

ASIRPA

Analysis of the Impacts of Public Agricultural Research

Varietal innovations in the ornamental sector

23.6.2015

Véronique Kapusta

Valéry Malécot

Case study performed for the Plant Biology and Breeding department of INRA
With methodological support from ASIRPA team



This case illustrates the impacts of the breeding of ornamental ligneous varieties by INRA in Angers since the mid-1970s. INRA's involvement drove the sector to pool its R&D investments through an Economic Interest Group (GIE) and to structure itself to disseminate the new cultivars obtained. The 37 cultivars thus bred, some of which have since become standards in their categories, have enabled garden centres and distributors to achieve turnover worth €150 million since 1985 (€58 million corresponding to new markets: *Lonicera* and clematis in pots, *Forsythia* for landscaping and *Caryopteris*). These efforts were also mobilised to compile guidelines on the descriptors used for DHS tests during the registration of cultivars in certain genera at a global scale. This varietal creation has had other impacts that are more difficult to quantify: resistant cultivars have contributed to limiting the dissemination of fire blight in France, and the breeding of ornamental apples used as pollinators has increased the productivity of eating apple orchards.

Context

The French nursery market (ligneous ornamentals and roses) is small (worth €522.5 million); by comparison, French rapeseed production in 2013 was worth €1.748 billion (Source FranceAgriMer 3 déc 2014, Observatoire structurel des entreprises de l'horticulture et des pépinières ornementales & Ministère en charge de l'agriculture, statistiques agricoles 2013, GrafAgri2014).

Companies in the horticultural sector (4154 in France¹, including 1431 nurseries are mainly SMEs (an average of 5 FTE per company and a turnover of €379,000). No technical centre, interprofessional bodies or federative structures organised this sector before INRA first intervened. Among these bodies, breeders generally have few or no research and development resources, and notably no biotechnology laboratories (tools for *in vitro* culture, molecular biology, microscopy or mutagenesis). The rare companies with an R&D department devote less than 5% of their turnover to this activity.

The materials sold are highly diverse (more than 50,000 taxons marketed, and an average of 5000 references in the catalogue of a producer of young plants), thus dispersing research efforts and preventing creation in all genera.

Finally, most of these plants are propagated vegetatively, and more rarely by sowing. Each new cultivar is therefore sold much less than in the case of cereals (ten varieties accounting for 79.9% of the cultivation area for durum wheat¹), or oilseeds (in the case of sunflower, the market is of a size comparable to that of the ornamental sector, where fewer than 300 varieties are marketed). Varietal creation thus appears to be less profitable in the ornamental sector.

For all these reasons, ligneous ornamentals are considered as orphan species, where public and private research investment is very limited, particularly in France. Indeed, based on applications for new European Plant Breeder's Rights Certificates (COV), C. Widehem showed that despite a constant annual number of applications between 1995 and 2005, the share of new French varieties declined (it accounted for 3.8% of new European varieties in 2005) and was concentrated on four genera (*Rosa*, *Chrysanthemum*, *Pelargonium*, *Petunia*).

The French ornamental sector is therefore dispersed, not organised and subject to strong European competition; although the French ornamental horticulture market is generally in deficit² it is growing. Indeed, a "need for Nature" among the French is increasing, reflected by a rise in the sales of outdoor plants (at least between 1989 and 2004, cf. DGAP report in 2012). In this context, French horticultural firms producing young plants in the ornamental sector often

find themselves economically dependent on new varieties from other countries, or are restricted to only selling old, unprotected materials. However, some companies have turned towards the marketing of cultivars they have developed themselves or in partnership. The primary objective for these companies is to increase their sales without having to pay royalties to a third party. The principal areas for this development of new cultivars are pest resistance, the diversification of colours and compact habit. Colour has an important role in triggering purchases by the general public, while a compact habit may be of interest to both individuals (small gardens), landscape gardeners (less maintenance) and producers (increase in the number of pots per m²). Pest resistance is sought by professionals and consumers as it can limit treatments and ensure better health status. Disease resistance, even if is currently secondary to INRA's objectives in terms of creating new varieties, has been a fundamental element of its programmes, particularly because of the concomitant development of fire blight in Europe, its appearance in France and the development of INRA's first new varieties resistant to this pathogen.

Inputs and productive configuration

Since 1970, INRA has been implementing variety creation programmes in ligneous ornamental plants, either alone or in collaboration with companies (the SAPHYR, SAPHINOV, EUROGENI Economic Interest Groups (GIE) and the BRIO programme). These activities were implemented by the Ornamental Horticulture Laboratory, set up in 1972 at the Fruit Arboriculture Station in Angers, following exchanges between the nurseryman Robert Minier and INRA's central management regarding the need for innovation as being vital to the ornamental sector (C Oghina-Pavie 2006). This laboratory subsequently became a team within the Joint Research Unit for Genetics and Horticulture (UMR GenHort), and then the Genetics and Diversity of Ornamental Plants team (GDO) at the Research Institute for Horticulture and Seeds (UMR-IRHS). For most of the period under evaluation, this work was carried out by the experimental unit in Angers (now the Horticulture Unit (UE Horti), working also in association with teacher-researchers from Agrocampus Ouest.

In 1972, the programmes started with breeding on ornamental Malus derived from the breeding of disease-resistant apple trees, and then on *Berberis*, *Forsythia*, *Weigela* and *Thuya*. The marketing of these initial creations was assured through a partnership with SAPHO (Syndicate for the Breeding of Ornamental Plants, or *Syndicat pour l'Amélioration des Plantes Horticoles d'Ornement*), which became a distributing company, set up for the purpose by certain partners with the INRA centre in Angers.

These foundations were long-standing, but subsequently supported research efforts thanks to the knowledge and skills developed in mutagenesis, hybridisation, *in vitro* culture and floral biology, as well as funding through ongoing research contracts. Organisation of the first collaborative research programme (with the GIE SAPHYR), which enabled the development of these activities, was linked to both new knowledge on ornamental plants and the commercial value of the initial cultivars developed by INRA itself. These different elements then made it possible to develop a continuum for research and innovation.

Thus certain companies formed a group in 1982 to create the GIE SAPHYR, whose aim in the context of a research partnership with INRA was to breed a new group of species, the *Pyracantha*. This programme continued until 1989. Mobilising the skills acquired in apple and pear by the research and experimental units focused on fruit tree and ornamental breeding and pathologies in Angers, this programme enabled investment in resistance to fire blight and scab in *Pyracantha*. The resulting varieties were bred jointly by INRA and the GIE.

The success of this partnership approach encouraged nurserymen to support a further research programme, leading to the creation of the GIE SAPHINOV whose objective was to diversify varietal creation. The programme concerned a list of ten and then 15 ornamental shrub genera (including *Abelia*, *Caryopteris*, *Clematis*, *Cotoneaster*, *Hydrangea*, *Lavatera*, *Lonicera*). This programme lasted from 1989 to 2007, and enabled the development of numerous new methodologies for ornamental plants by the research units: intra- and inter-specific hybridisation, chromosome doubling, molecular markers, etc. This work led to the breeding of 12 varieties between 1999 and 2014.

For all these GIE, the research partnership was constructed under a framework agreement that included financial support, the availability of equipment in the laboratories, attachments and staff mobility between INRA and the GIE (technicians and engineers, whose recruitment was often aided by INRA). *In vitro* culture, mutagenesis and molecular biology techniques were developed using INRA facilities and implemented in the Institute's laboratory by staff from both INRA and the GIE. During all these partnerships, INRA and Agrocampus Ouest offered a variety of scientific support: genetics, pathology, cell and molecular biology, botany. The GIE, whose composition evolved over the years (Saphyr: 11 partners, Saphinov 21 partners in 1994, eight in 2003) all operated according to the same model, involving most of the French breeders involved in the ornamental sector.

During all research programmes, exchanges with professional partners involved:

- 1) technical committees (one to three each year) which enabled the definition of objectives and then regular updates on progress and perspectives.
- 2) technical visits in the field to evaluate and select plant materials: first to the INRA site (greenhouses and plots) for pre-selection, and then to sites operated by GIE members once the pre-selected materials had been

propagated; this second stage enabled the addition of yield criteria to qualitative selection criteria (ornamental character, resistances, etc.).

In terms of research activities for the sector within the GAP Division (BAP as from 2013), during the 1980s, and as well as the centre in Angers, three INRA experimental units were involved in ornamental varietal creation (Ploudaniel, French West Indies, Fréjus). As from the 2000s, and following its evaluation, the GAP Division refocused its research in the ornamental sector both upstream and on the rose model. This refocusing contributed to reducing INRA's investment in the creation of ornamental varieties. After 2007, varietal innovation only remained at the Angers Research Centre and in a single group of species, the Genistae (brooms) (partnerships in rose not having been established). With the same core partners, the GIE EUROGENI was then set up and ran from 2005 to 2010, still under a research partnership for the joint breeding of varieties. This new project provided an opportunity to develop new skills, approaches and tools: phylogenesis, flow cytometry, molecular markers, early embryo rescue, etc.

In 2008, The EUROGENI programme served as an example for the varietal innovation unit of the Végépolys competitiveness cluster, designed to attract companies interested in varietal creation to become involved in a collaborative project called BRIO (Breeding, Research and Innovation on Ornamentals, 2010-2014), enabling the transfer of the integrative approach adopted for Genistae (ligneous) to non-ligneous ornamental plants. This tripartite project included six groupings of professionals (23 companies), public research through the IRHS (INRA, Agrocampus, Université d'Angers) and the Végépolys Innovation competitiveness cluster. BRIO focused on eight groups of species (*Agapanthus*, *Alstroemeria*, *Anemone*, *Dianthus*, Genistae, *Hibiscus*, *Hydrangea*, *Viola*). It positioned partnership research even further upstream, while private partners assured exploitation of the knowledge and pre-breeding plant materials produced in order to create varieties. It should be noted that during this project, apart from the Genistae, the varieties retained were not jointly bred but only bred by the private sector partners.

During the implementation of all these programmes, working plant collections were built up in collaboration with the partners and were characterised morphologically or even at a molecular level. These collections concerned all the genera studied (more than twenty genera: *Malus*, *Pyrus*, *Pyracantha*, *Weigela*, *Lonicera*, *Abelia*, *Berberis*, *Buddleia*, *Caryopteris*, *Alstroemeria* etc.). In collaboration with Agrocampus Ouest and the GEVES, some of these collections (*Pyracantha*, *Forsythia*, *Weigela* in particular) have become references and enabled detailed studies to describe the material, the aim being to develop descriptive grids and comparative tools for the submission of new COV in these genera³.

Research outputs

Over the period 1974-2014, some fifty cultivars, either the sole property of INRA or bred jointly by INRA and a GIE, were, are or will be protected and then marketed by SAPHO.

Programmes specific to INRA led to three varieties of ornamental apple (*Malus*, including *Malus* 'Evereste' PERPETU in 1974), six varieties of *Forsythia* (including *Forsythia* 'Courtalyn' WEEK END in 1984), and eight varieties of *Weigela*, created between 1974 and 1990.

The SAPHYR partnership led to the submission of four *Pyracantha* cultivars resistant to fire blight and scab (the SAPHYR ® Orange, Rouge and Jaune range, 1988-1993). The SAPHINOV partnership enabled 12 INRA-GIE jointly bred varieties (one *Abelia*, one *Caryopteris*, one *Cotoneaster*, three clematis, four honeysuckle, one *Hydrangea*, one Lavatera) and two INRA varieties (one *Weigela* and one *Pachystegia*). Thirteen of these varieties were patented in the USA or Canada, in Australia or even Japan. This corresponds to a new policy for SAPHO which, before 2000, only filed for protection certificates in France. At present, all varieties are filed in Europe, and the most promising are filed simultaneously in other countries (particularly in the USA).

Overall, out of the 37 cultivars created, the breakdown between the major research areas was: eight cultivars providing resistance to parasites, 21 with a more compact habit adapted to cultivation constraints, and 17 enabling a diversification of colours. It should be noted that some cultivars could combine several of these criteria, and in all cases the cultivars retained met the other general criteria for ornamental quality (floriferousness, decorative foliage or fruits, etc.), hardiness and tolerance to diseases and parasites, as well as

good adaptation to production criteria in a nursery. At a detailed level, Cadic (2005) produced a table describing the breeding goals for INRA cultivars distributed until that time, and it is given below, as supplemented in 2014 with more recent varieties.

The use of plants placed in working collections for creation involved the development of **descriptors** for phenotyping before the use of individuals as genitors; INRA thus formalised morphological indicators to describe these collections. Because of a lack of descriptors that could be used to file applications for varietal protection, and because some of the collections compiled in the context of research programmes specific to INRA and with the GIE SAPHYR were exhaustive, these collections served as a starting point (like reference collections) for the establishment of UPOV (International Union for the Protection of New Varieties of Plants) descriptors used internationally when filing new variety applications. INRA staff compiled these descriptors which, after evaluation, reorganisation and translation, were retained as international guidelines by UPOV.

From a technical standpoint, different **protocols for molecular characterisation**, hybridization, *in vitro* culture or embryo rescue, developed by INRA, were or are used routinely by GIE staff. More exceptionally, it was possible for some protocols to be compiled by employees of the companies involved, but their lack of biotechnology facilities generally made it necessary for this work to be carried out at the INRA site or in nearby associated laboratories (such as at Agrocampus Ouest).

Furthermore, and still in the context of the EUROGENI and BRIO projects, **descriptive databases** were created in order to obtain a homogeneous description of all the plants in the collection. These descriptions (datasets) include both morphological data and, for some plants, cytogenetic data (DNA levels or even chromosome counting) and genotypic data (generally ISSR markers). In the context of the Eurogeni project, a **methodology for the orientation of varietal creation** for ornamental plants was developed by staff from INRA and Agrocampus Ouest. This methodology was tested in the context of the BRIO project, extending its application to herbaceous plants. The methodology gave rise to datasheets, which were delivered in their final written form at the end of the BRIO project (or generally during the second half of 2014), with the purpose of orienting the choice of parents and the varietal creation techniques to be implemented as a function of breeding objectives.

Genera	Cultivar	Brand name	Technique	Objective
<i>Abelia</i>	'Abenov41'	PINK PONG ®	Hyb ^{tion}	3, 5
<i>Buddleia</i>	'Courtabud'	OPERETTE ®	Polyp ^{tion} in-vitro	2
<i>Caryopteris</i>	'Inoveris'	GRAND BLEU ®	Muta ^{èse}	2, 3
<i>Clematis</i>	'Cleminov51'	SAPHYRA ® Indigo	Hyb ^{tion} interspéc.	2, 3, 4
	'Cleminov29'	SAPHYRA ® Duo Rose	Hyb ^{tion}	2, 3
	'Cleminov27'	SAPHYRA ® Estrella	Hyb ^{tion}	2, 4
<i>Cotoneaster</i>	'Belka'	SAPHYR ® Green	Hyb ^{tion}	1, 2
<i>Forsythia</i>	'Courtacour'	BOUCLE D'OR ®	Muta ^{èse} et Hyb ^{tion}	2, 4
	'Courtadic'	MELISA ®	Muta ^{èse}	2
	'Courtalyn'	WEEK-END ®	Muta ^{èse}	2
	'Courtaneur'	MELEE D'OR ®	Muta ^{èse} et Hyb ^{tion}	2, 4
	'Courtasol'	MARÉE D'OR ®	Muta ^{èse} et Hyb ^{tion}	2, 4
	'Courdijau'	CASQUE D'OR ® , GOLDEN PEEP ®	Muta ^{èse} et Hyb ^{tion}	2, 4
<i>Hydrangea</i>	'Inovalaur'	SEMIOLA ®	Hyb ^{tion}	2
<i>Lavatera</i>	'Inovera'	CHAMALLOW ®	Var ^{tion} somacl ^{ale}	2, 3
<i>Lonicera</i>	'Inov86'	CAPRILIA ® Imperial	Muta ^{èse}	2, 3, 4
	'Inov42'	CAPRILIA ® Ever	Hyb ^{tion}	2, 3, 5
	'Inov71'	CAPRILIA ® Cream	Muta ^{èse}	2, 3, 5
	'Inov205'	CHIC ET CHOC ®	Hyb ^{tion}	2, 3, 4
<i>Malus</i>	'Courtabri'	POMZAÏ ®	Hyb ^{tion}	1, 2
	'Courtarou'	COCCINELLA ®	Hyb ^{tion}	1, 3
	'Evereste'	PERPETU ®	Hyb ^{tion}	1
<i>Pachystegia</i>	'Hardec	DAIZEA	Hyb ^{tion} naturelle	4
<i>Pyracantha</i>	'Cadange'	SAPHYR ® Orange	Hyb ^{tion}	1
	'Cadaune'	SAPHYR ® Jaune	Hyb ^{tion}	1
	'Cadrou'	SAPHYR ® Rouge	Hyb ^{tion}	1
	'Cadvar'	SAPHYR ® Panache	Sport	1, 5
<i>Thuja</i>	'Courtapli'	VERIGOLD ®	Hyb ^{tion}	3, 5
	'Courtatu'	VERIVER ®	Hyb ^{tion}	3, 4
<i>Weigela</i>	'Courtadur'	GRENADINE	Muta ^{èse}	2, 4
	'Courtalor'	CARNAVAL	Polyp ^{tion} et Hyb ^{tion}	3, 4
	'Courtamon'	FELINE	Polyp ^{tion} et Hyb ^{tion}	4
	'Courtanin'	NAIN ROUGE	Muta ^{èse}	2, 4
	'Courtared'	LUCIFER	Polyp ^{tion} et Hyb ^{tion}	3, 4
	'Courtatom'	COULEUR D'AUTOMNE	Muta ^{èse}	3
	'Courtavif'	RUBIVIF	Muta ^{èse}	3
	'Courtacad1'	BLACK AND WHITE	Hyb ^{tion}	3, 5

Table 1: List of cultivars bred by INRA in Angers between 1972 and 2014 with the techniques used to create variability (Hyb^{tion}: hybridisation, Muta^{èse}: mutagenesis, Polyp^{tion}: polyploidisation, Var^{tion} somacl^{ale}: somaclonal variation) and breeding objectives (1: pathogen resistance; 2: habit; 3: colour; 4: diversification of use; 5: foliage traits (persistence, colour)) (from: Cadic, 2005, supplemented).

These outputs were also based on high-quality science, as tested by this sample of publications in journals with an international reputation:

Auvray G., Malécot V. 2013. A revision of *Cytisus* sections *Alburnoides*, *Spartopsis* and *Verzinum* (Genisteeae, Fabaceae). *Edinburgh Journal of Botany* 70 : 61-120.

Auvray G., C. Gouron C. & Malécot V. 2012. Floral morphology to discriminate taxa between and within *Cytisus* sect. *Alburnoides*, sect. *Spartopsis* and sect. *Verzinum* (Genisteeae, Fabaceae). *Plant Systematics and Evolution* 298 :

1827-1835.

Auvray G., Malécot V. (2011) Revised lectotypification of *Spartium scoparium* L. *Taxon* 60 : 1480-1481.

Decourtye L. 1978. Utilisation de la mutagenèse pour l'obtention de nouvelles variétés d'arbustes ornementaux. *Comptes rendus des Séances de l'Académie d'agriculture de France* 64 (8) : 664-669.

Decourtye L. 1986. Différents facteurs déterminant l'évolution de la gamme variétale en pépinière. *Comptes rendus des séances de l'Académie d'Agriculture de France* 72 (9) : 809-816.

Cambecédès J., Duron M., Decourtye L. 1991. Adventitious bud regeneration from leaf explants of the shrubby ornamental honeysuckle, *Lonicera nitida* Wils. cv. 'Maigrün' : effects of thidiazuron and 2,3,5-triobenzoic acid. *Plant Cell Reports* 10 : 471-474.

Cambecédès J., Duron M., Decourtye L. 1992. Interacting effects of 2,3,5-triobenzoic acid, 1-aminocyclopropane-1-carboxylic acid, and silver nitrate on adventitious bud formation from leaf explants of the shrubby honeysuckle, *Lonicera nitida* Wils. cv. 'Maigrün'. *Journal of Plant Physiology* 140 : 557-560.

Rosati C., Simoneau P., Treutter D., Poupard P., Cadot Y., Cadic A., Duron M. 2003. Engineering of flower color in *forsythia* by expression of two independently-transformed dihydroflavonol 4-reductase and anthocyanidin synthase genes of flavonoid pathway. *Molecular Breeding* 12(3) : 197-208.

Widehem C., Cadic A. (coordination éditoriale) 2006. *L'Horticulture ornementale française : structures, acteurs et marchés*. Collection « Un point sur ... », INRA-Éditions, Paris, 114 pages.

Flow of knowledge and intermediaries

For all the research programmes involving a GIE (e.g. SAPHYR, SAPHINOV, EUROGENI), the staff recruited by the GIE were wholly involved in INRA's activities. Partner companies in the GIE were closely involved through technical committees during whose meetings all the activities carried out and prospects for the future were considered. These technical committees also provided an opportunity for updates on the initial orientations of the programme and the availability of materials for trials. Under this system, INRA scientists assured the coordination and monitoring of activities, and also provided some of the technical expertise, participating in the orientations of varietal creation and training staff from the GIE. INRA scientists also produced numerous informative articles and communicated during congresses and meetings:

Arène L., Kapusta V., Cadic A., 2005: Une nouvelle variété de clématite. *INRA Mensuel*, 123:3-4.

Cadic A. La création variétale aujourd'hui: Obtention et diffusion en horticulture d'ornement. Journées Techniques
Astredhor, Lyon, Janvier 2006.

Kapusta V., C. Pesteil, A. Cadic. Diversity study and breeding of Brooms (tribe of *Genisteae*). XXII EUCARPIA Symposium
section Ornamentals, "Breeding For Beauty" 11-15 Septembre 2006, Sanremo – Italie.

Malécot V., N. Macquaire-Le Poceau, G. Auvray, V. Kapusta (2009) Polymorphic ITS as a tool to identify hybrids and their parents in cultivated *Genisteae* (Fabaceae). In: J.M. van Tuyl & D.P. de Vries (eds.) Proceedings, XXIII International Eucarpia Symposium, Section Ornamentals: Colourful Breeding and Genetics [Acta Horticulturae 836] : 91-96

From the start of these varietal creation activities, the distribution of INRA varieties was assured in partnership with 29 nurseries grouped under the name SAPHO. Set up at the initiative of INRA, SAPHO notably determines the cultivars to be protected by a COV and fixes their marketing volumes. Through an agreement with INRA, SAPHO has since 1974 assured the distribution of all INRA varieties in the ornamental sector, in France and in other countries. For the oldest cultivars (e.g. *Malus*), the fees received throughout the duration of protection (25 years and 30 years for trees; source OCVV) are shared between SAPHO and Agri-Obtentions, INRA's subsidiary responsible for distributing its cultivars. For cultivars resulting from a partnership with a GIE, the royalties are shared between SAPHO, Agri-Obtentions and the GIE concerned. In all cases, it is SAPHO that assures the promotion of cultivars and searches for production or distribution partnerships. In terms of distribution in other countries, SAPHO has modified its protection and distribution practices since 2006. Thus for all new cultivars,

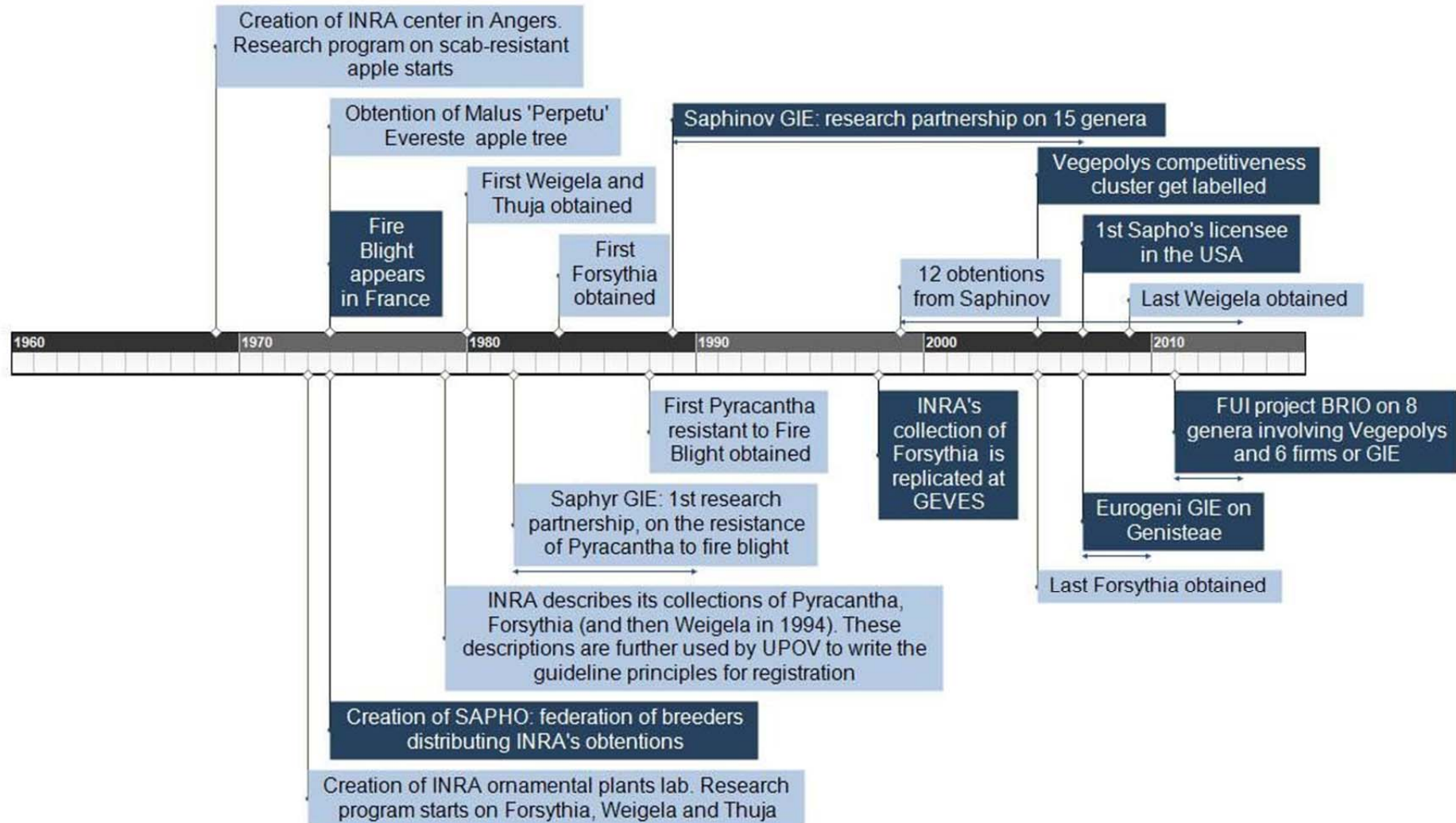
discussions are initiated regarding their international distribution. In order to comply with the delays regarding filing for a Plant Patent in the USA (a maximum of one year between the first sale in the world and filing of the claim in the USA), SAPHO envisages this filing from the start and looks for a US partner who could assure distribution. If such a partner is found, the application is made in the USA and in Europe. Historically, applications were made at a national level (e.g. *Malus* 'Evereste') and then at a European level, which frequently blocked subsequent protection in the USA. Finally, between 2006 and 2014, 12 cultivars resulting from collaborations with INRA were filed for patents in the USA, or for Plant Breeders Rights in Canada.

The Végépolys competitiveness cluster, set up in 2005, benefited from the discussions carried out at INRA in Angers on plans to create an innovation and transfer platform for ornamental plants. Through its varietal innovation platform (Valinov, which became Végépolys Innovation), Végépolys is a more recent partner, which in particular participated in extending varietal breeding activities to non-ligneous ornamentals (BRIO project). This involvement was characterised by the search for companies which might be interested in varietal creation, by the opportunities for exchanges with the INRA members concerned and in their possible close involvement in setting up and then implementing the BRIO project. Through this project, technical events for staff from the companies, and regular technical committee and management committee meetings, assured the day-to-day monitoring and transfer of information between both the direct participants in the programme (technical staff from the GIE, Végépolys, INRA and Agrocampus Ouest) and decision-makers (company managers).

The UPOV was an intermediary at quite another scale. Based on the Descriptions of Plant Collections compiled by INRA and forwarded to UPOV, this organisation subsequently compiled and validated its *Principes directeurs pour la conduite et l'examen des caractères de DHS* (Guidelines for the Management and Determination of DHS Traits) (*Berberis*, *Forsythia*, *Pyracantha*, *Weigela*). Validation of these guidelines by the UPOV resulted in their theoretical use by all countries belonging to this Union, when the breeders of new cultivars in these genera applied for protection certificates.

The GEVES (Variety and Seed Study and Control Group; *Groupe d'Etude et de contrôle des Variétés Et des Semences*) is also an intermediary insofar as, for a certain number of collections, it assures the long-term conservation of collections set up in the context of research programmes by allocating them a new function, that of being a reference collection for DNS tests. Furthermore, it includes in its procedures the comparative criteria listed in the UPOV evaluation guidelines.

Chronology



Events directly involving INRA

Other events (context...)

Impacts 1

Economic

Creation of new markets in the ornamental sector

At the final distribution stage (at various ages, ranging from a small pot to a fully-formed tree, in a nursery for individual consumers and for companies distributing to local government bodies and landscape gardeners), INRA varieties represented a market worth around €150 million cumulated over the period 1985-2014 (i.e. without counting the first ten years, when income mainly resulted from *Malus 'Evereste'*). More than a third of this turnover (€58 million) corresponded to the creation of new markets. Indeed, some INRA-GIE cultivars enabled the creation of new markets by causing a genus to be used in a new context. Thus a French market for *Forsythia* used for landscaping developed, with a value of nearly €1.2 million in 2014 and a total of €35 million since 1985 (between 1985 and 2014, 4.4 million plants) (as opposed to use in private gardens previously) and a French markets for *Lonicera* (€1 million in 2014 and a total of nearly €6.5 million between 2009 and 2014, with 430,000 plants) et clematis (more than €150,000 in 2014 and a total of nearly €1.5 million between 2005 and 2014, with 74,000 plants) grown in pots rather than in the open soil. In the case of *Caryopteris*, this is an entirely new market with a value of more than €1 million for 2014 alone, and more than €15 million since the plants were first sold (a total of 1.6 million plants between 2000 and 2014), which has developed because this genus was almost not marketed previously.

Stimulation and reorganisation of private research: impacts on breeders

Sharing of research through the creation of Economic Interest Groups (GIE):

Through its investment in research on the varietal breeding of orphan species, and in the context of initially informal collaborations, INRA encouraged some of its partners in the ornamental sector to organise themselves around research GIE (SAPHYR, SAPHINOV, EUROGENI) and a dedicated distributor (SAPHO). In addition, development of the BRIO project provided an opportunity for eight companies to share their R&D on *Hydrangea*, and set up a simplified joint stock company (*Société en Actions Simplifiées*, SAS Hydranova) which employed a breeder. Focused successively on areas of mutual interest to breeders, these GIE and the SAS enabled the sharing and long-term stability of human and physical resources and of knowledge, and ultimately boosted varietal creation by both INRA and the private sector. Table 2 shows the rise in private sector investment in research through the funding of GIE activities since the 1980s.

Name of GIE	Period	Total funding from companies	Annual funding from companies
SAPHYR	1982-1990	195 000	22 000
SAPHINOV	1989-2007	918 000	48 000
EUROGENI	2006-2008	168 000	56 000
EUROGENI part of BRIO	2010-2014	415 000	80 000

These activities markedly oriented the breeding policies of the nurseries involved, particularly by highlighting the value of internal R&D rather than the marketing of varieties bred elsewhere. According to the interviews carried out with private sector partners, without the new INRA or INRA-GIE varieties some of the partner companies could not have survived ("without innovation, the companies would have died").

As well as the rise in shared private investment through the funding of research by the GIE, the dynamic for varietal creation driven by INRA led some of its partners to increase their own involvement in R&D. Thus from 2006, one partner breeder set up its own R&D department. Since then, one person has been allocated full-time to varietal creation.

Orientation of R&D programmes and increase in their productivity:

The methodological data sheets on the orientation of varietal creation that resulted from the discussions implemented under the EUROGENI programme were used in a preliminary form during the BRIO project by INRA's partner breeders, and led GIE staff to categorise hybridisation trials as a function of their intrinsic difficulty. Thus in the context of the GIE Hydranova (partner in the BRIO programme), crossings were preferred or excluded according to this methodology, and the implementation of certain protocols (e.g. *in vitro* culture) was

planned for certain crosses and not for others. Similarly, in the context of the breeding programme on *Hibiscus*, new orientations appeared because of the results of this methodology. These data sheets thus had an impact on the productivity of private research by enabling the early elimination of less effective crosses.

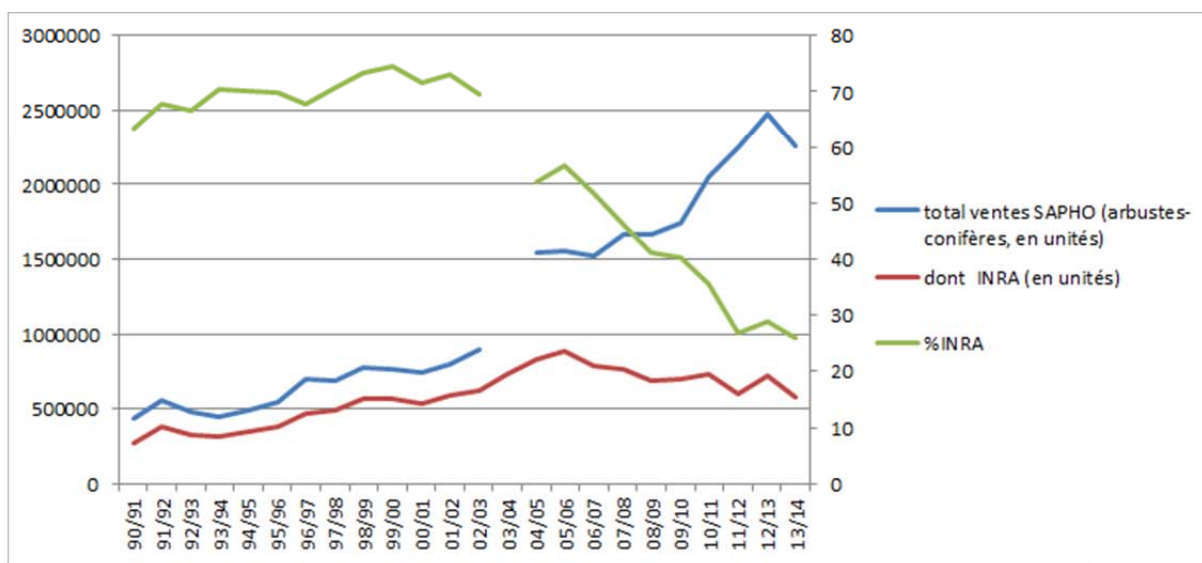
Increase in varietal creation:

It is more or less certain that some cultivars were the origin of other cultivars submitted by INRA, by its partners or by other breeders throughout the world. In particular, three clematis, one *Caryopteris* and seven *Forsythia* (including five in other countries) submitted by private sector actors probably resulted from INRA genetic materials. By contributing innovation (such as new morphologies) and overcoming obstacles to selection (such as interspecific hybrids), INRA or INRA- GIE cultivars probably thus drove varietal creation in the private sector. Furthermore, development of the niche markets referred to above boosted private breeding even more, and new varieties were submitted for these markets; since 2008, five French cultivars of *Clematis*, and since 2007 two varieties of *Caryopteris*, one Dutch and the other French. On the other hand, for *Pyracantha*, the varieties resistant to fire blight and scab that were bred by INRA replaced previous, susceptible cultivars, thus causing a switch in the market.

Creation of turnover by breeding nurseries

SAPHO nurseries, distributors of INRA varieties:

INRA varieties (bred alone or in partnership) formed the basis for the SAPHO catalogue (nearly 70% of the volumes sold during the 1990s), and have achieved cumulated sales worth more than €15.5 million since 1990 (young plants). These sales generated royalties worth more than €4 million, paid by SAPHO's customer nurseries and shared between SAPHO and INRA during the same period. Since the 2000s, because of the quality of these varieties and the market expertise it has acquired over time, SAPHO has grown and broadened its catalogue to varieties developed by other breeders (particularly since 2003; see Graph 1). This policy has led to a mechanical reduction in the share of INRA cultivars, whose sales through SAPHO have generally remained stable (Graph 1). Wholly INRA varieties, and those jointly bred, are perceived by the partners as a trading currency with other companies in order to gain rights to the distribution of cultivars obtained in other countries, and notably the UK, the Netherlands and North America (e.g. *Weigela* 'Courtacad01' and the CAPRILIA range of *Lonicera*). That said, according to the figures from partners in research and distribution, the sales volumes of cultivars bred jointly with INRA have been falling according to a quite classic "ageing" phenomenon that has affected these varieties (cf. Graphs 6 to 9 below). Furthermore, they noted that following a change to INRA's orientations during the 2000s on the breeding of ornamentals that limited creations by INRA, there is a risk that a future for new varieties may not be assured.

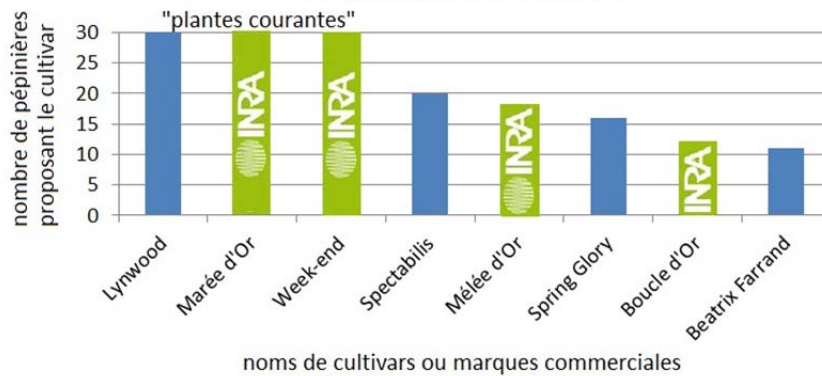


Graph 1: Evolution of sales of wholly INRA and jointly bred varieties relative to total sales by SAPHO between 1990-91 and 2013-2014, according to the number of units (red and blue curves, left-hand scale) and the percentage of INRA sales relative to SAPHO's total sales (green curve, right-hand scale) (source: SAPHO).

Adoption by all French nurseries:

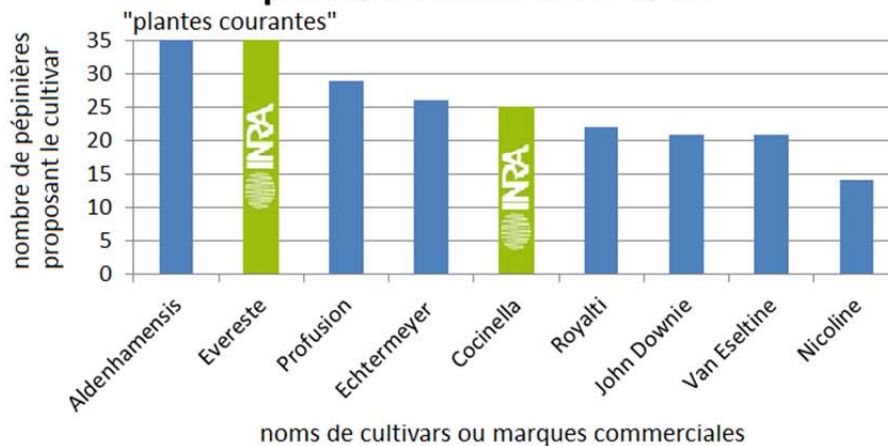
In the absence of any recent documentation enabling an evaluation of the adoption of cultivars by French breeding nurseries, the work entitled "35,000 plants" was nevertheless able to determine the relative presence of INRA cultivars in nursery catalogues. This publication, which dates from 1997, listed all the nurseries holding each cultivar, based on the 179 French nurseries listed in the "trees and shrubs" category. In 1997, INRA *Forsythias* ranked among the eight most common cultivars in the catalogues (out of 27 *Forsythia* cultivars recorded), two of them qualified as "common plants", or in other words present in the catalogues of the great majority of nurseries. The *Malus* were among the five most common cultivars (out of the 41 cultivars recorded, with two INRA cultivars being qualified as "common"), the *Pyracantha* among the seven most common (out of the 24 recorded) and *Weigela* among the 20 most common (out of the 53 cultivars recorded, including one "common" INRA cultivar). Graphs 2 to 5 represent the number of French nurseries selling the most common cultivars in each genus, with the green bars corresponding to INRA varieties.

cultivars de *Forsythia* les plus distribués en France



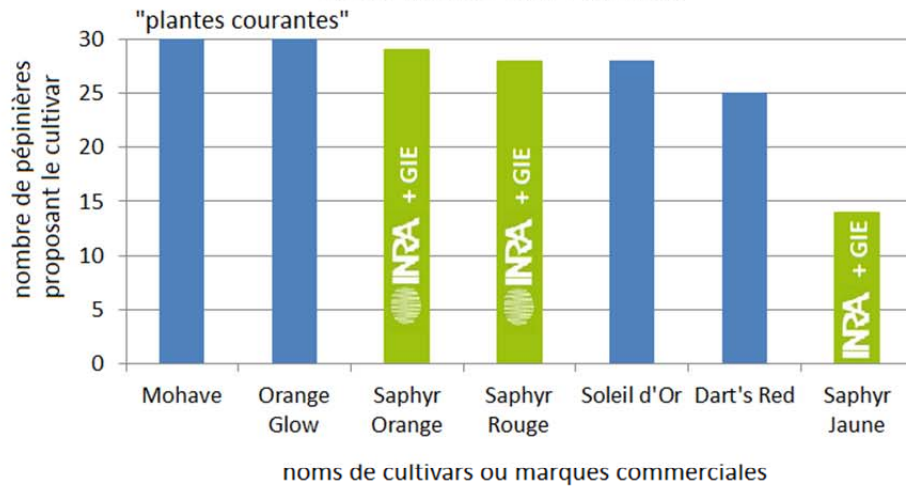
Graph 2: Number of nurseries offering the eight main *Forsythia* cultivars (out of the 27 recorded in the catalogues), according to "35,000 plants" in 1997.

cultivars de *Malus* d'ornement les plus distribués en France



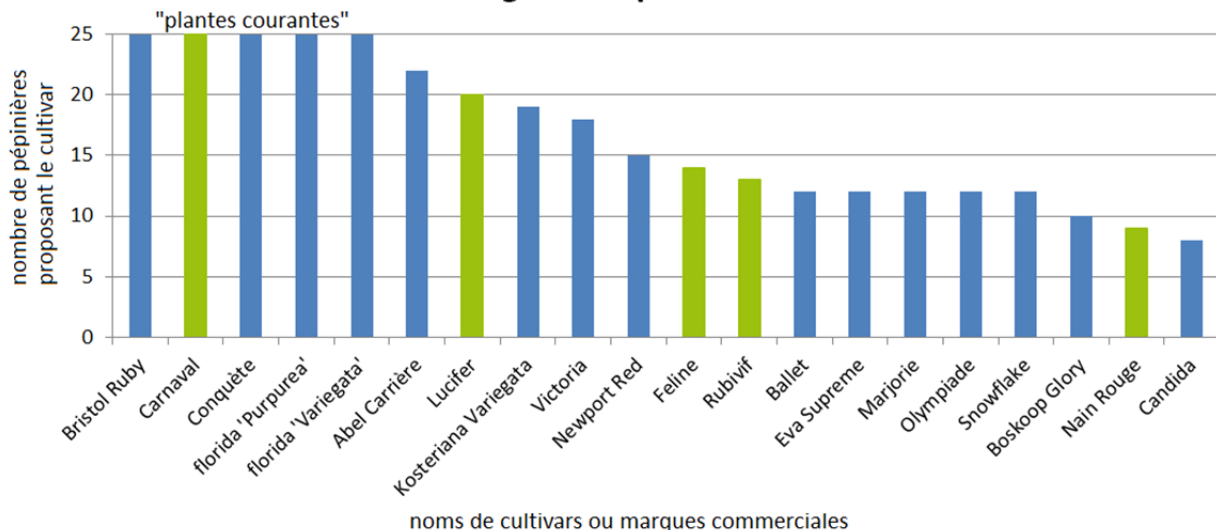
Graph 3: Number of nurseries offering the nine main ornamental *Malus* cultivars (out of the 41 recorded in the catalogues), according to "35,000 plants" in 1997.

cultivars de *Pyracantha* les plus distribués en France



Graph 4: Number of nurseries offering the seven main *Pyracantha* cultivars (out of the 24 recorded in the catalogues), according to "35,000 plants" in 1997. INRA varieties are in green.

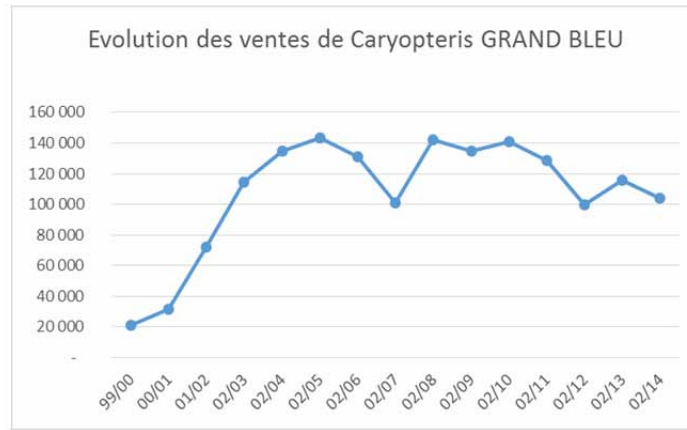
cultivars de *Weigela* les plus distribués en France



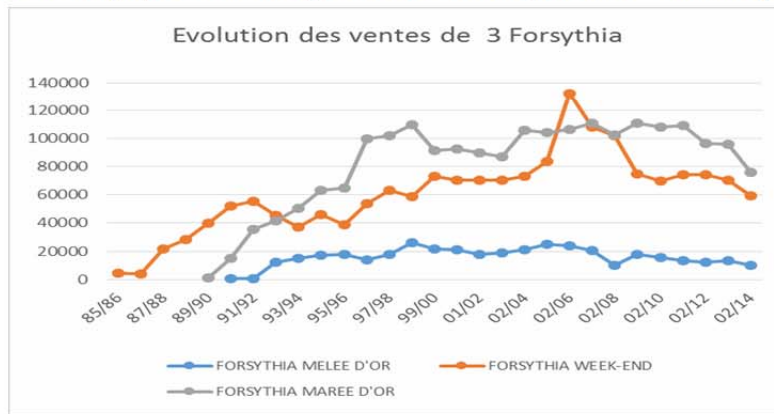
Graph 5: Number of nurseries offering the 20 main *Weigela* cultivars (out of the 53 recorded in the catalogues) according to "35,000 plants" in 1997. INRA varieties are in green.

The companies made repeated mention of the driving effect that INRA varieties had had on the rest of their catalogues. For sales to local government bodies and landscapers, an evaluation of this impetus could have been envisaged by counting the markets that include INRA cultivars relative to all the markets obtained by the companies. However, these figures do not exist, and could not be obtained in the context of the present study. At most, one could say that in volume terms, sales by one of the partner companies comprised at least 10% of varieties distributed by SAPHO. Furthermore, the sales volumes, and maintenance of these volumes for certain cultivars, as well as the ease at finding calls for proposals referring to them, indicate that these cultivars have become "standards" in their fields, particularly in the ranges used by landscape architects and hence in the calls for tenders issued by local government bodies.

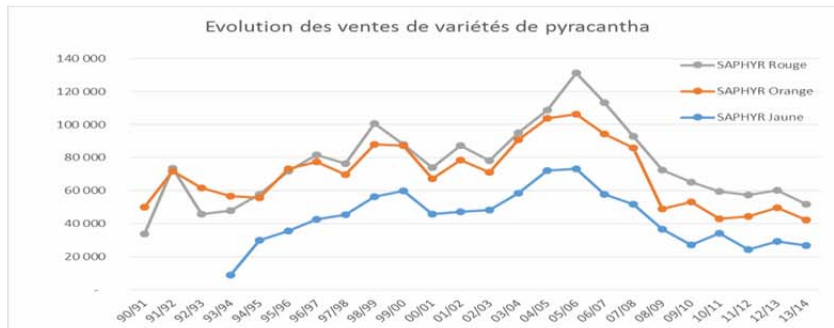
A final economic impact on nurseries concerned the reduction in losses through the cultivation of disease resistant varieties (against fire blight and scab, in particular), but it was not possible to evaluate this effect.



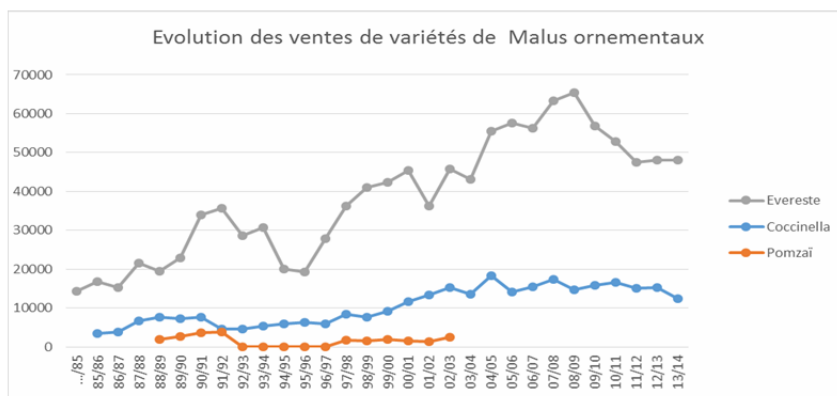
Graph 6: Evolution of sales of *Caryopteris* showing a relative stability of sales volumes (source: SAPHO)



Graph 7: Evolution of the sales of three Forsythia cultivars showing a slight downturn in sales volumes (source: SAPHO)



Graph 8: Evolution of the sales of three *Pyracantha* cultivars showing a downturn in sales volumes (source: SAPHO)



Graph 9: Evolution of the sales of three ornamental *Malus* cultivars showing the downturns in sales of 'Evereste' and 'Cocinella' and the halt to the commercialisation of 'Pomzaï' in 2003 (source: SAPHO)

Reduction in costs for local government bodies

Without being direct partners in INRA activities, local government bodies have gradually modified their tree management practices, particularly by reducing the intervals between pruning operations. These changes could be correlated with the market availability of compact varieties resulting from INRA programmes, but such a direct link is not proven, because many other species are planted in the green spaces managed by these bodies. The adoption of compact INRA varieties would notably reduce transport and labour costs.

Environmental

Some varieties have been selected specifically for their disease resistance (fire blight, scab), while in other cases research laboratories and nurseries have focused on only retaining those with a satisfactory tolerance of the main diseases and pests (mildew, Botrytis, aphids); this enables better crop health during production and then in green spaces and gardens, which is sure to imply a reduction in treatments, even though it is difficult to quantify this due to the dispersion of crops.

Political

Scoring grids, and above all the living collections built up and made available by INRA and the GIE for the four genera *Weigela*, *Berberis*, *Forsythia* and *Pyracantha*, have constituted a valuable tool for the implementation of European policies on the approval of ornamental varieties. They thus caused the CPVO (Community Plant Variety Office) to delegate the evaluation of European DHS dossiers to the GEVES. The specialisation thus acquired by the GEVES gave it visibility and credibility regarding its expertise. The first collections sent by INRA to the GEVES had a driving effect, allowing the GEVES to build up collections on other ornamental plant genera (*Albizzia*, *Buddleia*, *Magnolia*, *Wisteria*, etc.) or to recover collections from certain partners (*Pyracantha* and *Hydrangea* managed by Agrocampus Ouest until 2005). These collections provided the foundations of reference collections for the technical examinations necessary for the granting of European Plant Variety Certificates.

Most of these collections were also accredited as National Collections by the *Conservatoire des Collections Végétales Spécialisées*, CCVS. This accreditation, intended for informed amateurs, offers another - if limited - way to exploit the collections built up in the context of varietal creation programmes.

INRA's outputs have also contributed to the formulation of international regulations. Thus some of the descriptions of the collections developed in the context of research programmed served for the compilation of UPOV guidelines on the genera considered. Thus the *Principes directeurs pour la conduite et l'examen des caractères distinctifs, de l'homogénéité et de la stabilité* (DHS) for the *Forsythia* (UPOG/TG/69/3 dated 1979), *Berberis* (UPOV/TG/68/3 dated 1979), *Pyracantha* (UPOV/TG/147/2 dated 1994) and *Weigela* (UPOV/TG/148/2 dated 1994) genera were directly based on the material used during varietal creation programmes. For this reason, all the structures evaluating DHS for these genera must apply these criteria. These international UPOV guidelines have themselves been transposed at a European level by the CPVO (Community Plant Variety Office) (CPVO-TP/148/1 for *Weigela*, CPVO/TQ-069-EN for *Forsythia*, CPVO/TQ-147-EN for *Pyracantha*).

Support for the implementation of health policies

The *Pyracantha* and ornamental *Malus* cultivars resistant to fire blight and scab replaced the susceptible varieties that were still present on the market. This represented a major step forwards regarding the prevention of these two diseases, both in ornamental hedges and in terms of preventing their spread to fruit orchards. The *Malus* and *Pyracantha* cultivars resistant to fire blight offered a technical solution following the 1994 decree that banned the introduction of ornamental or fruit varieties susceptible to fire blight.

Impacts 2

Economic

The constitution and continuation of SAPHO provided isolated breeders with an opportunity to distribute their varieties at an international scale. INRA and INRA-GIE varieties served as triggers for this system. Indeed, SAPHO achieved 40% of its turnover at export in 2003, and one of SAPHO's customer nurseries reports that exports accounted for more than 45% of its sales of SAPHO varieties.

Indirectly, certain ornamental apple varieties led to a change in cultivation practices in eating apple orchards. Because the ornamental cultivars are highly floriferous over a long period, and resistant to diseases (scab, mildew), they are used as pollinators instead of mixed or secondary varieties (cross-pollination being obligatory for apple).

This use enabled an increase in the density of trees of the principal variety. Thus while classic arrangements involved a ratio of 1:2 or 1:3 between the pollinating variety (secondary) and the principal variety, the use of ornamental apples enabled a reduction in this proportion to 1:8 (cf. Trillot, 1986). The pollinating/productive apple ratio was thus halved, thus causing a marked increase in yield (number of apples of the principal variety*1.75).

Furthermore, the choice of planting ornamental cultivars as pollinators was made in the context of changes to orchard planting schemes, with the development of single-variety orchards with a high planting density. Thus before the 1970s, there were about 900 trees per hectare (or 450 of the principal variety and 450 of the secondary variety), while at the end of the 1970s, the planting density was close to 1550 trees (including 1/8 ornamental pollinators, or 172 exclusively pollinating trees and 1375 of the principal variety) (cf Lousteau et al., 1982). The introduction of pollinating cultivars thus enabled a doubling in the density of orchards (number of apple trees*2). This change to orchard planting schemes, necessarily involving ornamental cultivars as pollinators, thus almost quadrupled yields of the principal variety of apple.

INRA cultivars were partly the result of research on ornamental varieties by the Joint Research Unit for Genetics and Horticulture (UMR GenHort) (particularly *Malus* 'Evereste' bred in 1974, as well as *Malus* varieties resulting from crosses performed in 2002 and still registered by SAPHO), and partly the result of breeding programmes on eating apples by INRA's Fruit Tree Research Unit in Angers (notably Golden Gem, 'Baugène', distributed by Novadi).

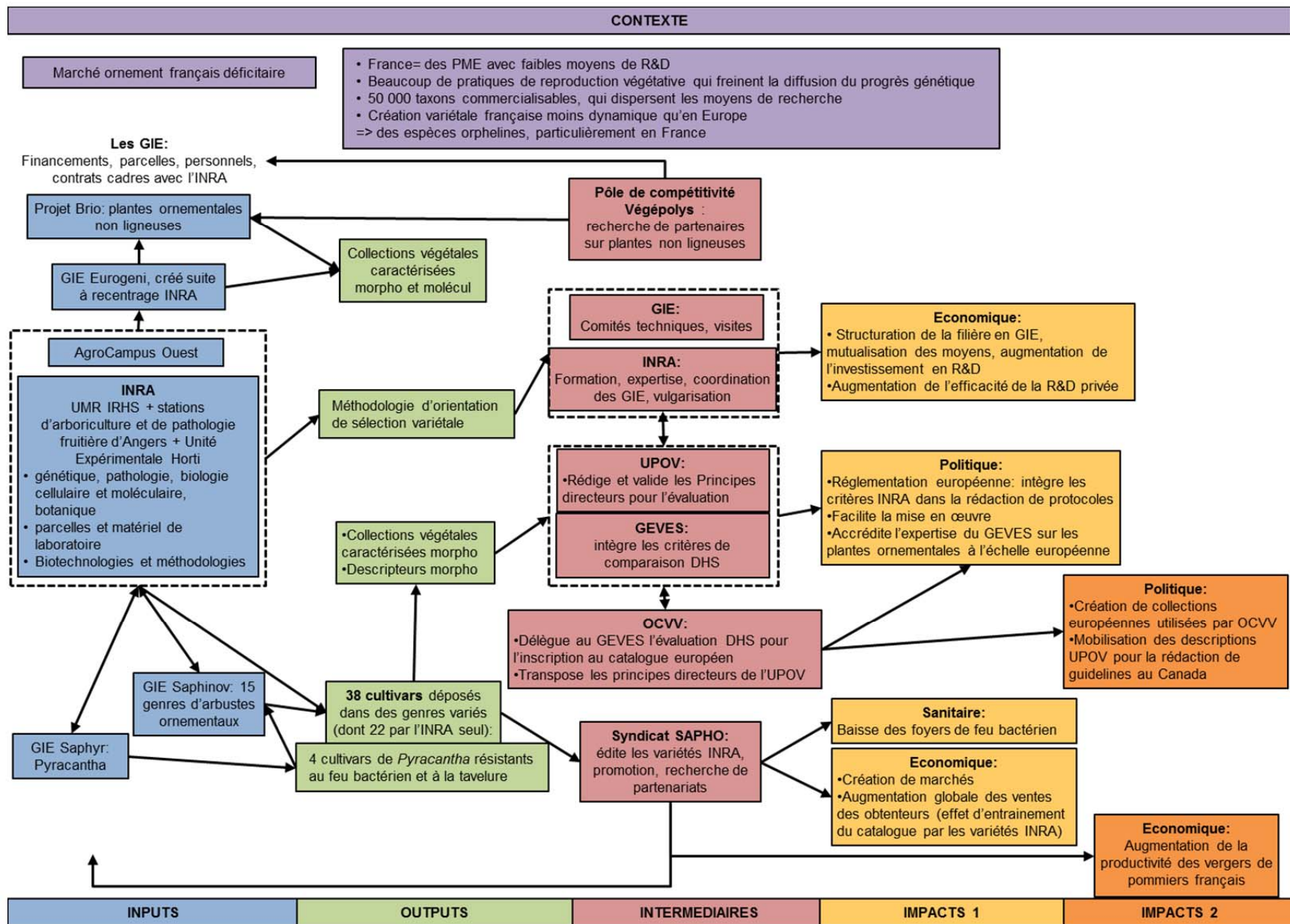
In 2015, all French orchards now use ornamental pollinators, a great majority of which are INRA cultivars (and indeed recommended by the CTIFL: Trillot et al., 2003). A more detailed study could clarify the French and foreign orchard areas using INRA cultivars and their associated economic gains (linked to the doubling of yield per hectare and the improved economic exploitation of the principal varieties when compared with secondary varieties), which are probably substantial.

For *Malus* 'Evereste' alone, taking the hypothesis that 50% of the one million plants sold since 1984 went to apple growers (and the other 50% to local government bodies), who used them in equal proportions with another ornamental pollinator, *Malus* 'Golden Gem' (according to the recommendations of Trillot et al. 1993), then 5800 ha of French orchards have been cultivated with *Malus* 'Evereste' since 1984 (or 13% of the 45,000 ha of French apple orchards in 2013). This figure is only indicative because it does not take account of:

- the sales of *Malus* 'Evereste' between 1974 and 1984 (because of a lack of data on that period) and the private propagation of ornamental apples carried out directly by apple growers. These factors would tend to increase the land planted with *Malus* 'Evereste'.
- The renewal of *Malus* 'Evereste' trees during this 40-year period, which could reduced these estimated areas by half.

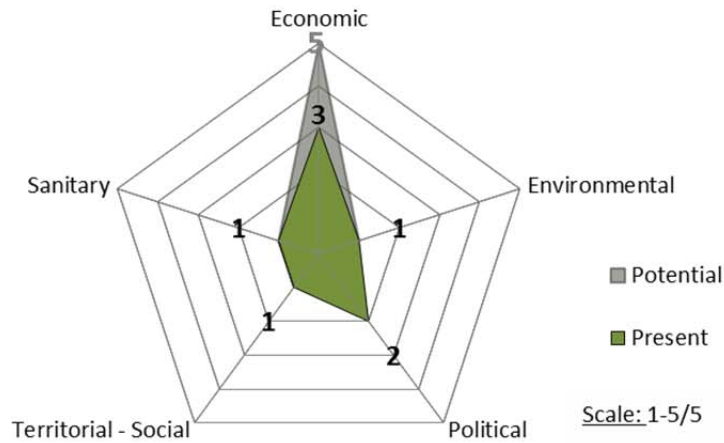
Political

The varietal criteria formulated by INRA and adopted in the UPOV guidelines informed international policies with respect to approvals, and particularly the production of guidelines pour variety registration tests in Canada. In the UPOV PLUTO database (which records all Plant Variety Certificate applications and plant patents at a global level), note can be made in particular of *Weigela* varieties protected in Canada and Japan whose evaluation used guideline tests based on the UPOV technical guidelines. Similarly, *Forsythia* that received a plant patent in the USA were described and tested using documents derived from UPOV technical guidelines.



Impact vector

Impact dimension	Importance	
Economic	3/5	€1.6 million invested since 1982 by companies in shared research through the GIE. Creation of 37 cultivars, which has sustained the economic activity of some companies in the sector.
	Potentially 5/5	<p>Creation of SAPHO, 70% of whose sales were INRA cultivars in 1990.</p> <p>INRA cultivars are amongst the eight best sales by nurseries in each of the four genera studied since 1997 (<i>Forsythia</i>, <i>Malus</i>, <i>Pyracantha</i>, <i>Weigela</i>). They have enabled turnover worth €150 million for distributors since 1985. These cultivars are also an exchange currency for nurserymen.</p> <p>INRA methodologies orient the crossings and protocols implemented by nurseries, thus increasing the productivity of breeding schemes.</p> <p>Acceleration of private breeding, introduction of traits of economic interest (compact habit) and finding solutions for breeding obstacles.</p> <p>Creation of French markets for landscaping <i>Forsythia</i>, potted clematis and <i>Lonicera</i> and <i>Caryopteris</i> = a total of €58 million up to 2014.</p> <p>Cultivars of INRA ornamental apple are used as pollinators instead of secondary varieties; they have enabled a doubling in the density of apple orchards and an increase (*1.75) in the proportion of productive trees from the principal variety by replacing the secondary variety => economic gains linked to doubling the yield per hectare and better economic exploitation of the principal varieties. In 2015, all French orchards were using ornamental pollinators, among which INRA cultivars (<i>Malus</i> 'Evereste' and 'Baugène' Golden Gem) are strongly recommended. Evereste alone has covered nearly 13% of the surface of French orchards since 1984.</p>
Environmental	1/5	Creation of varieties resistant to fire blight and scab: reduction in treatments
Sanitary	1/5	<i>Pyracantha</i> and <i>Malus</i> resistant to scab and fire blight (quarantine organism) have contributed to limiting their spread.
Political	2/5	<p>Support for the implementation of European accreditation policies:</p> <p>INRA-GIE scoring grids and collections are used as references by the GEVES for the registration of ornamental varieties. They have thus formed the basis for the implementation of European policies by the CPVO regarding the registration of ornamental varieties by supporting delegation of the DHS procedure to the GEVES. Support for the implementation of French health policies:</p> <p>The <i>Pyracantha</i> and <i>Malus</i> cultivars resistant to fire blight offered a technical solution following the 1994 decree banning the introduction of blight-susceptible ornamental or fruit varieties.</p> <p>Contribution to the formulation of European and international regulations:</p> <p>The descriptions in collections guided the compilation of the guidelines on the UPOV management and DHS procedures. These guidelines were transposed at a European level (CPVO) and influenced those used for registration tests for varieties in Canada and Japan.</p>



Data Sources

FranceAgriMer 2014, Observatoire structurel des entreprises de l'horticulture et des pépinières ornementales

Lousteau P., Jacoutet I. et Brossard D., 1982. La pomme de table en France – production, commerce extérieur, consommation, évolution et formation des prix. CTIFL, 64 pages.

Oghina-Pavie, C. Sept histoires de recherche agronomique en Anjou. 2006. Ed Terre des Sciences et INRA Centre d'Angers, 55pages.

Trillot M., 1986. La conception du verger. Pp. 19-27 dans Decourtye L., Lemoine J., Le Lezec M., Tasei J.-N., Thibault B. et Trillot M. Pollinisation poirier pommier. CTIFL.

Trillot M., Massseron A. et Tronel C., 1993. Pomme – les variétés. CTIFL, 202 pages.

Widehem C., Cadic A., (coordination éditoriale), 2006. L'Horticulture ornementale française : structures, acteurs et marchés. Collection « Un point sur ... », INRA-Editions (Ed.), 114 pages.

Alain Cadic, retired INRA scientist Bernard Le Pautremat, GEVES

Yves Lespinasse, retired INRA scientist Olivier Pantin, SAPHO

Patrick Pineau, Pépinières Minier

Eric Renault, SAPHO and Pépinières Renault