

ASIRPA

*Socio-economic analysis of the diversity of
Impacts of Public Research for Agriculture*

**Platanor®: a series of plane
(Platanus sp.) accessions resistant to
canker stain**

Executive Summary

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Didier Andrivon

Summary

This case study shows how long-term research, carried out with the support of local authorities, helped develop new genetic resources to contribute to preserving natural landscape heritage threatened by an invasive plant disease. It details the efforts carried out by INRA to breed plane (*Platanus* sp.) clones adapted to the Mediterranean climate and resistant to the quarantine pathogen *Ceratocystis platani*, a fungal parasite of planes and sycamores which infects plane roots and bark and imposes felling as the only preventative measure to limit the spread of disease. The issue is all the more pressing that the pathogen, introduced from its native America during WWII, now spreads along the Canal du Midi, a UNESCO World Heritage site.

The work started with the introduction of resistant plane progenitors from America in the early 1990s, followed by a series of crossing operations with locally adapted germplasm. At the same time, the first reliable resistance screening test was developed and validated, and used throughout the breeding programme to screen progenies for resistance to *C. platani*. The first commercial clone derived from these operations is called Vallis Clausa (after the region where it was bred, Vaucluse in Southern France), and marketed as part of a commercial line called Platanor®. Vallis Clausa was granted property rights (Certificat d'Obtention Végétale in 2008), and further additions to the Platanor® line, derived from a second series of crosses involving also resistance progenitors to other plane diseases (anthracnose) and pests (plane tiger) are expected in 2014-2015.

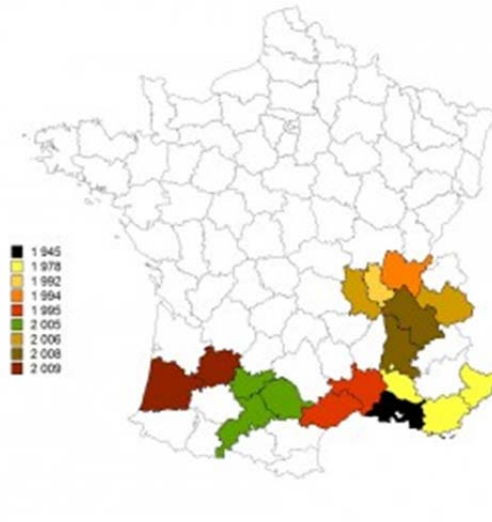
The primary impacts from this programme are twofold. One is the development of genetic material allowing to enforce more satisfactorily the mandatory control measures destined to limit the spread of *C. platani*. While these measures consisted before exclusively in the removal of infected trees and prohibition of new plane plantations on infected sites, the development of the Platanor® clones now offers the opportunity to replace infected trees by young resistant ones, thereby preserving the original landscapes and benefiting from the services provided by these emblematic trees in both urban and rural settings. The second impact is an economic one. The trees were licensed to a corporate tree multiplier (Pépinières Rouy Imbert or PRI), who was the exclusive attributor of the multiplication license. Since the marketing of Platanor® Vallis Clausa started in 2006, about 6000 trees were sold in France and neighbouring countries (Spain, Italy, Switzerland), for a gross estimated turn-over of 3.6M€. Unfortunately, PRI went bankrupt in 2012 and the diffusion of the resistant material is now compromised. INRA is currently working on new agreements to resume the distribution of the Platanor® clones, including the second generation ones which should be ready by 2015. The estimated market is over 20 M€ for the replacement of the Canal du Midi planes alone, and the potential market is much larger when considering both the urban and rural roadsides in France, but also the foreign markets in the whole Mediterranean area. A major secondary impact is the preservation of unique heritage landscapes, like the Canal du Midi, thanks to the development of this innovative set of tree genotypes.

Context

Planes (*Platanus* sp.) are large trees widely used along roadsides and waterways in southern France and the Mediterranean basin. Their large leaves and canopy provide welcome shade, and their root system is also very useful in maintaining canal and river banks. They contribute to the aesthetic quality of roadways in most Mediterranean areas, and as such are part of local natural heritage.

Canker stain, caused by the fungus *Ceratocystis platani* (*Ceratocystis fimbriata*), is a fatal disease that attacks planes and sycamores. The pathogen is of American origin, and came to France during WWII via ammunition casks made from infected wood. Reports of the disease in Marseille go back to 1945; since then, the disease has been spreading rapidly over the past 20 years throughout southern and south-western France, where plane trees (*Platanus orientalis*) commonly line roads and waterways (see map). Since 1992, about 1,300 plane trees have been felled in the Rhone-Alpes region alone, and approximately 50,000 have been felled in all of France over the past 50 years. The disease is now spreading in France's Midi-Pyrénées region, notably along the Canal du Midi, a major and historical waterway listed as a UNESCO World Heritage site. It is also present in Italy, Greece, Spain and possibly other Mediterranean countries.

Canker stain has been spreading in southern France since the first report of the disease in 1945. Source : <http://www.fredonra.com/collectivites/le-chancre-coloire-du-platane/>



The pathogen is wind-borne and easily dispersed, infecting trees through wounds (especially after pruning) or roots, and spreading through the medullar rays. It leads to discoloration of bark and wood, and ultimately kills trees by upsetting sap flow. Because of the internal progress of the pathogen within infected trees, there is currently no efficient chemical control solution available, and prophylactic measures are primarily relied upon (felling and removal of infected trees; careful disinfection of pruning tools, etc.). In 1978, the European and Mediterranean Plant Protection Organisation (EPPO) listed *Ceratocystis platani* on the A2 Quarantine List (an inventory of organisms harmful to plants and requiring mandatory control measures to prevent their spread or achieve eradication; [http://archives.eppo.int/EPPOStandards/PM1_GENERAL/pm1-02\(22\)_A1A2_2013.pdf](http://archives.eppo.int/EPPOStandards/PM1_GENERAL/pm1-02(22)_A1A2_2013.pdf)).

Inputs and productive configuration

Research objectives and INRA skills

Research on plane canker began at INRA Avignon in the mid 1980s following the first severe outbreaks of the disease in southeastern France. Researchers were able to decipher its etiology, gather key epidemiological data, and develop several methods to detect and prevent the disease.

All attempts to develop chemical control solutions have been unsuccessful to date, leading to the conclusion that genetic resistance is the only sustainable way to reduce prevalence and curb the effects of the disease. However, no resistant plane accession adapted to Mediterranean conditions has been available so far. Because plane breeding is a very long and difficult process, corporate players were not involved in actively searching for resistant material. This prompted INRA to develop a breeding programme targeted to canker stain resistance.

Research to develop resistant plane clones, carried out by Dr André Vigouroux, started in the early 1990s. Common plane (*Platanus acerifolia*) is a hybrid between the North American *Platanus occidentalis* and the Mid-eastern species *Platanus orientalis*. To breed resistant clones from controlled hybrids, several accessions of *Platanus occidentalis* (resistant to canker stain but susceptible to anthracnose) were imported from the USA in 1990, while *Platanus orientalis* clones (resistant to anthracnose and adapted to Mediterranean climate) were provided by the Forestry Division of INRA (experimental Unit from Bormes les Mimosas). Two sets of hybrids were produced: the first aimed at introducing stem canker resistance into planes adapted to the Mediterranean climate, while the second aimed at combining this resistance with resistance to other pests and diseases (e.g. anthracnose, plane tiger) also affecting planes.

Within this project, INRA manages the collection of plane genetic resources (33 parental clones of *P. occidentalis* and *P. orientalis*, as well as 20 hybrids already assessed from the first crosses and 100 under selection from the second set). Five trees per clone are kept, and multiplied through cuttings to allow their

eventual transfer to other sites, the original trees having grown too large to be safely moved. INRA also manages a collection of *C. platani* isolates, and operates the breeding scheme it developed.

All experiments were carried out by the Plant Pathology unit of SPE in Avignon, including the experimental site of Les Banettes (leased by INRA) under an agreement with the French Plant Protection Service (required since the pathogen is quarantined).

Resources

INRA contributions

INRA provided the bulk of the resources dedicated to this programme. The breeding activities and maintenance of genetic resources required significant input from INRA in terms of human resources (see table 1). Dr André Vigouroux led this project until his retirement in 2003. He was commissioned by INRA for one additional year to complete the assessment of the original clones derived from the first set of hybrids, and at that time started the second series as well. To complete the programme, SPE remained active throughout, even after research ceased with the retirement of André Vigouroux in 2004.

Table 1: INRA human resources dedicated to plane breeding programme

	1990-2003	2004-2006	2007-2009	2009-2013
A Vigouroux (INRA, Research Director)	Senior scientist, Project head	Scientific advisor	Scientific advisor	Scientific advisor
JP Jullian (INRA, Research Technician)	Experimental activities	Experimental activities	Experimental activities (until 2008)	
MH Daurade (INRA, Research Technician)	Experimental activities (until 2000)			
R Olivier (INRA, Assistant Engineer)	Trial supervision	Project leader*		
P Nicot (INRA, Research Scientist)**			Project leader	
C Troulet			Trial supervision	Trial supervision (until 2010)
Experimental infrastructure team	assistance with trees	assistance with trees	assistance with trees 220 h in 2008 310 h in 2009	assistance with trees 250 h in 2010 270 h in 2011 110 h in 2012
D Andurand** (INRA, research engineer)				Project leader
L Neu*** (Assistant engineer, contractual)				Trial supervision (10/2010-9/2013)

*By the end of 2006, following the retirement of R Olivier, the SPE UR 407 unit planned to cease its direct involvement in the project, but actually maintained it (with the approbation of SPE) until the assessment of the second set of clones is complete (2014-2015).

** In 2007, upon request by the Ministry of Agriculture and regional authorities from Provence Alpes Côte d'Azur (PACA), Languedoc Roussillon and Midi Pyrénées, INRA General Directors asked SPE to continue with ongoing breeding activities. Philippe Nicot, plant pathologist, was mandated to supervise the project. In 2009, Dominique Andurand took over from P. Nicot as project leader.

*** From 2009-2013, thanks to financial support provided by INRA and the PACA region, an assistant engineer was recruited for three years to complete assessment of the second generation of clones.

In addition to the salaries of permanent staff dedicated to the programme, INRA also made a substantial financial contribution for breeding operations. From the start of the project in 1990, the INRA Plant Pathology Research unit in Avignon leased and maintained the experimental domain of Les Banettes (until 2015), where plane clones were planted and multiplied. The lease was extended for the duration of the programme (Plant Pathology Unit until 2007, INRA PACA Research Center administration, the SPE Division and the INRA National

Innovation and Valorisation service thereafter). INRA (essentially the SPE Division) also financed the installation of an irrigation system on this experimental domain (7,300 euros) and a fence required by the Plant Protection service since *C. platani* is quarantined (22,500 euros). INRA also contributed greatly to day-to-day operations, maintaining agricultural equipment, carrying out pest control and tree-handling activities (inoculation, cutting, etc.) and managing the pathogen collection, for a total marginal cost (excluding public salaries) of about 6,500 euros per year.

Agreements and involvement of Pépinières Rouy-Imbert (PRI)

As early as 1996, INRA set out to find a public or private industrial partner, since no previous agreement between INRA and plant production industries included plane as a target species. Rouy-Imbert (later Pépinières Rouy-Imbert, or PRI), a tree grower based in Avignon, showed interest in a partnership, and agreed to support the breeding programme for 30,000 FF/year for three years, in exchange for a license to exploit resistant clones.

Two successive research contracts (references INRA B 01951, 1998-2001, prolonged one year in April 2001; and BO 5249, 2003-2006) were drawn up between INRA and PRI, with the support of AgriObtentions (INRA subsidiary in charge of exploiting plant accessions derived from INRA research programmes). Both contracts defined the distribution of tasks between INRA and PRI for the programme, and granted PRI exclusive rights to all new plant material generated. All new material obtained during the work carried out under the agreements is regarded as the joint property of INRA and PRI in equal parts, the parental material remaining the sole property of INRA.

PRI contributed financially to the breeding programme under these agreements from 1998-2002 and 2003-2006 (Table 2). It also contributed on an occasional basis with tilling, planting and tree handling operations in 2009-2010 on the experimental site of Les Banettes.

Financial support from local authorities, 1994-2013

Because plane trees are an important feature of landscapes in southern France, local authorities have proved very receptive to INRA efforts to provide a sustainable solution to the threat caused by canker stain. As a result, both local and regional authorities have subsidized the breeding programme through a series of grants (Table 2), based on applications made by the scientists running the programme.

Table 2: Financial support from local and regional authorities

Year	Funding body	Subsidies
1994-1995	Department Vaucluse Council /FDGEC	1994: 400,000 FF; 1995: 200,000 FF
1997	PACA regional Council	100,000 FF
2001	Department Vaucluse Council	40,000 FF
2001	PACA regional Council	51,000 FF
2010-2013	PACA regional Council	15,500 € per year over 3 yrs (10/2010-09/2013)

* Currency changed in 2002 from French Francs (FF) to Euros (€); conversion rate 1 €= 6.55957 FF

Outputs

Development and validation of a resistance test protocol for plane canker stain

A test to measure resistance to canker stain, which requires a period of eight years, has been developed and validated. Screening for resistance is thus a lengthy process, but the test ensures that resistant material stands up well to *Ceratocystis* infection through successive inoculations via wounds and roots. It involves the following steps (Vigouroux & Olivier, 2004):

year 0: crossing and sowing of seeds

year 2: inoculation of trunks of young trees (2 cm diameter)
year 4: cutting of promising clones 1 m above soil level, and development of shoots
year 5: inoculation of shoots 18 months old
year 7: inoculation of roots
year 8: final results.

Breeding resistant material

The first set of hybrids (1994-2004) led to the creation and registration of PLATANOR® Vallis Clausa (Vigouroux & Olivier, 2004): the joint property of INRA and PRI, granted community protection (CPOV) in 2008 and marketed since 2006 by PRI.

The second set of hybrids, involving new parents to increase the genetic basis of resistance to canker stain and introduce resistance to other pests (plane anthracnose, plane tiger), is still under selection. Broadening the genetic basis for resistance to *C. platani* will alleviate the risk of sudden adaptation of the pathogen to a single source of resistance if this is widely deployed, and the introduction of resistance to multiple pests will offset the risk of *C. platani*-resistant trees coming under attack by another major pest. The first multi-resistant hybrids are expected to join the PLATANOR® line in 2014 or 2015 (www.inra.fr/Grand-public/Sante-des-plantes/Toutes-les-actualites/Platane-PLATANOR-R-Vallis-clausa).

Knowledge flow and intermediaries

Industrial partnership

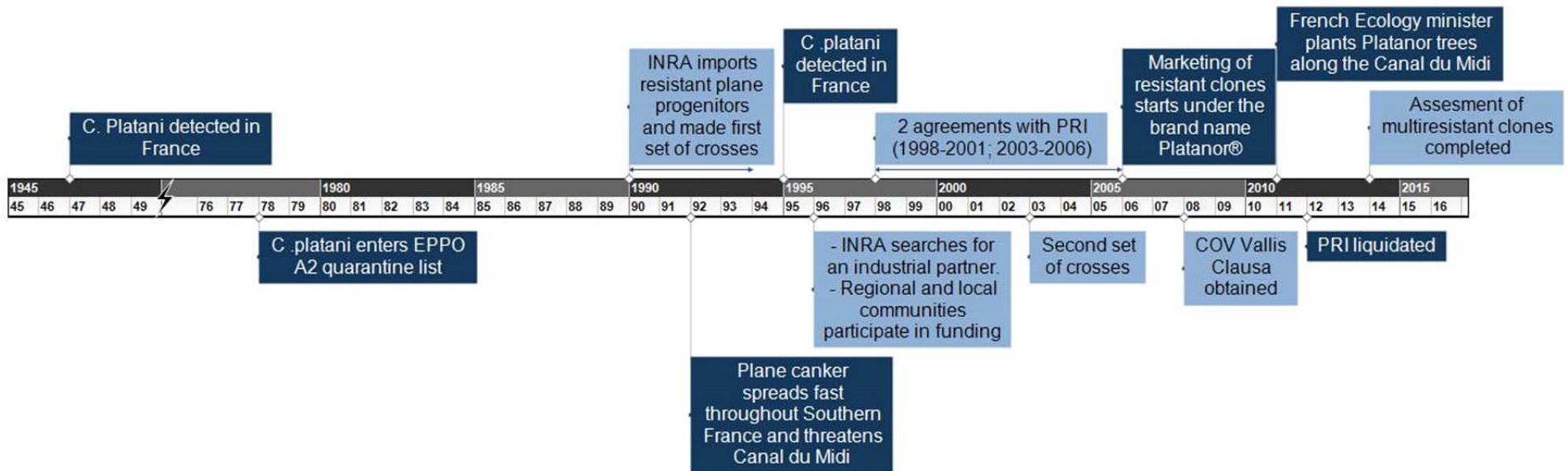
PRI, as the exclusive attributor of the resistant material, has been involved in the multiplication, raising and marketing of Vallis Clausa since 2003, when it was agreed between INRA, PRI and AgriObtentions that cuttings of resistant plants, made by AgriObtentions, would be transferred to PRI at a young stage (3-4 leaves) for cultivation in nurseries and market distribution. Throughout its partnership with INRA, PRI was supported by the expertise of Dr André Vigouroux, who maintained a consultancy role for the company after retiring from INRA.

Unfortunately, PRI soon began to experience financial difficulties. Protective insolvency measures had been in place since 2001, and the company finally went bankrupt on June 26, 2012. It was liquidated on July 24, 2012. The liquidation process is still underway, and the fate of joint property such as the resistant clones has yet to be decided. INRA has begun looking for other companies to distribute Platanor® clones, but agreements are on hold until PRI is fully liquidated and decisions are taken as to the future of the PRI share of joint property.

Policy enforcement

Platanor® Vallis Clausa is explicitly mentioned in directives enforced by French authorities for the mandatory control of *C. platani* wherever it is present; it is the only plane clone that may be planted in infected areas.

Chronology



Caption:

Events directly involving INRA

Other events (context...)

Impacts 1

Public policy:

Official directives regarding obligatory control operations against plane canker stain passed by most administrative departments in southern France forbid, among other measures, the planting of plane clones other than Vallis Clausa on any site undergoing eradication of *C. platani*. Also, an official declaration must be filed before planting (cf. Drôme Department, http://www.fredonra.com/files/2012/11/CC_arret%C3%A9_pref_DR%C3%94ME.pdf; similar legislation is passed in all departments involved in *C. platani* control). Platanor® clones therefore provide a biological solution, allowing plane populations to be maintained in areas infected by *C. platani*, including highly valuable sites from a touristic and natural heritage point of view, such as the Canal du Midi, a UNESCO World Heritage site.

Economic

Between 2006 and 2012, PRI sold some 5,854 Vallis Clausa trees in France and neighboring countries (Table 3). Given that sales prices range between 400 and 1,000 € per tree depending on age, this represents a gross turn-over of approximately 3.5 M€. Two-thirds of the trees were sold in France, but foreign markets (especially Spain and Italy) are expanding. However, sales were hampered in 2011 and 2012 by PRI's financial difficulties.

Table 3: Platanor® Vallis Clausa sales declared by PRI since introduction on the market

Year	France	Spain	Italy	Switzerland	Total
2012	942	379	215	26	1562
2011	217		495	-	712
2010	836	-	261	-	1097
2009	411	7	541	-	959
2008	502	75	-	-	577
2007	546	-	229	-	775
2006	172	-	-	-	172
	3626	461	1741	26	5854

Current sales represent less than a tenth of the potential market in France alone. Replacing the planes lining the Canal du Midi alone would require some 40,000 trees (i.e. around 20M€); today, about 15,000 of them are already infected and should be removed. Only 2,500 had been planted by 2011, and replanting is slow because of limited supply and high costs involved in felling and replanting operations (<http://www.midinews.com/news-36162.html>). Voies Navigables de France (VNF), the public institution managing the Canal and all inland waterways, estimates the total cost of replanting at 200M€ over 20 years (of which 54M€ to purchase the trees). To cover this cost, VNF recently launched a public sponsoring campaign targeting companies as well as individual citizens, illustrating the high natural heritage value of the Canal and its trees (<http://www.replantonslecanaldumidi.fr/fr/la-campagne-de-mecenat>).

Another potential large market is urban and roadside trees (e.g. the call from the city of Apt for the provision and planting of 50 Platanor® trees: <https://www.klecoon.com/boamp/boamp-appels-offres-fourniture-plantation-50-platanes-platanus-platanor-vallis-clausa-1898975.htm>).

Impacts 2

Social and collective heritage

Thanks to its long-term commitment to breed resistant plane clones, INRA is now recognized as a major contributor to the preservation of natural heritage landscapes in southern France. The Institute is expected to play a key role in retaining the Canal's rank as a UNESCO World Heritage site. According to VNF's website, 'the Canal du Midi hosts millions of visitors every year (1.5 million in 2010); 350 companies and 2,000 permanent jobs directly depend on activities linked to this site, representing annual economic activity of some 122 M€'.

While it is difficult to translate into economic terms, preserving the unique landscapes of southern France by planting resistant plane trees will probably have a lasting impact on the appeal of southern France, where tourism is all-important to the local economy.

Environmental

Widespread planting of Vallis Clausa planes in areas infected by *C. platani* itself presents a risk in terms of resistance, since it can potentially lead to a new epidemic situation with as yet no solution if the pathogen adapts to the resistance sources used in Vallis Clausa. The hope is that methodology developed for screening resistant accessions will be useful in identifying new sources of resistance able to provide some genetic diversity among resistant clones. Furthermore, Vallis Clausa has limited resistance to other major pests. This is one of the reasons why the second set of hybrids, involving resistance sources to multiple pests, was created.

Conclusions

For INRA, the development of Vallis Clausa and the Platanor[®] line of resistant planes was primarily an engineering project, raising no new fundamental research issues. It was designed to respond to an urgent and major threat, and as such justified the implementation of a specific strategy for introducing a new product onto the market. In retrospect, while the technical objectives have been met, with the development of both an efficient screening method and resistant clones suitable for planting in infested areas, the development and transfer of these innovations to the market has so far only been partial, due to the financial difficulties of our industrial partner and its subsequent liquidation.

Considering the value of the resistant material obtained for the preservation of historical and natural heritage landscapes, the potential market for Platanor[®] clones is vast. This is why INRA is now actively looking for solutions to keep those clones available to public and private agencies involved in the maintenance and preservation of urban and rural landscapes. This will probably require more time, due to the legal consequences of the liquidation of our original partner, but there is good reason to hope that appropriate solutions will be found in the very near future.

Impact Pathway

CONTEXT

- Severe Canker outbreaks, mainly in South France (80s)
- Technical limits: no chemical treatment, no resistant variety available

Canker listed in Quarantine list of EPPO : mandatory control measures enforced (Plant Protection Service)

Systematic felling of planes: patrimonial disaster

Bankruptcy PRI

Funding:
 - Local communities in South France (PACA region, Vaucluse departement)
 - Private company PRI: 3years funding

INRA Avignon
 ethiology, epidemiology
 ⇒Methods for detection of the pathogen and preventative control
 ⇒Plane clone crosses

Experimental site Les Banettes
 (complying with quarantine rules) :
 planting and multiplying clones

Pathogen collection

INRA UE Bormes les Mimosa:
 plane collection of Genetic material

Resistance testing protocol
 for plane canker stain

Breeding original resistant material: Platanor® trademark:
 -Canker stain Resistant Cultivar « Vallis Clausa » COV co-obtented with PRI
 -Set of clones resistant to canker stain and to other pests

Breeding planes resistant to canker stain and to other pests (in process)

Scientific publications

French Ministry for ecology: order for Platanor planting on Canal du Midi

INRA Transfert + AgriObtentions

PRI (local breeder): plants production (under exclusive license including improvements)

Political:
 •Public concern for natural heritage
 •Contribution to local policies: official directives passed in all Departments concerned with *C. platani* control, forbidding the replanting of plane clones other than Vallis Clausa

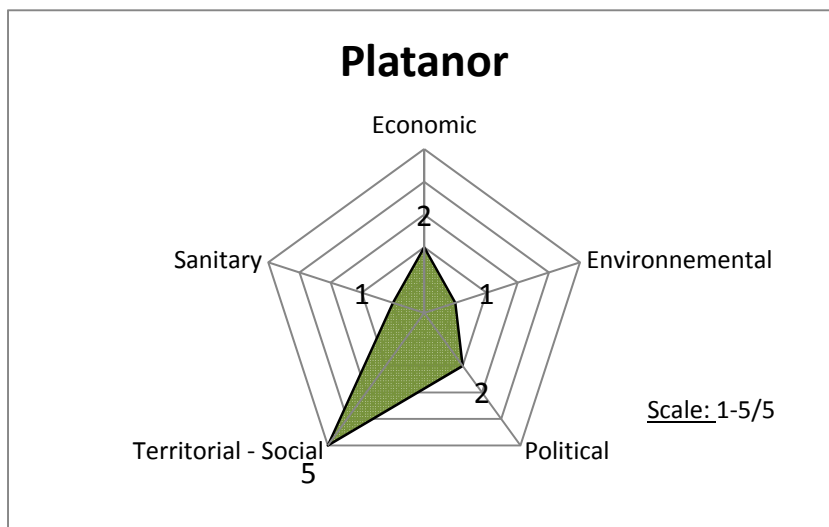
Economic:
 -6000 plants sold mostly in France but also in Italy, Spain and Switzerland. Turnover PRI 4M€ (2006-2012)
 -Local communities as clients
 -Potential market: 40 000 trees (>20M€) on Canal du Midi only (2014-2030). Today sales account for around 10% of the total market (total market being around 40M€)

Social and patrimonial:
 •Canal du Midi maintained on UNESCO list
 •Economic benefits from tourism in Canal du Midi: 122M€/y

Environment:
 Second set of clones developed to enhance the diversity of resistant planes and prevent resistance development



Impact vector



Impact dimension	Importance (/5)	
Economic	2/5 Potentially 3	6,000 Platanor® plants sold in France, Italy, Spain and Switzerland. Potential market: 40,000 trees (> 20M€) on Canal du Midi only. Current sales (3.5 M€ 2006-2012) account for around 10% of total domestic market. Economic activity from tourism in Canal du Midi= 122M€/yr
Environnemental	1/5	Tools for resistance identification in all existing varieties
Territorial-Social	5/5	Heritage conservation: Canal du Midi maintained on UNESCO World Heritage list Tourism preserved
Political	2/5	Platanor® empowered local sanitarian policies (local decrees taken in all French departments affected by canker) on a policy domain concerning public awareness (natural heritage) Directives and local regulations

Data sources :

Web pages related to Platanor® use

www.inra.fr/Grand-public/Sante-des-plantes/Toutes-les-actualites/Platane-PLATANOR-R-Vallis-clausa

<http://www.midinews.com/news-36162.html>

<http://www.midilibre.fr/2013/05/06/platanor-le-super-platane-au-secours-du-canal-du-midi,691672.php>

<http://www.leparisien.fr/environnement/canal-du-midi-le-platanor-arme-fatale-contre-le-champignon-tueur-26-07-2011-1545637.php>

<http://www.ladepeche.fr/article/2011/11/09/1211701-160-platanor-et-190-tilleuls-replantes.html>

<http://www.lamarseillaise.fr/les-archives/item/9610-le-platanor-va-succeder-aux-plus-beaux-arbres>

<https://www.klekoon.com/boamp/boamp-appels-offres-fourniture-plantation-50-platanes-platanus-platanor-vallis-clausa-1898975.htm>

http://www.fredonra.com/files/2012/11/CC_arret%C3%A9_pref_DR%C3%94ME.pdf

<http://www.replantonslecanaldumidi.fr/fr/la-campagne-de-mecenat>

Scientific papers

Vigouroux A , Olivier R., 2004. First hybrid plane trees to show resistance against canker stain (*Ceratocystis fimbriata* f. sp. *platani*). *Forest Pathology* 34:307-319

Contributors INRA:

Philippe Nicot

Dominique Andurand

Véronique Saint Ges

Drafted by D. Andrivon, in collaboration with Ariane Gaunand and Laurence Colinet (ASIRPA Group at INRA)