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

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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).

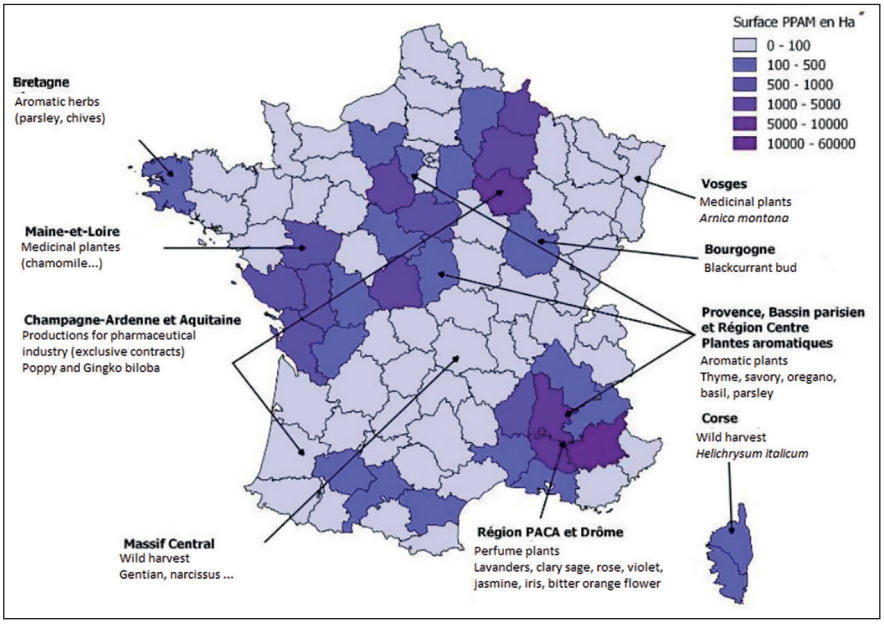

Figure 1. Surface distribution of HMAPs in continental France in 2018. ©FranceAgriMer (adapted). *1 Ha = 0.01 km^2.

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.

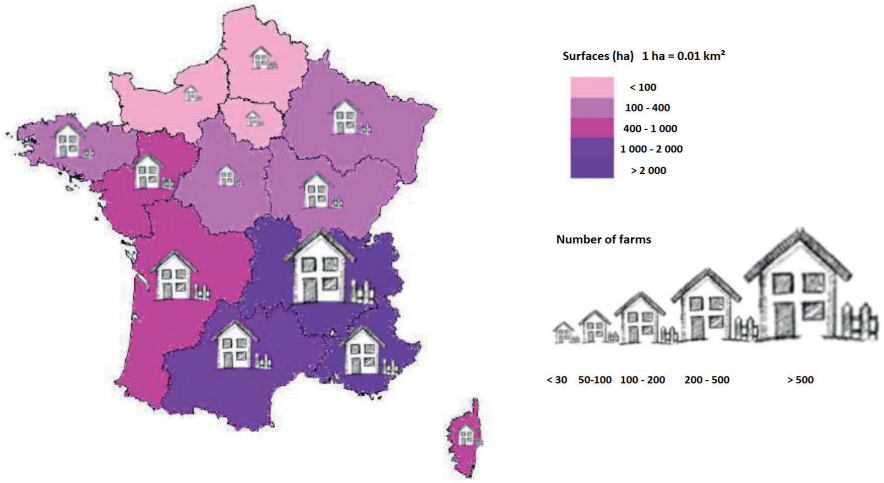

Figure 4. Number and area of farms (organic certified and in conversion) per region in 2018. ©FranceAgriMer; Figures from AgenceBio.

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.

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