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Connecting forestry and agroforestry partnerships across Europe

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OG SPNA: Precision silviculture in Nouvelle-Aquitaine Vigil'encre

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SPNA (Precision silviculture in Nouvelle-Aquitaine) is a project financed by the Poitou-Charentes Rural Development Program 2014/2020 - Call for sub-measure 16.1 Operation A "Support for the creation and operation of IAP operational groups" - Action 2 "Financing of operational groups". The initial objective of the SPNA is to develop and disseminate innovative tools, recently developed or close to implementation, to facilitate and encourage the sustainable management of Pinus pinaster (maritime pine) and Castanea sativa (chestnut) in New Aquitaine, France. This operational group aims to develop and disseminate technical and economic tools to help managers in their silvicultural choices, and to characterize the status and possible evolution of certain regional species in a context of climate change.

The Institute for Forestry Development (IDF), the applied research and development department of the National Center for Forest Property (CNPF), was the project coordinator, with local involvement from the CNPF's Nouvelle-Aquitaine delegation. The project involves ten regional forestry partners and players from research, R&D, public and private forest management, as well as representatives of forest owners and local authorities: Alliance Forêts Bois, CC Fumel Vallée du Lot, Forest Health Department (DSF) of Ministry of Agriculture and Food Sovereignty (MASA), EI Purpan, FCBA, GDF Sud-Dordogne, IGN, INRAE, ONF Centre-Ouest-Aquitaine.

1. Documentation on European chestnut

The European chestnut belongs to the Fagaceae family, like oak and beech. Chestnut distribution extends from North-West Africa to North-West Europe, and from South-West Asia to Eastern Europe, the Caucasus and the

Caspian Sea. Chestnut covers an area of over 2.5 million hectares in Europe. The main chestnut forests are concentrated in certain countries: in order of importance, France, Italy, then Spain, Portugal and Switzerland. This species is found at altitudes between 200 m. and 1800 m. (Conedera, M. et al., 2016).

Chestnut has a long history of cultivation, particularly in Italy, Spain, Portugal, France and Switzerland. This versatile species provides numerous ecosystem services. It is cultivated for its wood (coppice and high forest), for fruit production (traditional orchards) and for a wide range of secondary products (Conedera, M. et al., 2016).

Chestnut is a deciduous tree that can reach 30 to 35 m in height. It has a long lifespan when cultivated (up to 1,000 years) and thus a large circumference (nearly 12 meters at chest height). This species is monoic and the flowers (Figure 1) develop from late June to July, with anemochoric or entomochoric pollen dispersal. In autumn, the female flowers transform into spiny cups containing chestnuts (Figure 2), which are shed in September (Conedera, M. et al., 2016).

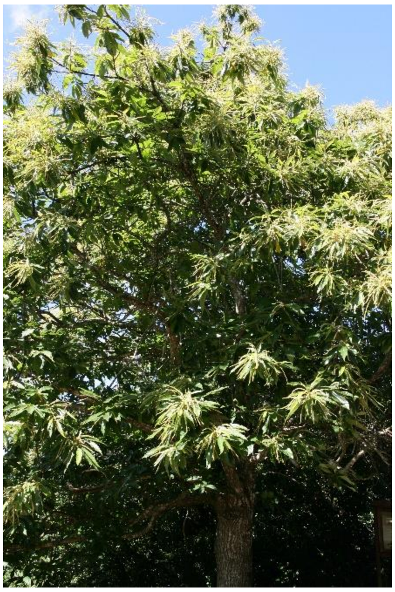

Figure 2. Image of a chestnut tree in bloom.

Figure 1. Chestnuts in their "bogue" (spiny cups).

Chestnut is a plastic species, but relatively demanding in terms of ecology. Its main constraints concern water supply (drought and waterlogging), nutritional inputs and the effects of extreme temperatures. It is sensitive to late frosts and highly adapted to disturbances caused by fires (vigorous shoots). These abiotic stresses can be implicated in dieback symptoms.

Asian chestnut species (C. crenata and C. mollissima) and their interspecific hybrids are resistant to chestnut ink disease. In more recent orchards, these hybrids are used as grafting stock, because of their resistance, or as fruiting varieties, to improve fruit production.

2. European chestnut ink disease

Chestnut ink disease (Figure 3) is caused mainly by *Phytophthora cinnamomi* and *Phytophthora cambivora*. These oomycete species are pathogenic to a wide range of tree species (coniferous and deciduous) and ornamental plants. They infect the fine roots of their host plants, thanks to their mobile spores (zoospores). These spores are released when humidity and temperature conditions are favorable. Following germination, the mycelium of *P. cinnamomi* and *P. cambivora* can invade root tissue.

Figure 3. Sampling and ELISA analysis of a chestnut sample for the presence of chestnut ink (Phytophthora cambivora).

In necrotic roots, these oomycetes rapidly form new zoospores which can then contaminate other trees, resulting in an outbreak distribution of diseased trees in plots. *P. cinnamomi* and *P. cambivora* can also maintain and multiply in the soil. Their dispersal in the soil is favored by excess water. They are also spread by infected plants and substrates. It is therefore crucial to check the health of plants used for new planting.

2.1. Chestnut ink disease can be observed through various symptoms

- root necrosis: roots infected by P. cinnamomi or P. cambivora can be recognized by their black color. They are no longer functional and rot as a result of tissue death. These root losses are the primary symptoms. They are difficult to observe on mature trees. Attempts should be made to dig up the large main roots running up to the collar of dying trees. It is advisable to look for naturally regenerated seedlings, so that root systems can be easily observed. These infections can result in two types of symptoms;
- cortical necrosis of stems or trunks: when the pathogen has caused severe root damage, this extends to the base of the trunk (the collar). Black discharges flow from cracks in the bark covering the infected parts of the crown. If the bark is stripped away, the cortical tissues and bare wood are brown in color, while under the bark in the uninfected zone they are pearly white. These necrotic tissues are the tissues invaded by the pathogen;
- Dieback: The necrosis of fine roots results in water dysfunction. Infection and destruction of a large part of the root system reduces the tree's supply of nutrients and water. The tree then shows symptoms of generalized decline, which can be accompanied by wilting, chlorosis, yellowing and defoliation. These symptoms are all the more marked in periods of drought, and lead to the tree's death, sometimes very rapidly.

2.2. Two types of methods are recommended for managing chestnut ink disease

- preventive methods: it is important to check seedlings before introducing them into a new environment, to avoid planting in conditions that are conducive to P. cinnamomi and P. cambivora, and to avoid planting on infected sites (hence the importance of carrying out a precise diagnosis beforehand);
- use of resistant grafting rootstocks: it is advisable to graft fruit varieties onto resistant hybrid rootstocks, where pedoclimatic conditions and varieties allow.

3. Other diseases and pests of European chestnut, and possible confusion with European chestnut ink disease

The main chestnut diseases are caused by exotic pathogens or pests, with which the European chestnut tree has had little or no co-evolution, and to which it is highly susceptible. These are mainly ink (a root disease), canker (an aerial disease caused by *Cryphonectria parasitica*), chestnut cynips (an aerial disease caused by *Dryocosmus kuriphilus*) and, lastly, the pathogen *Phytophthora ramorum*, currently present mainly in nurseries on ornamental plants, which is a quarantine organism and must be eradicated as soon as a plant is infected.

When an observer needs to know whether a chestnut tree is affected by ink, it is essential to be able to observe one or more of the symptoms that characterize this disease. Unfortunately, these are not specific and can be caused by a variety of other biotic and abiotic factors (Table 1).

Table 1: Elements for ink diagnosis and elements for invalidating other diagnoses in the case of different symptoms affecting European chestnut.

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Symptoms	**Elements for ink diagnosis**	**Elements for other diagnoses**
Mortality	Generalized dieback.	Canker disease: sectorial mortality, subcortical mycelium, orange fruiting bodies.
Twig wilting and/or mortality	Root and collar necrosis observed. No rhizomorphs.	Nutritional deficiency, water stress: no necrosis. Armillaria: root infections, subcortical rhizomorphs.
Defoliation	Leaves reduced.	Cynips: galls and leaf deformation.
Black discharge	Cortical necroses observed under oozing after stripping.	Wood-eating insect galleries: no necrosis. Frost: wood splitting.
Root necrosis	Infected or destroyed fine roots, infected taproot or large roots, sometimes up to the collar.	Armillaria: rhizomorphs.
Trunk necrosis	Trunk necroses originate from root necroses.	Javart: lesions not linked to roots.

4. Vigil'encre application: recognition and reporting

Vigil'encre https://ephytia.inra.fr/fr/P/157/Vigilencre (INRAE, 2025) is an application offering a wide range of tools (Figure 4). It provides a range of information on the European chestnut tree and on a large number of diseases that can affect it, in particular ink disease.

This tool can be used to carry out reconnaissance using the "identify" tool, which consists of an image-based diagnosis based on a series of photographs showing the symptoms visible in the various compartments of the tree. Image recognition is carried out: - for the species (by describing the crown, trunk, chestnut and male catkin); - for ink disease (on the collar and roots, trunk and for dieback); - for other diseases likely to affect chestnut (on the leaves, roots, trunk and for dieback).

Once the user has formed a picture of what he is observing in the field, he can then make a report, which can be localized, and post photographs. Notification of the report is automatically provided to the tool administrator.

If the person making the report has volunteered to take samples (of soil, crown necrosis or infected root systems), he or she can pass them on to the INRAE research laboratory, which will be able to confirm or refute its diagnosis after analyzing the samples.

A sampling procedure has been put in place to facilitate sampling and enable the transmission of a usable sample to the laboratory.

It consists of three stages:

1. Sample identification and labelling

A form number is assigned to each report. Samples taken and sent must be identified by this number.

2. Soil sampling

When to sample: the *Phytophtora spp.* responsible for the disease thrive and multiply in moist soils. To increase pathogen detection, it's best to take samples after a period of heavy rain, ensuring that samples are neither too dry nor too wet.

What to sample: each sample must be taken at the foot of a tree showing symptoms of decline. To get a good representation of the soil at the foot of the tree, it's best to take three samples from each tree, in line with the foliage, at a depth of around 10 cm.

How to take the samples: if possible, use an auger; for very shallow or stony soils, a spade can be used. In both cases, surface debris must be removed. It is recommended to take three samples in different directions 1m from the trunk. These soil subsamples are then collected in a plastic bag, which is homogenized to obtain a single sample. A 500 g soil sample is sufficient for detection.

3. Plant sampling

When to sample: Samples should be taken as soon as symptoms are observed, between May and September, before the plants or trees die. As *Phytophtora spp.* do not survive well in samples that dry out, samples should be shipped as quickly as possible and/or kept cold before shipping.

What to collect: when young chestnut plants are observed dying off, the easiest thing to do is to collect them with their roots. However, dead plants should not be harvested and shipped. If, after removing the corky bark, cortical necroses are observed at the neck of the trees, samples can be taken from the terminal part of the necrosis and from adjacent non-necrotic tissues.

<u>How to harvest</u>: to remove the plants, it is necessary to use a suitable tool to preserve a maximum number of intact roots. For shipment, plants should be wrapped in newspaper, avoiding over-compaction. To remove necrotic tissue from the collar, you can use a penknife, chisel or axe, depending on the size of the tree and the operators involved. In both cases, please pack each sample in a paper bag.

Otherwise, whenever possible, identification is carried out using photographs taken by the user.

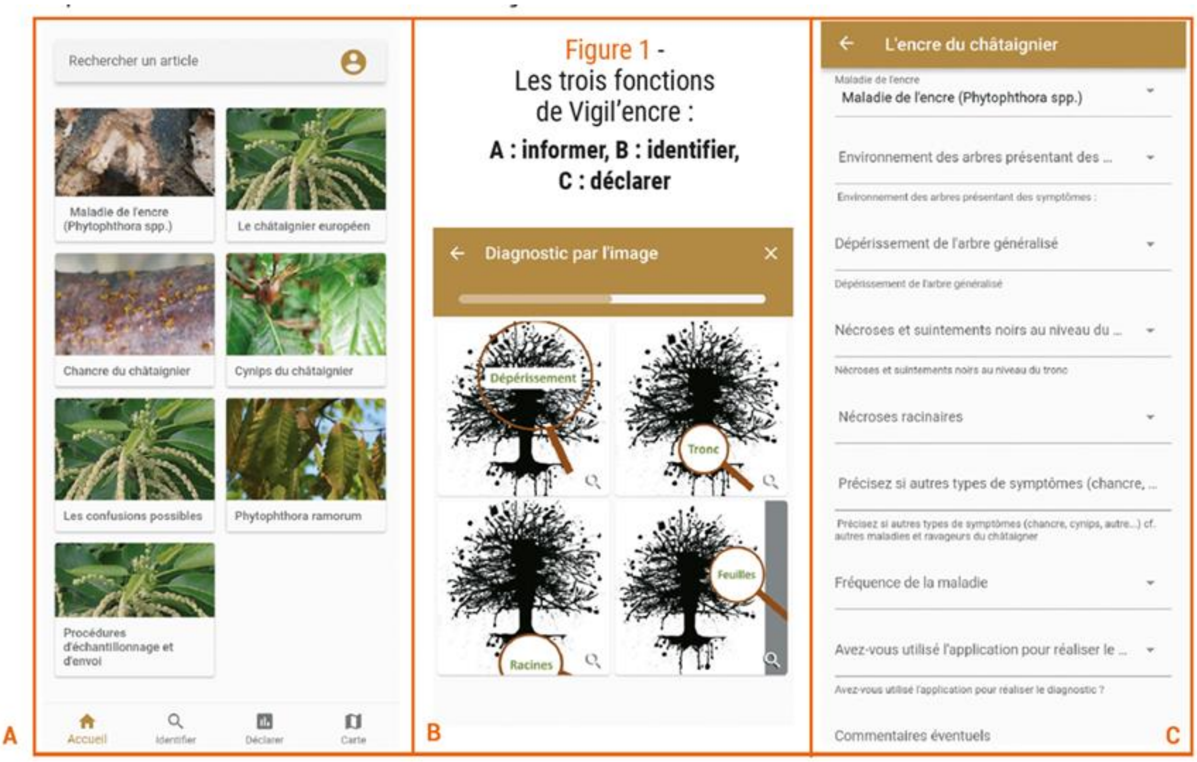

Figure 4. Overview of Vigil'encre's three functions: a) inform, b) identify and c: declare.

5. Conclusion

All reports of ink disease made using the Vigil'encre application are stored in a database which is used by INRAE as part of its participatory research on the disease. Citizens, foresters and landowners can thus participate in research into this pathogen.

Other applications are also available on the INRAE website (https://ephytia.inra.fr/), enabling users to take part in participatory science networks (such as AGIIR or Signalement TIQUE) and contribute to biodiversity data collection. In addition, various tools on the platform provide access to knowledge on alternative control methods and biocontrol practices.

6. Further information

Watch a video presentation by Cécile Robin, from INRAE, of the Vigil'encre mobile application, designed to improve knowledge and diagnosis of the Chestnut ink disease. This video was financed by the Nouvelle-Aquitaine region and FEADER (SPNA-Diff project), promoting the actions of the EIP-AGRI project SPNA - Precision silviculture in Nouvelle-Aquitaine, which aims to develop and disseminate innovative tools to facilitate the management of maritime pine and chestnut, 2 of the region's flagship species. https://youtu.be/nRGPu5Z5uQU?si=_aGPUEXrUH6fMKsy

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