learning expditions », etc.

Quand on observe votre parcours dans le domaine de l'amélioration variétale en fruits à pépins, couronné par le succès d'Ariane et de Story® Inored, ou votre investissement comme président du comité scientifique du CTIFL ou co-animateur du GIS Fruits, on remarque cette volonté d'être en contact avec les professionnels de la filière fruits. Pourquoi cela est-il essentiel pour vous et, plus largement, pour la recherche ?

F. L. : Pour espérer que la recherche donne naissance à des applications utiles pour les agriculteurs, l'interaction avec les professionnels est indispensable. Pour cela, le chercheur ne doit pas être dans la posture de celui qui leur délivre la bonne parole. Il doit arriver à sentir leurs attentes.
De leur côté, les professionnels doivent bien comprendre que la recherche a besoin de temps et n'est pas toujours en mesure de répondre, dans l'immédiateté, aux problématiques qui émanent du terrain.
C'est pourquoi nous tenons à ce que les professionnels assistent au congrès. Nous allons d'ailleurs créer des « challenges » en ouvrant sur le site www.ihc2022.org un espace où les professionnels pourront poser leurs questions ou exposer leurs besoins. On s'engage à leur trouver des correspondants pour leur répondre. Ces échanges pourraient donner lieu à des rencontres lors du congrès, voire donner naissance à de futurs projets de recherche. Mais au-delà des ces grands rendez-vous, l'interaction chercheurs-professionnels doit se concrétiser au quotidien. C'est d'ailleurs tout l'apport d'un groupement d'intérêt scientifique comme le GIS Fruits.

En cinq dates

1991
Thèse de doctorat de l'université de Rennes et entrée à l'Institut de recherche en horticulture et semences (RHS), centre Inrae Pays de la Loire

2011-2015
Coordinateur du projet européen FP7 FruitBreedomics

DEPUIS 2018
Président du comité scientifique du Centre interprofessionnel des fruits et légumes

DEPUIS 2015
Co-animateur du GIS Fruits avec Sylvie Colleu (puis animateur depuis 2020)

DEPUIS 2019
Président de l'International Horticulture Congress 2022 et coordinateur du projet européen H2020 Invite

Lorsque vous avez reçu, en décembre 2020, le Laurier d'Innovation d'Inrae pour votre parcours, vous avez fait part de votre volonté d'initier un consortium européen pour partager des outils et des programmes communs de sélection. Pourquoi ce projet vous tient-il tant à cœur ?

F. L. : J'ai eu la chance de coordonner plusieurs projets européens, comme FruitBreedomics jusqu'en 2015 ou encore Invite actuellement. À chaque fois, j'ai pu constater l'intérêt d'une collaboration scientifique à grande échelle, notamment dans le domaine de la création variétale.
À titre d'exemple : avant le projet FruitBreedomics, nous disposions d'une centaine de marqueurs génétiques, indispensables pour gagner du temps lors de la sélection de nouvelles variétés. Cinq ans après, nous en avions identifié plus de 480 000. Nous n'aurions jamais pu atteindre un tel chiffre sans un travail commun.
Cela fait très longtemps que j'ai en tête cette idée de consortium européen pour gagner en efficacité. Les programmes d'amélioration génétique actuels sont très couteux, durent très longtemps et ne sont pas forcément structurés optimalement pour répondre aux enjeux environnementaux de demain. En mutualisant en amont les programmes et les outils, en travaillant sur des quantités beaucoup plus importantes de matériel génétique, nous aurons sûrement plus de chance de découvrir de nouvelles variétés répondant aux enjeux de demain. Je pense que cela serait envisageable sur des programmes de création de nouveaux porte-greffe en pommier et poirier, un levier crucial dans l'adaptation au changement climatique. ■

(1) International Society for Horticultural Science

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ANJOU ÉCO

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MAI 2022

LE MAGAZINE ÉCONOMIQUE DE LA CHAMBRE DE COMMERCE ET D'INDUSTRIE DE MAINE-ET-LOIRE

Angers, capitale du végétal

P.40

CHAMBRE DE COMMERCE ET D'INDUSTRIE
1er ACCÉLÉRATEUR DES ENTREPRISES

SIVAL [1], Congrès Mondial d'Horticulture, Salon du Végétal...

2022, Angers se met au vert

L'innovation est au cœur du travail d'IFO, à Seiches-sur-le-Loir

Outre le retour du Salon du Végétal, nouvelle ère en présentiel en septembre, Angers accueillera aussi le Congrès Mondial d'Horticulture [2] en août prochain. Autant d'événements majeurs qui font sens sur des terres où se trouve la plus forte densité d'acteurs de la filière végétale française.

L'année 2022 restera pour Angers sans nul doute dans les annales comme un cru d'exception, une année pleine de sève. Après le SIVAL en mars, Angers accueillera en août prochain, la 31e édition du Congrès Mondial de l'Horticulture, le Salon du Végétal, en septembre. Comme le souligne à juste titre Marc Flamant, élu de la CCI de Maine-et-Loire, « *le choix d'Angers n'est pas dû au hasard. Notre région regroupe un écosystème riche et dynamique (centres d'expertises, de recherche, de formation, d'entreprises, siège de Végépolys Valley, Pôle de compétitivité à vocation mondiale...). De plus, rappelons que l'Anjou offre une prestigieuse variété d'espèces et rayonne dans toute l'Europe pour la qualité de ses productions horticoles. La tenue de cet événement à Angers est une véritable opportunité pour développer davantage notre notoriété internationale tant sur le végétal que sur d'autres atouts économiques, touristiques. Les impacts attendus sont nombreux : reconnaissance et identification des compétences et savoir-faire de notre territoire, notoriété touristique, développement de partenariats scientifiques, techniques, économiques...* ».

La quintessence de l'expertise en matière de végétal se donne rendez-vous à Angers

Remontons le temps. Nous sommes en août 2014. Une délégation française se déplace à Brisbane (Australie). Mission : présenter la candidature d'Angers pour accueillir, huit ans plus tard, en août 2022 le Congrès Mondial de L'Horticulture. « *Rendons hommage à Catherine Leblanc (à l'époque adjointe au Maire d'Angers, et Présidente d'Angers Loire tourisme et directrice de l'ESSCA) qui a cru en cette délégation et soutenu cette initiative alors inédite en nous encourageant et en réunissant le budget nécessaire pour financer notre déplacement à Brisbane. Le processus de candidature internationale était alors réservé aux grandes capitales mondiales, et peu de métropoles osaient tenter leur chance. Depuis ce succès, Angers a confirmé son statut de destination d'accueil de grands événements internationaux en accueillant le World Electronics Forum en 2017. En Octobre 2021, Destination Angers, agence de rayonnement du tourisme d'affaires et du tourisme sur le territoire, a lancé le programme Ambassadeur pour encourager et accompagner les initiatives de candidatures congrès, leviers de retombées et de rayonnement pour nos filières d'excellence et pour le territoire.* », explique Valérie Mathieu-Fichot, directrice du Convention Bureau à Destination Angers. Effectivement, accueillir un événement de cette ampleur est loin d'être anecdotique. La prochaine tenue du Congrès Mondial d'Horticulture (IHC - International Horticultural Congress) qui aura comme fil rouge « *l'horticulture pour un monde en transition* », est une reconnaissance indéniable de cette excellence angevine en matière de végétal spécialisé. L'édition 2022 sera résolument tournée vers la R&D et le monde professionnel pour favoriser les échanges entre chercheurs et entreprises sur les grands enjeux du secteur, les dernières découvertes et les solutions d'avenir. Elle se tiendra sur deux sites : au Centre de congrès Jean Monnier, QG du congrès et à l'Université d'Angers, partenaire de l'événement.

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cyril.roch@maineetloire.cci.fr

Dans les coulisses d'IHC 2022

Depuis plusieurs mois déjà, le comité d'organisation, les partenaires professionnels et toutes les forces vives du territoire se préparent à accueillir cet événement d'exception. « *Après un important travail de conception en amont, et de promotion qui se poursuivra jusqu'au congrès, nous sommes entrés dans la phase de pré-production opérationnelle, et c'est toute la filière événementielle qui se mobilise à nos côtés (cf encadré, infographie). Destination Angers a déclenché le dispositif « Accueil grands événements »* avec ce que cela induit (centrale d'hébergement, Pass bus et tram avec RATPDev, partenariat avec Pony Bike pour encourager les modes de déplacements doux, covering des taxis et du tram aux couleurs de l'événement, conciergerie, travail en étroite collaboration avec le service communication et commerce de la ville, les Parcs et Jardins...). Depuis l'été 2021, nous avons alloté des chambres d'hôtels. En collaboration avec le Club hôtelier angevin et les hôtels d'Angers et d'Angers Loire Métropole, nous avons mis en place une offre « *6 nuits + 1 offerte* » encourageant les congressistes à prolonger leur séjour sur le territoire ». Le dispositif commence à porter ses fruits avec une moyenne des réservations enregistrées à ce jour de sept nuitées par participant. « *Un roadbook proposé par l'Office de tourisme aidera les congressistes à personnaliser leur expérience touristique pendant leur séjour, tandis que la plateforme digitale IHC 2022 leur permettra d'anticiper et d'optimiser leur parcours de visite durant le congrès, de participer à des sessions lives et des replays, de prendre des rendez-vous. Bien sûr, avec cet événement exceptionnel, nous avons dû revoir l'ensemble de notre organisation afin d'assurer la continuité du service pour nos clients récurrents ainsi que pour les autres congrès et salons que nous accueillerons en 2022. Nous nous appuierons sur cet événement d'ampleur pour lancer la charte d'accueil des grands événements à l'automne 2022 et poursuivre sur le terrain l'action engagée depuis 2021 avec nos partenaires, pour améliorer l'impact social et environnemental des événements accueillis sur le territoire* ».

Ce Congrès Mondial d'Horticulture, unique au monde dans le domaine de l'ornement, des fruits et légumes, des plantes aromatiques et médicinales, fédère la plus grande communauté scientifique mondiale du secteur du végétal spécialisé. Il se tient tous les quatre ans sur un continent différent. Il réunira pour cette édition 2022 plus de 2 000 congressistes issus de 100 nationalités. Au programme, des sessions plénières, 25 symposias, des tours techniques, une exposition, beaucoup de réseautage... Un atout indéniable pour les communautés scientifiques, professionnelles et pour le territoire (français et angevin). François Laurens, chercheur à l'INRAE et président du Congrès en 2022, rappelle que « *l'esprit souhaité pour l'édition 2022 est que ce soit un congrès d'un niveau scientifique élevé, rapprochant le nord et le sud et s'ouvrant davantage à la communauté professionnelle et au grand public* », ce qui est assez novateur et inédit.

« Une reconnaissance indéniable de l'excellence angevine en matière de végétal spécialisé »

Au regard des évolutions de la société et de la profession, les grands enjeux adressés à la communauté scientifique lors de ce congrès seront les suivants : compétitivité des filières et compétences, alimentation, santé et bien-être du citoyen, durabilité des systèmes de production, adaptation au changement climatique et atténuations de ses effets. En amont, dès ce mois d'avril, les professionnels du secteur pourront s'inscrire et adresser aux scientifiques leurs problématiques et autres défis auxquels ces derniers pourront répondre lors des symposias ou des ateliers.

Ce congrès est organisé par Destination Angers et Végépolys Valley en partenariat avec l'INRAE, l'Institut Agro Angers-Rennes, l'Université d'Angers, CIRAD, sous l'égide de l'ISHS (International Society for Horticultural Science), société savante née en 1959 à l'initiative de Roger de Vilmorin, suite au congrès sur ce thème organisé en France en 1958 à Nice. L'International Society for Horticultural Science est aujourd'hui un véritable réseau mondial comprenant plus de 67 000 personnes, du monde entier, majoritairement des chercheurs et enseignants - chercheurs, mais aussi des professionnels liés à ce secteur d'activité.

Année 2022, plus verte que jamais

Tout au long de l'année, Angers se mettra au vert... Gravitant autour de l'événement phare (IHC 2022) des manifestations et événements mettront en lumière le végétal. Comme autant de satellites, ils contribueront au rayonnement du territoire et des savoir-faire de la filière locale. « *Depuis 2020, élus, acteurs institutionnels, économiques, nous travaillons à la préparation de cet événement. C'est une grande fierté d'accueillir une manifestation de cette ampleur d'autant dans la capitale du végétal* », souligne Mathilde Favre d'Anne, Présidente de Destination Angers, adjointe Tourisme et rayonnement. Ainsi, de janvier à décembre, une programmation d'événements dédiée au végétal au sens large, à la nature,

IHC : un congrès VITRINE DE L'ENSEIGNEMENT horticole

.e Congrès mondial de l'horticulture sera organisé par la France, à Angers (49), du 14 au 20 août. Pour la première fois dans cet événement, la diversité de l'enseignement :echnique et supérieur sera mise en avant. Plusieurs initiatives sont déjà annoncées.

Le Congrès mondial de l'horticulture (IHC), qui se tiendra au centre des congrès d'Angers (49) du 14 au 20 août prochain, se mobilisera pour les formations. Habituellement, il concerne :urtout les producteurs, les fournisseurs et la re- :herche. Objectif en 2022 : proposer une véritable : vitrine nationale de l'enseignement horticole et lu paysage, dans le technique et le supérieur » lans sa diversité, devant des professionnels du nonde entier.

.'horticulture s'entend ici par l'ensemble des pécialités des productions végétales spécialiées, « pépinières, floriculture, arboriculture, naraîchage » et autres spécificités (depuis la proluction des semences jusqu'à l'accompagnenent des aménagements paysagers en espaces uraux et urbains). Un espace dédié comprendra plusieurs dynamiques et temps forts.

Pour son édition française, le congrès international IHC veut mettre en avant l'enseignement horticole dans sa richesse, son dynamisme et sa diversité, devant des visiteurs professionnels du monde entier. IHC 2022

Réalisations remarquables, écoles l'été ou écoles-ateliers, témoignages, :oncours de thèses...

.e stand de l'enseignement technique devrait afficher l'engagement de la DGER (ministère de 'Agriculture) sous la bannière « Le végétal spécialisé : la transition agroécologique et numérique », insi que l'offre de formation nationale. Des tands, présentations et animations (lire l'encadré) sont à disposition des écoles techniques olontaires (financement Réso'them-Hortipaysages* et appui « prog143 de l'enseignement echnique »).

'our cet événement mondial, il sera opportun l'être capable de parler un minimum anglais. .'aide d'étudiants bilingues est souhaitée...

.es organisateurs d'IHC** ont créé un espace dédié sur leur site Internet afin d'impliquer particulièrement enseignants et étudiants. Il s'agit aussi le promouvoir la formation et l'innovation pédagogique, jusqu'à améliorer et promouvoir l'événement dans les établissements de formation et l'enseignement à travers le monde.

.insi, diverses actions seront organisées avant, endant et après le congrès :

valorisation du savoir-faire des étudiants lauréats les concours nationaux dans leur pays, avec l'exposition de leurs réalisations avant et durant la nanifestation ;

- organisation d'un concours international pour doctorants débutants (pour leur thèse soutenue en 2020-2022), dans un format inspiré du 3MT (three minutes thesis) basé sur une présélection internationale ;
- sélection, au sein de chaque symposium, de la meilleure présentation orale et du poster par les étudiants avec le ISHS « Young Minds Award » ;
- organisation d'un atelier sur l'innovation dans les méthodes d'apprentissage, avec un focus particulier sur le e-learning ;
- encouragement à organiser des écoles d'été ou des écoles-ateliers de recherche avant ou après l'événement, sur les grands thèmes du congrès ;
- promotion de l'événement IHC 2022 dans les écoles techniques horticoles-agricoles et l'enseignement supérieur, sous forme de clips vidéo, d'ateliers pratiques ou d'autres activités pédagogiques ;
- promotion des institutions de formation françaises et européennes lors de l'IHC (visites, séminaires)...

Odile Maillard

*DGER Reso'them-Hortipaysages. Régis Triollet, animateur national. Restitution des diverses propositions de contributions à envoyer avant mardi 31 mai à minuit (avant la prochaine réunion du comité de pilotage) pour finaliser le projet, auprès de regis.triollet@educagri.fr

**Programme complet d'IHC : plénières, conférences et ateliers, visites touristiques... et propositions auprès de secretariat@ihc2022.org et sur https://www.ihc2022.org/

Un stand pour les « réalisations remarquables »

Au stand de l'enseignement technique, des « présentations de réalisations remarquables » seront possibles sous forme de posters grand format, de conception libre. Il est encore temps pour les écoles volontaires de s'inscrire (à proposer avant fin mai à regis.triollet@educagri.fr). La direction communication de la DGER pourra accompagner leur réalisation. Des témoignages (en animations présentielles ponctuelles et/ou en projection vidéo) pourront mettre en valeur des étudiants, des lycéens, des apprentis et des stagiaires, ainsi que des professionnels en action. Mercredi 17 août dans l'après-midi, une demi-journée spéciale d'accueil animera le stand. Les autres jours, posters et vidéos resteront visibles, avec une présence tournante d'enseignants ou d'élèves afin de répondre à toutes les questions des visiteurs.

LA TENDANCE *en mai*

P. FAYOLLE

Paysage : les ÉTATS-UNIS, miroir de la France en 2022 ?

Une récente étude américaine publiée par Val'hor dévoile les écueils se profilant pour les entreprises du secteur. La ressemblance avec l'Hexagone est parfois forte !

« Le secteur du paysage anticipe une hausse de la demande en plantes locales et en projets de plantations en phase avec le changement climatique. » Cette phrase n'est pas issue d'une énième enquête sur la situation en France, mais bien aux États-Unis. Toutefois le secteur manque de bras et les salaires vont grimper, retardant les chantiers et renchérissant les prix. Toujours selon les professionnels, la pénurie de végétaux va se poursuivre.

Qui va conduire les camions ?

La prochaine grande crise pour le paysage outre-Atlantique pourrait venir du manque de conducteurs de camions, partis en retraite anticipée depuis la pandémie ou monopolisés par le e-commerce. Toute ressemblance avec ce qui se passe en France n'est pas fortuite... En 2021, le pays a enregistré une inflation de 7 %, les coûts en horticulture sont en hausse de 12 à 14 %. Ce qui « risque d'avoir des répercussions sur le paysage ».

Pour s'en sortir, les professionnels font davantage appel à la technologie, surtout pour le transfert d'informations, mais manquent de temps et de moyens pour former les équipes...

Pascal Fayolle

Repères

- **C'est dans sa lettre électronique** « En quête de vert » du 17 mars que Val'hor a publié l'étude américaine. Le rapport, que l'on doit à GoMaterials, fournisseur B to B pour le paysage, « a été réalisé à partir de nombreuses études sur les entrepreneurs et paysagistes concepteurs ».

UN MONDE DURABLE

DES FEMMES AU CHEVET DES ABEILLES, DES COLIS SANS PLASTIQUE ET UNE VILLE RÉSOLUMENT ENGAGÉE DANS LA TRANSITION ÉCOLOGIQUE : VOILÀ DES INITIATIVES CONCRÈTES AU SERVICE DE NOTRE PLANÈTE.

PAR JULIE CAUDAL ET BÉNÉDICTE BOUDASSOU

Des femmes et des abeilles

On ne le répètera jamais assez : les abeilles, c'est la vie ! Le déclin de leurs populations, aussi bien sauvages que domestiques, est plus que préoccupant. Conscients de l'importance qu'il y a à les protéger, l'UNESCO et la maison Guerlain ont lancé « Womens for Bees » (Les femmes pour les abeilles), un programme qui a pour vocation d'enseigner à des apicultrices du monde entier la création et la gestion d'une exploitation apicole durable. Une aventure bourdonnante 100% au féminin documentée avec talent par la jeune photographe Charlotte Abramow dans son exposition Piquées.

Exposition Piquées, du 22 avril au 22 juillet 2022, boutique Guerlain, 68 av des Champs-Elysées, Paris, accès libre.

Carton plein

La chasse au plastique est lancée ! Promesses de fleurs, spécialiste de la vente de plantes en ligne, s'est lancé un défi ambitieux : débarrasser ses colis de tout plastique. Réflexion, prototypes, tests… Il aura fallu 2 années de travail pour imaginer des emballages en carton, ou papier, recyclés et recyclables, suffisamment résistants pour protéger les végétaux (allant du bulbe à l'arbuste) des aléas du transport tout en gardant les mottes humides jusqu'à leur destination finale. Désormais disponible sur son site, l'option « commande sans plastique » permet d'économiser en moyenne 500g de plastique sur chaque commande. On dit bravo !

www.promessesdefleurs.com

(Voir notre carnet d'adresses p. 130)

Ville nature

Les récompenses pleuvent pour Angers. Élue ville française la plus verte en 2020, 1ère ville de France où il fait bon vivre en 2022, la capitale de l'Anjou est désormais reconnue comme « Tree Cities of the World » par les Nations Unies pour la gestion de son patrimoine végétal urbain. Cela fait plusieurs années déjà qu'Angers se distingue par son engagement fort en faveur de l'environnement. Mise en place d'un arrosage intelligent dans ses parcs et jardins (avec 30% d'économie d'eau à la clé), plantation d'arbres, désimperméabilisation des sols pour une meilleure infiltration de l'eau de pluie… Les projets concrets se multiplient pour donner plus de place à la nature en ville. Une démarche d'avant-garde, qui, on le souhaite, fera des émules !

Pour en savoir plus : www.angers.fr

Angers, la capitale du végétal

Le végétal de demain

Formation, production et innovation, Angers est aussi un territoire d'excellence végétale sur le plan national et international. Et pour preuve, la ville accueille en 2022 deux événements majeurs pour l'avenir de la filière horticole. A la mi-août, le congrès international de l'horticulture – les « JO de la recherche végétale » - va attirer les scientifiques du monde entier afin d'aborder les grands enjeux du végétal, notamment la durabilité des systèmes de production et le changement climatique. En septembre, c'est au salon du Végétal que convergeront tous les professionnels de la filière pour exposer leur savoir-faire et présenter leurs innovations. Cette année, une zone mixte baptisée le « cœur végétal » sera accessible au grand public. Au programme : vente de plantes et balade dans les jardins éphémères pour découvrir les nouvelles tendances et les bonnes pratiques !

Pour en savoir plus : www.ihc2022.org et www.

Immersion dans les jardins

Si vous êtes dans la région angevine cet été, ne ratez pas la visite de Terra Botanica. Dans ce parc, un fabuleux voyage au pays des plantes vous attend. Plus de 500.000 végétaux issus des quatre coins du globe sont à découvrir au travers de jardins extraordinaires. Pour amuser les petits comme les grands explorateurs, des attractions parfois folles les attendent également : décollage en ballon pour prendre de la hauteur, flânerie en barque, projections dynamiques en 4D… Cette année, la déambulation se prolonge la nuit tombée avec un tout nouveau parcours son et lumière pour plonger le visiteur au cœur de l'arbre-monde ! Un parcours insolite qui suscite l'émerveillement pour mieux éveiller les consciences.

Terra Botanica, Angers (49), www.terrabotanica.fr

German / English Articles

FRUCHTHANDEL SPECIAL

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CONTENTS IN GERMAN AND ENGLISH

FRUIT LOGISTICA | BERLIN | 5-7 APRIL 2022

STAND INTERFEL HALL 22

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Annähernd 3.000 Teilnehmer werden sich im Kongresszentrum und auf dem Campus der Universität von Angers zusammenfinden.

Angers ist Ausrichtungsort des IHC-Kongresses 2022

International Horticultural Congress ▶ Die in der westfranzösischen Region Pays de la Loire, im Départment Maine-et-Loire, gelegene Stadt Angers wird vom 14. bis zum 20. August 2022 zum Mekka der internationalen Pflanzenwelt. Sie ist Austragungsort der 31. Ausgabe des International Horticultural Congress IHC.

Diese weltweit größte Veranstaltung im Pflanzensektor ist im Hybrid-Format geplant, an dem die Delegierten in Präsenz vor Ort oder aber aus der Ferne über eine Online-Plattform teilnehmen können. „Dieser Weltkongress ist eine einzigartige Gelegenheit für das Zusammentreffen der gesamten wissenschaftlichen Gemeinschaft des Sektors. Nach Nizza im Jahr 1958 ist nun in diesem Jahr Angers Ausrichter der Veranstaltung", freut sich François Laurens, Forscher am INRAE (Institut national de recherche pour l'agriculture, l'alimentation et l'environnement) und Präsident des IHC-Kongresses.

Die Stadt an der Loire gilt als die Hauptstadt der Pflanzenwelt Frankreichs schlechthin, beherbergt sie doch ein Zentrum des Nationalen Forschungsinstituts für Landwirtschaft, Ernährung und Umwelt und ist zudem der Sitz des Gemeinschaftlichen Sortenamts der Europäischen Union. Darüber hinaus ist in Angers auch das auf Pflanzen spezialisierte Kompetenzzentrum Végépolys Valley mit internationalem Anspruch angesiedelt, das zu den Co-Organisatoren des diesjährigen Kongresses zählt.

Gartenbau für eine Welt im Wandel

Als größtes landwirtschaftliches Erzeugerland in der Europäischen Union und eines der größten weltweit ist Frankreich als Veranstalter des IHC-Kongresses prädestiniert. Unter der Schirmherrschaft der International Society for Horticulture Science ISHS wurde das Thema „Horticulture for a world in transition" (Gartenbau für eine Welt im Wandel) zum zentralen Leitmotiv des Kongresses gewählt. Die Veranstaltung wird sich demnach mit den großen aktuellen Herausforderungen befassen, die den gesamten Sektor derzeit bewegen. Zu ihnen zählen unter anderem die Anpassung an den Klimawandel und die Abschwächung seiner Auswirkungen, die Agrarökologie und die Nachhaltigkeit der Produktionssysteme, die Ernährung und menschliche Gesundheit sowie die Wettbewerbsfähigkeit und die Qualifikationen für gartenbauliche Wertschöpfungsketten.

Annähernd 3.000 Teilnehmer, Mitglieder und Nicht-Mitglieder der ISHS, Wissenschaftler aus über 90 Ländern, aber auch Lehrer, Produzenten, Industrielle, Ressourcen-Manager, Ökologen und Ökonomen, Architekten, Landschaftsgärtner, Studenten und viele weitere Berufsgruppen werden sich im Kongresszentrum und auf dem Campus der Universität von Angers zusammenfinden.

In Angers ist ein Zentrum des Nationalen Forschungsinstituts für Landwirtschaft, Ernährung und Umwelt INRAE angesiedelt.

Symposien mit übergreifenden Themen

Die Organisatoren des IHC 2022 haben sich drei große Ziele gesetzt: ein hohes wissenschaftliches Niveau von der Grundlagenforschung bis zur angewandten Forschung zu gewährleisten, die Verbindungen zwischen Forschung, Lehre und Industrie zu stärken und die internationale Zusammenarbeit zwischen

Insgesamt 25 Symposien mit übergreifenden Themen werden von internationalen wissenschaftlichen Komitees organisiert.

der Nördlichen und der Südlichen Hemisphäre auszubauen. Plenarsitzungen, Ausstellungen, B2B-Networking-Treffen und vor allem 25 Symposien mit übergreifenden Themen von der Genetik bis zur Anwendung werden von hochrangigen internationalen wissenschaftlichen Komitees organisiert.

Mit fast 80 % internationalen Teilnehmern ist die offizielle Kongress-Sprache Englisch. Einige Symposien und Sitzungen werden aber auch simultan ins Französische übersetzt. Die Teilnehmer haben außerdem die Möglichkeit, den wissenschaftlichen und kulturellen Reichtum sowie die pflanzliche Vielfalt der Region Pays de la Loire im Rahmen von technischen und touristischen Besichtigungen, wie zum Beispiel bei Besuchen in Laboratorien, technischen Instituten und Industrieunternehmen, zu entdecken.

Weltweit größte wissenschaftliche Veranstaltung ihrer Art

Der Internationale Gartenbaukongress (IHC) ist die weltweit größte wissenschaftliche Veranstaltung ihrer Art, die seit 1958 alle vier Jahre unter der Schirmherrschaft der ISHS, einem weltweiten Netzwerk von 7.000 Mitgliedern, zu Themen des spezialisierten Pflanzenbaus veranstaltet wird. Ziel dieser wissenschaftlichen Gesellschaft ist es, Forschung und Lehre im Bereich der spezialisierten Pflanzenwissenschaften zu fördern und zu begünstigen sowie die Zusammenarbeit und den Wissenstransfer auf internationaler Ebene durch Veranstaltungen und Veröffentlichungen zu erleichtern. Der Kongress findet alle vier Jahre auf einem anderen Kontinent statt und wird 2026 im japanischen Kyoto veranstaltet.

Der Kongress 2022 wird vor Ort von Destination Angers, Végépolys Valley, dem INRAE und Agrocampus Ouest, der Universität Angers und dem CIRAD organisiert. Vertreter von Végépolys Valley zählen zu den Ausstellern auf der diesjährigen FRUIT LOGISTICA und stehen Interessenten in Halle 22 für weitere Informationen zur Verfügung. **i.e.**

Halle 22/F-04

Angers is to host the IHC Congress 2022

International Horticultural Congress ► The city of Angers, situated in the western French region Pays de la Loire, in the Département Maine-et-Loire, will be the mecca of the international plant world from 14th to 20th August 2022. It is host to the 31st International Horticultural Congress IHC.

The world's largest event in the plant sector is planned in hybrid format, where delegates can take part in person or remotely via an online platform. "This world congress is a unique opportunity for the sector's entire scientific community to meet together. After Nice in 1958, Angers is now organising the event this year," François Laurens, researcher at INRAE (Institut national de recherche pour l'agriculture, l'alimentation et l'environnement) and President of the IHC Congress expressed his delight.

The city on the Loire is considered to be the capital par excellence of France's plant world. It houses a centre of the National Research Institute for Agriculture, Food and the Environment INRAE and is also the headquarters of the Community Plant Variety Office of the European Union. Furthermore, Angers is also home to Végépolys Valley, centre of excellence specialising in plants, international in scope, which is one of the co-organisers of this year's congress.

As largest agricultural producer country in the European Union, France is predestined as organiser of the IHC Congress.

Fotos: Végépolys Valley

Horticulture for a world in transition

As largest agricultural producer country in the European Union and one of the biggest worldwide, France is predestined as organiser of the IHC Congress. Under the auspices of the International Society for Horticulture Science ISHS, the subject "Horticulture for a world in transition" was chosen as the central

One of the major goals is to ensure a high scientific level, from basic through to applied research.

theme of the congress. The congress will accordingly address the current major challenges which are affecting the entire sector at present. These include inter alia adapting to climate change and mitigating its impact, agroecology and the sustainability of production systems, nutrition and human health as well as competitiveness and qualifications for agricultural value chains.
Some 3,000 participants, members and non-members of the ISHS, scientists from over 90 countries but also teachers, producers, industrialists, resource managers, ecologists and economists, architects, landscape gardeners, students and many other professional groups will come together in the congress centre and on the campus of the University of Angers.

Symposia with overarching subjects

The organisers of IHC 2022 have set themselves three major goals: ensuring a high scientific level, from basic through to applied research, strengthening links between research, teaching and industry and developing international cooperation between the northern and southern hemisphere. Plenary sessions, exhibitions, B2B networking meetings and above all 25 symposia with overarching subjects, ranging from genetics through to application, will be organised by high-level international scientific committees.
Given almost 80 % international participants, the official language of the congress is English but some symposia and sessions will also be translated simultaneously into French. Participants will also have the opportunity of discovering the scientific richness and cultural heritage as well as the plant diversity of the Pays de la Loire region during technical and tourist visits, such as to laboratories, institutes of technology and industrial enterprises.

World's largest scientific event of its kind

The International Horticultural Congress (IHC) is the world's largest scientific event of its kind, which has been since 1958 under the auspices of the ISHS, a worldwide network of 7,000 members, on subjects of specialised plant cultivation. The aim of this scientific society is to promote and encourage research and teaching in the field of specialised plant sciences as well as to facilitate cooperation and knowledge transfer at an international level through events and publications. The congress takes place every four years on a different continent and will be held in Kyoto, Japan, in 2026.
The 2022 congress is being organised on site by Destination Angers, Végépolys Valley, INRAE and Agrocampus Ouest, the University of Angers and CIRAD. Representatives of Végépolys Valley will be at this year's FRUIT LOGISTICA and will be available to provide further information in Hall 22. **i.e.**

Hall 22/F-04

Participants will have the opportunity to visit laboratories, institutes of technology as well as production sites.

Interdisziplinäre Vielfalt zu Gast in Angers

International Horticultural Congress ▶ Vom 14. bis zum 20. August wird die als „Capitale du végétale" (Hauptstadt der Pflanzen) bekannte westfranzösische Stadt Angers zur Heimat des International Horticultural Congress. Was dabei 2022 anders als zuvor ist und was die Teilnehmenden in diesem Jahr vom breit aufgestellten Programm erwarten dürfen, haben François Laurens und Emmanuelle Rousseau dem Fruchthandel Magazin auf der FRUIT LOGISTICA erläutert.

Inga Detleffsen

Der Kongress ist ein wenig wie die Olypmpischen Spiele", vergleicht François Laurens. Er ist Forscher am Nationalen Forschungsinstitut für Landwirtschaft, Ernährung und Umwelt INRAE (Institut national de recherche pour l'agriculture, l'alimentation et l'environnement) und Präsident des International Horticultural Congress. „Er findet alle vier Jahre statt, immer auf wechselnden Kontinenten. Und bei jedem Kongress wird der Austragungsort der übernächsten Veranstaltung bekanntgegeben", erklärt Laurens, als das Fruchthandel Magazin ihn auf der FRUIT LOGISTICA trifft.

Verglichen mit Kyoto, dem Austragungsort für 2026, ist die Anreise dank der Direktzüge ab Paris für europäische Teilnehmer unkompliziert. Das Besondere in diesem Jahr ist, dass der Teilnehmerkreis erstmalig erweitert wird und sich das Programm 2022 auch explizit an Nicht-Wissenschaftler richtet, etwa an Lehrende, Produzenten, Industrielle, Ökologen, Architekten und viele weitere Berufsgruppen der Branche. Die Organisatoren rund um das „Vegepolys Valley"-Cluster wollen durch das Aufeinandertreffen von Forschung, Praxis und Lehre die interdisziplinäre Zusammenarbeit fördern. Dabei ist das Programm des IHC zunächst wie ein wissenschaftlicher Kongress aufgebaut. Es gibt 25 Symposien, die sich vier großen Themenblöcken zuordnen lassen: Anpassung an den Klimawandel und Abschwächung seiner Auswirkungen, Agrarökologie und Nachhaltigkeit der Produktionssysteme, Ernährung und menschliche

François Laurens und Emmanuelle Rousseau sind vom multidimensionalen Ansatz des diesjährigen IHC überzeugt.

Gesundheit sowie Wettbewerbsfähigkeit und Qualifikationen für gartenbauliche Wertschöpfungsketten. An vier Vormittagen werden die einzelnen Plenarsitzungen jeweils von zwei Impulsvorträgen eröffnet, bei denen Themen wie Innovation, Klimawandel oder weitere gesellschaftlich relevante Strömungen eine Rolle spielen werden. Dabei sind die Vortragenden spannenderweise nicht „vom Fach", sondern sollen die Teilnehmenden als externe Ideengeber zu neuen Perspektiven inspirieren.

Die 25 Symposien hingegen beschäftigen sich gezielt mit sehr konkreten Themen, die von Precision Farming, New Breeding Techniques und Genetik, Gewächshausanbau, Automatisierung, Produktqualität und Nachernte, Pflanzenschutz, Wassereinsparung bis hin zum Urban Farming reichen und an einen oder mehreren Tagen vertieft werden. Dazu gehören neben zwölfminütigen Beiträgen auch dreiminütige Blitzvorträge in kleineren Gruppen. Das Interesse, hier Projekte vorzustellen, ist groß, wie Emmanuelle Rousseau, bei Vegepolys Valley zuständig für die Kommunikation, erläutert: „Wir haben 2.300 Abstracts für die Vorträge erhalten – etwa 700 davon werden Teil des Programms, nachdem sie von einem Fachkomitee ausgewählt wurden."

Für Nachwuchs und Nicht-Wissenschaftler

Für Promovierte oder Promovierende gibt es ein zusätzliches Highlight: Bei einem Wettbewerb zur weltweit besten Abschlussarbeit konnten sie bis Mitte April ihre Thesis einreichen, um sie bei Annahme in drei Minuten dem internationalen Publikum zu präsentieren. Den drei Gewinnern winken Geldpreise. „Damit möchten wir die Veranstaltung auch für jüngere Forscher interessant machen, die darüber hinaus auch von besonders günstigen Teilnahmebedingungen profitieren", erklärt Laurens. Er ist vom multidimensionalen Ansatz des diesjährigen IHC überzeugt: „Dieser Kongress ist sehr vielfältig. Normalerweise besuche ich als Genforscher meist Veranstaltungen, bei denen es ausschließlich um Apfelgenetik geht. Der IHC hingegen ermöglicht einen umfassenden und vielschichtigen Blick auf unsere Branche, sei es, was einzelne Produkte angeht, sei es, was Arbeitsfelder betrifft." Dadurch entstehe ein großer Mehrwert, denn durch den interdisziplinären Austausch steige die Chance, gemeinsam Lösungen für aktuelle Herausforderungen zu finden, erklärt Laurens.

Entlang des Programms sind feste Zeitslots für Networking-Einheiten eingeplant. Zudem gibt es am Ende eines jeden Tages anderthalbstündige Workshops, bei denen die Teilnehmer in kleinen Gruppen gemeinsam an bestimmten Fragestellungen arbeiten. Am Mittwoch haben insbesondere Produzenten die Möglichkeit, an technischen Touren teilzunehmen, bei denen in der Umgebung um Angers die Themen des IHC aufgegriffen werden.

Foto: Destination Angers

Ohnehin richtet sich der Kongress in diesem Jahr auch an Profis aus der Branche: „Wir haben unterschiedliche Ticket-Pakete entwickelt, mit denen insbesondere Nicht-Wissenschaftler ein bestmögliches Erlebnis auf dem IHC haben", betont Rousseau. Dazu gehört auch, dass ab April individuelle Interessen über einen Fragebogen auf der Webseite des Kongresses eingesendet werden können, woraufhin das IHC-Team individuell die interessantesten Symposien und Exkursionen zusammenstellt. Auch Tageskarten für Mittwoch und Donnerstag sind möglich.

In kleineren Workshops können die Teilnehmerinnen und Teilnehmer einzelne Themen vertiefen und gemeinsam erarbeiten.

Die Veranstaltungssprache ist aufgrund des internationalen Publikums Englisch, wobei vor allem für die für Mittwochnachmittag geplanten Touren je nach Gruppenzusammensetzung eine Verdolmetschung zum leichteren Austausch untereinander angedacht ist. Speziell für Unternehmen bietet der IHC auch Sponsor-Pakete sowie Ausstellungsflächen im Kongresszentrum an. „Einige Plätze sind sogar noch frei", so Rousseau abschließend. Weitere Informationen zum genauen Programm der hybriden Veranstaltung sowie alle weiteren Details gibt es auf der Seite des Kongresses: www.ihc2022.org. ●