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MONGEFITOFOR HANDBOOKS

MONITORING AND MANAGEMENT OF SOME CHESTNUT DISEASES IN TRANSBOUNDARY ALPINE AREAS

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Series: "MONGEFITOFOR HANDBOOKS"

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PREFACE

Forests are an important component of the landscape of the Autonomous Region of Valle d'Aosta and of the Italian-Swiss cross-border areas, performing many essential functions for the conservation, preservation and protection of the territory and of the communities that inhabit it. In order to guarantee in time and space the fulfilment of these functions, forest health must be constantly monitored and preserved. The need to pool experience, acquired knowledge and projects in relation to the monitoring and management of the main threats to forests has therefore led the Autonomous Region of Valle d'Aosta, the two Swiss cantons of Grisons and Ticino, the Department of Agricultural, Forest and Food Sciences (DISAFA) of the University of Torino and the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in Birmensdorf - Zurich to cooperate in an ambitious project named MONGEFITOFOR (Linee Guida per il MONitoraggio e la Gestione delle Emergenze FITOsanitarie nelle FOReste delle Alpi centro-occidentali - Emerging Threats to Tree Health in Forests of the Central and Western Alps: Guidelines
for Monitoring and Management), implemented within the framework of the European Territorial Cooperation Programme INTERREG V-A Italy-Switzerland 2014/2020. Several threats to forest health were addressed within the project. This handbook presents the results of monitoring activities targeting chestnut diseases and includes recommendations for their management in cross-border alpine areas. In fact, this handbook was created thanks to the knowledge gained from the synergy among the project partners who shared experience, knowledge and skills during the various activities conducted in Italy and Switzerland.

This handbook is an operational tool for the forestry sector but, at the same time, contributes to disseminating to technicians, administrators, stakeholders and to the general public knowledge and good practices to protect chestnut in the Alps.

The Councillor for Agriculture and Natural Resources
Marco Carrel

THE MONGEFITOFOR PROJECT

MONGEFITOFOR (Linee Guida per il **MON**itoraggio e la **G**estione delle **E**mergenze **FITO**sanitarie nelle **FOR**este delle Alpi centro-occidentali - Emerging Threats to Tree Health in Forests of the Central and Western Alps: Guidelines for Monitoring and Management) is a project funded by the European Union through the Territorial Cooperation Programme ***INTERREG*** V-A Italy-Switzerland 2014/2020 in which Italian and Swiss local institutions and research bodies cooperate to monitor the ***health status*** of cross-border ***forests*** and to propose sustainable strategies for their management and protection, thus promoting their ***resilience***. The ***project*** is coordinated by the Forestry Corps of the Autonomous Region of Valle d'Aosta (Struttura Corpo Forestale della Valle d'Aosta) (IT) and has as partners the University of Turin - Department of Agricultural, Forest and Food Sciences (DISAFA) (IT), the Swiss Federal Institute for Forest, Snow and Landscape Research WSL (Birmensdorf) (CH), Canton Grisons - Office for Forests and Natural Hazards (CH) and Canton Ticino - Forestry Section (CH).

The project relies on the consideration that forests are an essential element of the ***landscape*** of the Alpine valleys and have a multifunctional value encompassing not only the ***production*** of timber, but also the maintenance of ***biodiversity***, the ***hydrogeological protection*** of slopes and providing recreation and leisure for tourists, visitors and citizens. However, to ensure these fundamental functions, forests must be adequately protected. The MONGEFITOFOR project aims to address, on a cross-border level, some of the most important phytosanitary emergencies that have affected the forests of the hilly and low-mountainous areas of the central-western Alps in recent years (**Box 1**). These include ***chestnut blight***, i***nk disease*** and some ***diseases*** caused by the ***fungus Gnomoniopsis castaneae*** on ***chestnut trees***, to which this ***technical-scientific field handbook*** is dedicated. It is intended to be of support not only to owners, managers and administrators of forest resources, but also to technicians and operators in the sector who wish to expand their knowledge and improve their skills.

BOX 1

Insights into the MONGEFITOFOR project

The MONGEFITOFOR project, which started in 2019 and will end in 2023, focuses on the monitoring of emerging threats to forest health affecting tree species that play a key role in forest ecosystems of the foothill and submontane zones of the cross-border areas between Italy and Switzerland: **chestnut** (*Castanea sativa*), **European ash** (*Fraxinus excelsior*) and **Scots pine** (Pinus sylvestris), to which specific technical-scientific handbooks of the series "**MONGEFITOFOR HANDBOOKS**" are dedicated. Moreover, the MONGEFITOFOR project also released multimedia content providing technical information and additional insights, accessible on the following platforms:

WEB SITE
https://fitosanitario.regione.vda.it/progetto-mongefitofor

FACEBOOK
https://www.facebook.com/Mongefitofor-103015101617192/

INSTAGRAM
https://instagram.com/mongefitofor?igshid=1f0k8nykdbkwl

YOUTUBE
https://www.youtube.com/channel/UCeafnk1hcccn8Vlm4wqFvSg

THE CHESTNUT TREE: GENERAL OVERVIEW OF THE SPECIES

The genus Castanea comprises 13 tree species distributed in both hemispheres as a result of natural or anthropogenic spread. Internationally, the most representative and economically important species are ***Castanea sativa*** Mill. (European chestnut, hereafter referred to ***chestnut***), *C. crenata* Sieb. et Zucc. (Japanese chestnut), *C. mollissima Blume* (Chinese chestnut) and their hybrids. The chestnut is distinctly ***multifunctional***, as it is able to provide a considerable variety of ecosystem services depending on the context, but is particularly valued for the production of ***edible fruits*** (chestnuts and marrons) and ***woody assortments*** with multiple uses.

Classification of the species must include the context in which it is placed. In fact, the chestnut is a species with different values, which are expressed in a variety of ways in ***agrarian***, ***agro-forestry*** and ***forestry environments***. In a highly anthropised context aimed at the production of agro-foodstuffs, the chestnut is a ***fruit tree*** subject to a set of specific cultivation, agronomic and phytosanitary practices. In this case, the chestnut is often subjected to grafting operations aimed at improving quality, quantity and production yields (**Figure 1**). In forest environments, ***coppice*** is adopted for the chestnut tree (**Figure 2**), where the trunk component (if present) consists of ***suckers*** (**Figure 3**). Chestnut coppicing has historically been aimed at the production of assortments like poles, while standard trees are uncoppiced chestnut trees. Standard trees are released for one or more coppice rotations for reasons that include not only the possibility of obtaining larger wood assortments, but also to ensure ***natural regeneration***.

1A

1B

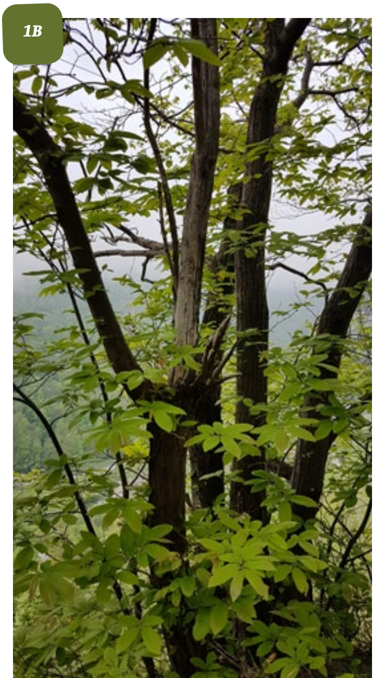
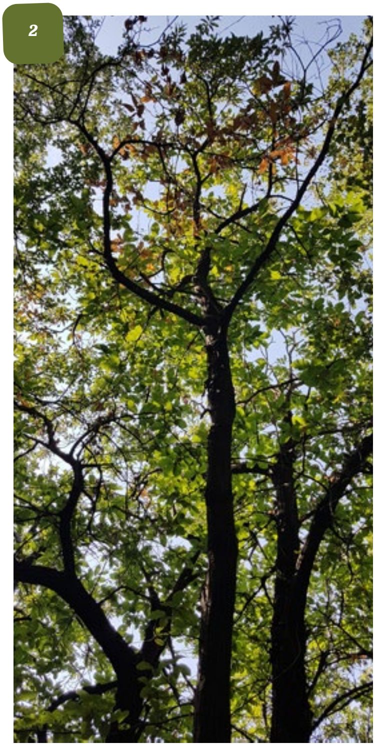


FIGURE 1
COPPICE-GOVERNED CHESTNUT STAND. STUMPS DURING THE DORMANT PERIOD IN A STAND DOMINATED BY CHESTNUT (A). DETAIL OF A STUMP WITH FOUR MATURE SUCKERS (B).

FIGURE 2
STANDARD CHESTNUT TREE RELEASED IN A COPPICE. THE STANDARD TREE IN THE CENTRE IS DOMINANT AND HAS AFFECTED THE GROWTH OF THE TWO NEIGHBORING TREES, WHOSE SHAPE IS DETERMINED BY THE NEED OF LIGHT.

FIGURE 3
TRADITIONAL CHESTNUT ORCHARD WITH TREES OF CONSIDERABLE HEIGHT AND DIAMETER , DURING THE DORMANT PERIOD (A). A CHESTNUT TREE IN THE FRUITING PHASE, CULTIVATED IN A RATIONAL CHESTNUT GROVE, WHERE TREES ARE KEPT LOW IN SIZE AND WHERE CULTIVATION AND AGRONOMIC INTERVENTIONS ARE REGULARLY PRACTISED TO MAXIMISE THE QUALITY AND QUANTITY PROFILES OF CHESTNUT AND MARRON PRODUCTION (B).

2



3A

3B

Given the general scope of MONGEFITOFOR project, this manual deals with chestnut ***coppice***, ***coppice with standards*** and the spontaneous and accessory ***chestnut*** component present in other floristic-vegetation formations of the Italian-Swiss cross-border areas.

The chestnut is a tree species that can reach a height of 25-30 m, but whose diameter can also exceed several metres in the case of old, veteran or particularly long-lived specimens. Characterised by its peculiar flower biology and morphology, the chestnut tree has flowers distributed in male or bisexual catkins differentiated by the same individual and whose anthesis occurs in the spring period, mainly between the second half of May and the first half of July. The chestnuts, edible achenes protected by a spiny burrs, ripen from late August to November. The chestnut is a species whose ***seed*** is defined as ***recalcitrant***, i.e. it tends to lose its viability if subjected to storage practices such as dehydration and subsequent storage at low temperatures (e.g. humidity 5-10% and temperature below 5°C). Germination capacity constraints start to be relevant when the water content of the seed falls below 20-40%, which is why storage from harvest to spring can only take place if adequate moisture conditions are maintained (e.g. stratification in sand or damp peat, sheltered from the action of sun and wind). The chestnut owns a ***suckering capacity***, which lasts indefinitely for the entire life span of the tree, making the species particularly suitable for coppice. If the stump is cut close to the ground, the suckers that develop have the possibility of freeing themselves by self-rooting, developing roots in complete autonomy. The relevant and prolonged suckering capacity, accompanied by the emission of vigorous suckers, is one of the main factors that make the chestnut tree particularly ***competitive*** against other tree species. Indeed, the chestnut tree often shows a tendency to form monospecific stands. The chestnut's root system is ***robust*** and has a good capacity to explore the soil and, although it is not particularly deep, it ensures that the tree is firmly ***anchored*** in the ground. The stem tends to be straight, stubby and robust, characteristics that make it appreciable in relation to productive purposes.

From an autoecological perspective, the chestnut is a typical species of the basal belt and hilly plane which, however, may be find in the mountain belt if the conditions are favourable. Considered a ***ther-***

mophilous species, it requires a period of at least six months with average temperatures above 10°C in order to vegetate. In terms of rainfall input, the chestnut requires rainfall over 600 mm per year, as it is a ***drought-fearing*** species. In relation to climate, the species prefers ***sub-Atlantic*** conditions, shunning areas where continentality tends to be overly pronounced. In eco-pedological terms, the chestnut is particularly demanding as it tends to select ***soils*** with a neutral, subacidic and ***acidic reaction***, with a loose texture and good ***aeration*** capacity. Adaptations to carbonate soils are rare but may occur locally, provided the location is characterised by high rainfall. With regard to nutrient requirements (particularly nitrogen and potassium), the chestnut can be considered a demanding species. In relation to light, the chestnut is ***averagely heliophilous***, although the seedlings can tolerate shade. The ***autoecological*** requirements of the chestnut tree can be summarised by means of a series of quantitative indices, which outline its salient characteristics (**Table 1**).

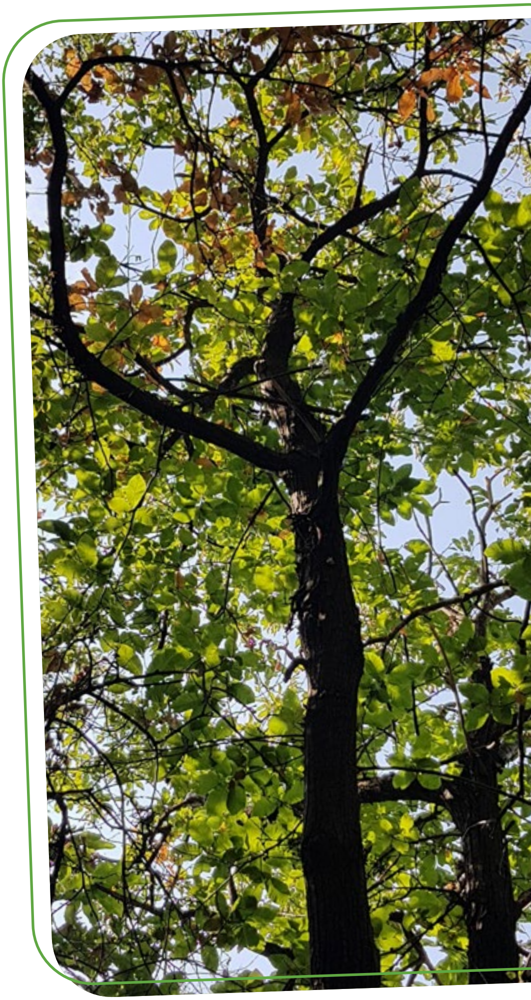


TABLE 1

Summary description of chestnut ecology. For each environmental factor, the corresponding Landolt index is given (1 to 5, values extrapolated from Lauber and Wagner, 2001) with corresponding description.

Environmental factor	Index	Description
Water needs	**3**	Needs medium-humid soils
Soil reaction (pH)	**2**	Prefers soils with a medium acid pH (3.5-5.5)
Nutrient requirements	**2**	It grows on soils with a medium to low nutrient supply between the extremes represented by pioneer and nitrophilous species
Light	**3**	It is not a sciaphilous species, but neither it is markedly heliophilous and is therefore adapted to intermediate light conditions
Temperature	**5**	It preferably grows in areas with warm temperatures typical of southern Europe
Continentality	**2**	Adapted to sub-Atlantic climates, it does not tolerate well late frosts and pronounced temperature fluctuations

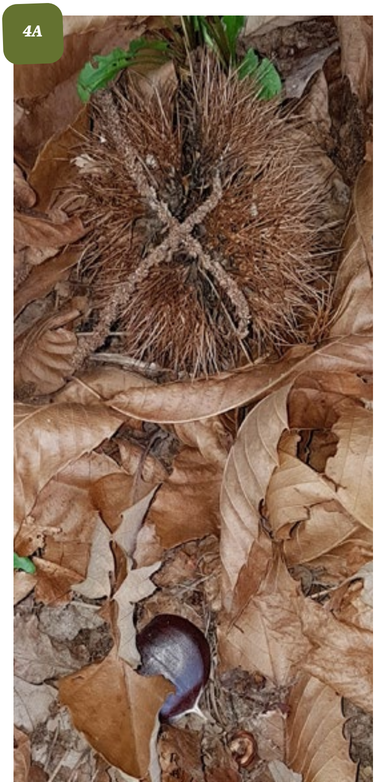
TABLE 1
SUMMARY DESCRIPTION OF CHESTNUT ECOLOGY. FOR EACH ENVIRONMENTAL FACTOR, THE CORRESPONDING LANDOLT INDEX IS GIVEN (1 TO 5, VALUES EXTRAPOLATED FROM LAUBER AND WAGNER, 2001) WITH CORRESPONDING DESCRIPTION.

SYNECOLOGY AND CHARACTERISATION OF FOREST STANDS WITH CHESTNUT

The chestnut often constitutes *monospecific stands* or alternatively it tends to be one of the most abundant species, although it may participate in various floristic-vegetation consortia as an accessory or sporadic element. In terms of typology, if we exclude orchards for fruit production, in the Italian-Swiss cross-border areas we can identify mainly mesoneutrophilous chestnut groves with Salvia glutinosa and acidophilous chestnut groves with Teucrium scorodonia. In the former, chestnut is associated with other broad-leaved trees including ash, maple, cherry and hazel, while in the latter, oak, beech and birch may appear. There are numerous variations to the above forest types, in which black locust, downy oak, Scots pine or larch, just to name a few, may be present and/or abundant. When the chestnut is pure, especially in sites where soils tend to have more acidic pH, the undergrowth is poor and characterised by reduced plant biodiversity, although these conditions are particularly suitable for the natural regeneration of the species, because of the reduced inter-specific competition. Indeed, the seed can germinate easily because the achene is in direct contact with the soil and is not disturbed by the presence of a herbaceous or shrub layer that could inhibit germination (**Figure 4**).

FIGURE 4
ABSENT OR SPARSE HERBACEOUS AND SHRUB COVER FACILITATES THE NATURAL REGENERATION OF CHESTNUT, ALLOWING THE SEED TO MORE EASILY COME INTO CONTACT WITH THE SOIL, GERMINATE AND PRODUCE VIGOROUS SEEDLINGS.

4A



4B

ECOSYSTEM FUNCTIONS AND SERVICES OF STANDS HOSTING CHESTNUT

Chestnut stands in which the species is dominant or abundant are able to exert a wide range of ***functions*** and provide various ***ecosystem services***, including:

• the production of ***wood assortments***;

• the production of ***non-woody products***;

• ***hydrogeological protection*** and slope consolidation;

• the provision of services associated with ecological-environmental function (e.g. sequestration of atmospheric carbon dioxide and ***carbon stocks***, contribution to biogeochemical cycles);

• the creation of stands that play an important role for ***landscape***, providing suitable sites for ***tourism*** and recreation.

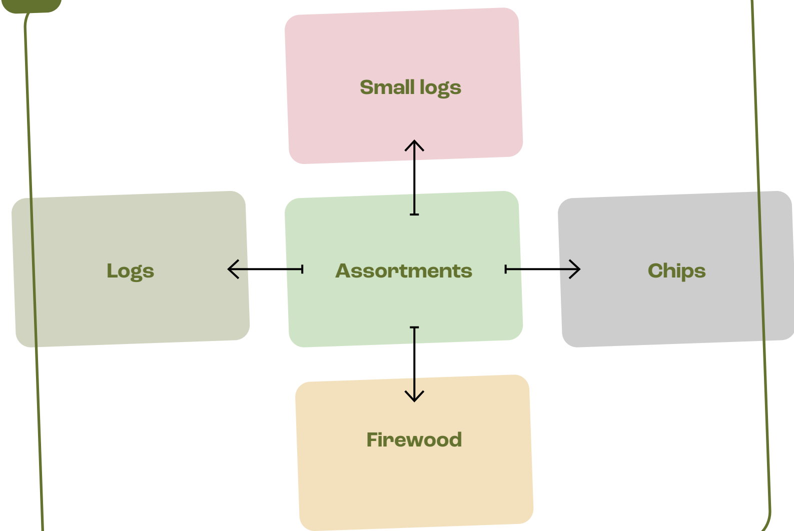
The ability of chestnut to fulfil the various functions and to provide ecosystem services is to a large extent constrained by the fact that forest stands are coppiced. In coppice stands forest management is oriented towards ***productive purposes***. ***Chestnut wood*** (**Figure 5**) is valuable from an aesthetic point of view and for its physical-mechanical properties. It is a wood with clear differentiation between sapwood and heartwood, durable as it is rich in extractives (particularly ***tannins***), semi-hard, but easy to work, with a density of 580 kg/m3. Particularly rare to find, but highly valued by the market, is chestnut ***briar***. This consists of wood from the basal portions of trees, with high aesthetic value, which can be used for the production of highly valuable furniture, or sliced to obtain decorative panels. The main wood assortments that can be harvested from the coppice and standard trees are shown in **Figure 6**.

FIGURE 5 *- CHESTNUT WOOD. XYLOTHEQUE SPECIMENS: ON THE LEFT, A SECTION OF CHESTNUT BRIAR, PARTICULARLY PRIZED FOR ITS AESTHETIC VALUES; ON THE RIGHT, A TYPICAL LONGITUDINAL SECTION.*

FIGURE 6 *- MAIN WOODY ASSORTMENTS FROM THE CHESTNUT TREE.*

5

6



Small chestnut logs are obtained from suckers up to 25 cm in diameter and are used in carpentry and in the furniture industry, while larger logs come from trunks with larger diameters, up to 40 cm at chest size, and can be used for more valuable processing. Depending on market requirements, the logs can be processed to make ***veneers***, ***sliced*** and ***sawn timber***. Traditional uses of chestnut wood entail the production of beams, planks, ***poles*** of various sizes (e.g. for street furniture in parks and gardens, for agriculture, for soil bioengineering), staves, beads, shingles and similar products. It should be emphasised that there has been a rediscovery of chestnut wood oriented towards its technological ***enhancement***, aimed at producing innovative wood products such as solid wood panels with miniature joints, or hollow joists assembled with epoxy or polyurethane adhesives. Shredding assortments are low-value wood products, which are suitable for the production of panels, or for the extraction of tannins. Smaller assortments unsuitable for typical log or log processing or larger logs affected by major defects (abnormal shape, excessive knottiness, scalloping or other) are destined for shredding. The extracted tannin is used in particular industrial processes in the paint, tanning and chemical sectors, albeit in niche markets. As firewood, the chestnut tree is mainly suited to limited uses and on a local scale, as the presence of tannins and the fact that it is not easy to dry make the species unsuitable for this type of use.

In addition to supplying woody assortments, chestnut coppice enables the direct or indirect harvesting of ***non-woody products***, including ***chestnuts***, albeit in quantities and qualities that are not comparable to those of fruit orchards. In addition, the chestnut tree contributes to important supply chains such as, for example, honey production. Indeed, chestnut ***honey*** is highly appreciated by consumers for its distinctive organoleptic profile. The chestnut is also an ectomycorrhizal species, establishing symbiosis with various ***edible*** basidiomycete ***fungi***. Moreover, chestnut forests are suitable habitats for the differentiation of fruiting bodies of a wide range of mushrooms appreciated by the market and consumers for their gastronomic values, including the so-called ‘royal ovules’ (e.g. Amanita caesarea) and ‘porcini’ (Boletus edulis and other species of the same genus).

Although coppice is not the most suitable form of governance for slope consolidation, chestnut coppices may help ***protect*** slopes from ***erosion*** and ***soil loss***. Indeed, the canopies and stems intercept rainfall, regulate water runoff and reduce surface runoff, while the root systems retain soil by performing their function of anchoring stumps and standard trees (**Figure 7**).

FIGURE 7 *- CHESTNUT COPPICE MIXED WITH OTHER BROADLEAF TREES ON A STEEP SLOPE. IN THIS CONTEXT, THE FUNCTION OF PROTECTION AGAINST THE RISK OF EROSION AND SOIL LOSS IS FUNDAMENTAL*

Contributing to the protection of settlements, infrastructures and other artefacts from the risks associated with rockfalls, landslides and avalanches, the chestnut tree and the forests in which it grows are at the same time a key element of the ***forest landscape*** that characterises the hill and mountain environments of the Italian-Swiss cross-border areas. Chestnut trees are not infrequently inserted in contexts where the forest lends itself to the enjoyment of tourists, hikers, cyclists and families, especially at the time of fruiting. Given the longevity of the species, some stumps or mature trees can themselves become elements of particular attractiveness and landscape interest, as is the case with some specimens of ***old*** or ***veteran*** trees (**Figure 8**). Moreover, these trees generally act as ***reservoirs of biodiversity***.
Although chestnut stands are not counted among the forests with the highest levels of plant biodiversity, they are considered important ***habitats*** for the conservation of wildlife, which includes amphibians, reptiles, birds, mammals and micro-mammals, just to name a few.

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SILVICULTURAL AND MANAGEMENT ASPECTS

Chestnut coppice silviculture tends to be consolidated by practice, corroborated by experience and codified by literature and classical manuals, which are based on solid technical-scientific foundations. Intervention options vary essentially according to the age and conditions of trees and stands, and differ between coppice in the juvenile phase, mature coppice, coppice evolving beyond the regular rotation and coppice with standards.

Young coppice consists of stumps whose suckers are approximately 15 years old or less. In this context, intraspecific competition is very high and it is therefore advisable to intervene promptly and at a suitable intensity, with the aim of favouring the potentially more promising suckers, before excessive competition will becomedetrimental to the diametrical increments of future subjects.

Mature coppice suckers are approximately 20 to 30 years old. In this scenario, if the intention is not to proceed immediately with the final cutting, it is possible to wait, but with immediate thinnings in

FIGURE 8

OLD CHESTNUT TREE. THE HOLLOW STEM CAN BE SEEN AS A RESULT OF THE ACTION OF DECAY-CAUSING FUNGI IN THE CENTRAL CYLINDER, WHICH HAVE CAUSED THE CAVITIES VISIBLE ON THE OUTSIDE (EXPOSED DECAY). OLD-GROWTH OR VETERAN TREES, OFTEN RESERVOIRS OF BIODIVERSITY, CAN REPRESENT CHARACTERISTIC ELEMENTS OF THE FOREST AND AGRO-FORESTRY LANDSCAPE OF THE ITALIAN-SWISS CROSS-BORDER AREAS.

favour of the most promising subjects.

Coppicing beyond the regular rotation (which is generally between 16 and 30 years) represents a generally unfavourable condition, on which a process of free evolution is presumably ongoing because of site abandonment. Depending on general sites conditions, either clear cut or thinnings aimed at favouring still promising individuals, if these are present , may be performed.

Coppice with standard trees involves a composite approach. On one hand, standard trees should be preserved, especially if vigorous and healthy; on the other hand, there is a need to favor the most promising suckers. Depending on site, either selective thinnings or regeneration cuts can be performed.

When the stand is monospecific or the chestnut is largely dominant, but there are other tree species suitable for the site, favoring stand evolution towards a more balanced ***multi-species composition*** is also possible.

The general silvicultural indications provided in this chapter are valid for forest stands in which chestnut does not show phytosanitary problems. In the presence of symptoms of disease, or as a precautionary measure to prevent its onset, it is advisable to supplement good management practices with further targeted operations to protect and safeguard tree health.

GENERAL OVERVIEW OF THE MAIN CHESTNUT DISEASES

Historically, chestnut tree was demonstrated ***susceptible*** to a number of infectious diseases, most notably ***chestnu blight*** caused by the ascomycete fungus *Cryphonectria parasitica* (Murrill) M.E. Barr. and ***ink disease*** caused by the chromista *Phytophthora cambivora* (Petri) Buisman and *P. cinnamomi* Rands. Both of these diseases can cause considerable damage to chestnut fruit orchards and coppices, often in association with high mortality rates. Alongside these two historical chestnut diseases, new diseases have recently emerged. One of the main ones is represented by ***Gnomoniopsis castaneae*** Tamietti, an ascomycete fungus that since the 2000s has emerged not only as the main agent of chestnut rot internationally, but also as a potential agent of ***bark cankers*** and sometimes of ***leaf necrosis***. The chestnut tree can also be affected by other infectious diseases which, although locally and sporadically may be relevant, are generally not counted among the main threats of chestnut. These include a ***foliar disease*** caused by the ascomycete fungus *Mycosphaerella maculiformis* (Pers.) J. Schröt., ***root rots*** induced by basidiomycete fungi belonging to the genus *Armillaria*, and ***stem rots*** caused by various basidiomycete fungi including *Daedalea quercina* (L.) Pers., *Fistulina hepatica* (Schaeff.) With. and *Laetiporus sulphureus* (Bull.) Murrill. ***Decline*** of chestnut trees and stands has also been reported with increasing frequency since the early 2000s in north-western Italy. Although stands were affected byheavy infestations of insects, with particular reference to *Dryocosmus kuriphilus Yasumatsu* (Hymenoptera Cynipidae), the Asian chestnut ***gall wasp***, there have also been numerous reports of frequent and severe hailstorms occurring in the same areas, presumably as a result of the climate change. While infestations of *D. kuriphilus* have been drastically reduced thanks to biological control campaigns, ***diseases caused by pathogenic chromista*** and ***fungi*** and the effects of ***climate change*** represent a ***persistent*** threat to the stability of ***ecosystems*** in which chestnut is present or dominant. For this reason, the phytosanitary monitoring conducted during MONGEFITOFOR project mainly focused on chestnut blight, ink disease and diseases associated with *G. castaneae*. Nevertheless, the selected stands were surveyed more generally for their health conditions.

CHESTNUT BLIGHT

Chestnut blight is an ***infectious disease*** caused by the ascomycete fungus ***Cryphonectria parasitica***. This ***pathogen***, first reported in Europe in the 1930s, has rapidly spread across the continent through almost the entire range of the European chestnut. At present, there are few European countries where *C. parasitica* is not present. The accidental introduction and subsequent spread of *C. parasitica* has caused alarm and concern on the European continent, as the pathogen had previously been responsible for the almost complete ***extinction*** of the American chestnut (*Castanea dentata* [Marsh.] Borkh.) in the United States. Indeed, it is estimated that *C. parasitica* spread across the US over a 3.6 million hectare area at a rate of approximately 30 km per year, leading to the death of 3.5 billion American chestnut trees between 1904, when it was first reported in New York City, and around 1950. Although the impact of the disease on the European chestnut has not been as dramatic, chestnut blight is considered one of the ***most important*** pests for this species, causing high ***mortality*** rates.
Early symptoms of the disease can be detected on the ***stem*** and ***branches***. In general, ***wounds*** are needed for infection to occur. Indeed, *C. parasitica* is a typical ***wound pathogen***, i.e. a micro-organism that can infect the host through wounds exposing inner tissues, irrespective of whether these are of natural origin (e.g. hail wounds, lesions caused by wildlife) or anthropogenic (grafting, pruning, cutting, other injuries) (**Figure 9**). The infectious inoculum of the pathogen penetrating through wounds in the bark mainly consists of spores. On the bark of the tree, the fungus produces rounded, punctiform vesicular outgrowths, visible to the naked eye and approximately 0.5-2 mm in size. These '***pustules***' are ***yellow-orange*** or ***reddish in colour*** (**Figure 10**) and host special structures that release ***spores***. These may be ***ascospores*** of sexual origin, released by the perithecia, or ***conidia*** of asexual origin, released by the pycnidia.
The ascospores are mainly ***air-borne and dispersed by wind***, while the dispersal of conidia is facilitated by ***rain-splash***, but both factors play an important ***epidemiological role***. A recent study (Lione et al. 2022, see Essential Bibliography) showed that in the north-western Alps, C. parasitica spore production occurs

throughout the year. However, spore loads have two peaks, one in spring and one in autumn, followed by a summer and a winter minimum (Figure 11). When the number of rainy days with precipitation comprised between 1 and 10 mm/day increases over the course of a week, the inoculum pressure (spore loads) also tends to increase at the end of the week. As the ***risk of infection*** at a given site depends on the inoculum pressure, in the ***north-western Alpine sectors*** this is ***highest*** in ***spring***, ***autumn*** and during ***rainy weeks***.
Once infection has occurred, the ***mycelium*** of the pathogen, consisting of ***cream-coloured***

9

10

FIGURE 9
CRYPHONECTRIA PARASITICA CAN PENETRATE INTO THE HOST THROUGH WOUNDS BY MEANS OF ASCOSPORES OR CONIDIA. THE PICTURE SHOWS A MECHANICAL INJURY ON A CHESTNUT STEM.

FIGURE 10
PUSTULES DEVELOPED BY CRYPHONECTRIA PARASITICA ON INFECTED PLANT TISSUES

mycelial fans, develops and grows under the bark, colonising the ***cambium, which is finally killed***. In order to inspect the cambium and the presence of *C. parasitica* mycelium, debarking is needed (**Figure 12**).

11

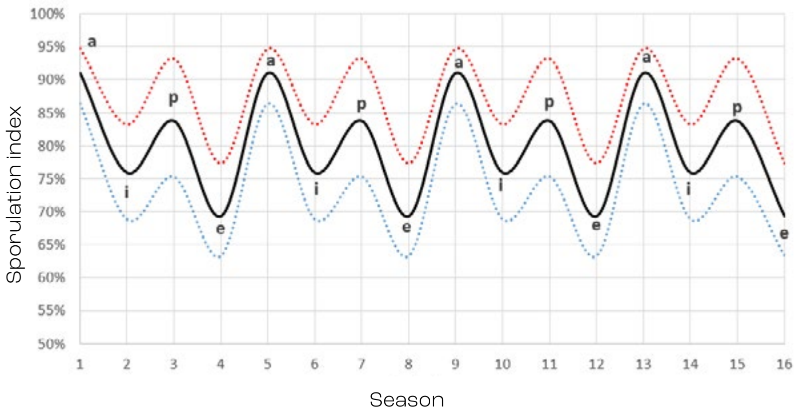

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FIGURE 11
INOCULUM PRESSURE OF CRYPHONECTRIA PARASITICA IN THE NORTH-WESTERN ALPINE SECTORS (IN BLACK) EXTRAPOLATED FROM DATA REPORTED IN THE LITERATURE (LIONE ET AL. 2022). THE GRAPH SHOWS THE SIMULATED TREND OVER A 4-YEAR PERIOD (16 CONSECUTIVE SEASONS, 1 TO 16 IN ABSCISSA). AN EMPIRICAL SPORULATION INDEX IS SHOWN FOR EACH SEASON (A: AUTUMN; I: WINTER; P: SPRING; E: SUMMER) (IN ORDINATE). THE AUTUMN AND SPRING MAXIMA, AND THE SUMMER AND WINTER MINIMA ARE EVIDENT. THE RED AND BLUE CURVES INDICATE THE UNCERTAINTY OF THE SIMULATION (95% CONFIDENCE INTERVALS).

FIGURE 12
SYMPTOMS CAUSED BY CRYPHONECTRIA PARASITICA ON A CHESTNUT SUCKER. AFTER DEBARKING, THE CAMBIUM , WHICH APPEARS AS BRIGHT GREEN TISSUE, BECOMES VISIBLE (1). THE SAME INCISION, MADE FURTHER TO THE LEFT, INSTEAD SHOWS THE NECROSIS OF THE CAMBIUM CAUSED BY THE PATHOGEN (2). THE CREAM-COLOURED MYCELIUM OF C. PARASITICA CAN BE OBSERVED UNDER THE BARK (3). REDDISH DISCOLOURATIONS OF THE BARK CAN BE VISIBLE FROM OUTSIDE (4) AS WELL AS LONGITUDINAL BARK LESIONS IN THE FORM OF CANKERS (5) . FURTHER DETAILS ARE ILLUSTRATED IN THE FOLLOWING FIGURES.

However, infection also leads to several ***visible symptoms***, the observation of which can be conducted directly in the field. The early symptoms of the disease can be seen on the surface of the woody organs, on which ***depressed areas*** appear as a result of the loss of functionality of the cambium (**Figure 13**). At a later stage, ***changes in the colour of the bark*** appear (**Figure 14**).

FIGURE 13
CHESTNUT SUCKER ON SHOWING A DEPRESSED AREA . THE DEPRESSION (HIGHLIGHTED IN YELLOW) IS THE RESULT OF THE INACTIVATION OF THE CAMBIUM CAUSED BY THE INFECTION OF CRYPHONECTRIA PARASITICA.

FIGURE 14
YOUNG CHESTNUT TREE WITH CHANGES IN THE COLOUR OF THE BARK, APPEARING AS ORANGE OR BRICK-RED PATCHES, THE APPEARANCE OF WHICH IS A SYMPTOM INDUCED BY CRYPHONECTRIA PARASITICA.

13

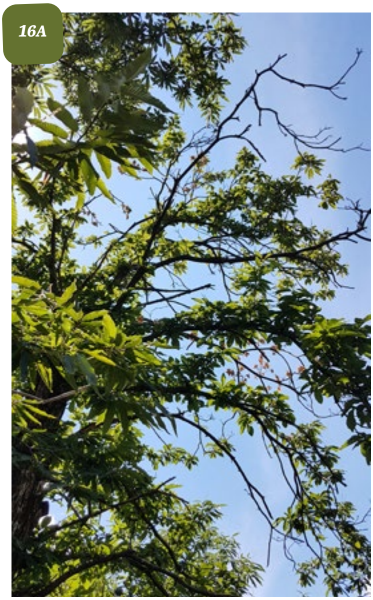
14

The growth stresses generated by the local death of cambium in an organ which is still growing lead to the onset of the most characteristic symptom of the disease, namely the ***canker***. Two main ***types of cankers*** can be found on chestnut trees, the lethal canker and the healed, non-lethal canker. With a ***lethal canker*** (**Figure 15**) the lesions are generally more prominent and under the canker a proliferation of young shoots may be oberved. The upper portion of the woody organ on which the canker develops is generally killed by the fungus (**Figure 16**). Instead, in the case of ***healed canker*** (**Figure 17**) the expression of symptoms is attenuated: lesions are less marked and tend to be localised superficially, there is no emission of shoots at the base of the canker and the tree will react to the pathogen. Importantly, no death of woody organs is observed.

15

FIGURE 15
LETHAL CANKERS THAT HAVE OCCURRED ON CHESTNUT SUCKERS FOLLOWING INFECTION WITH CRYPHONECTRIA PARASITICA. AT THE BASE OF THE CANKER SHOWN IN THE IMAGE ON THE LEFT, YOUNG SHOOTS CAN BE OBSERVED SPROUTING CAN BE OBSERVED RECURRENTLY IN THE PRESENCE OF LETHAL CANKERS.

16A



16B

16C

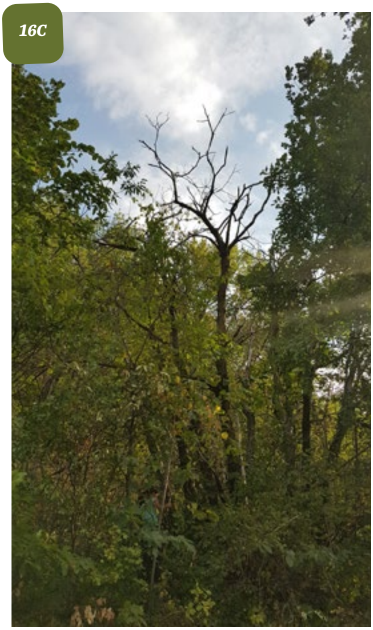


FIGURE 16
CHESTNUT TREES WITH SYMPTOMS IN THE CROWN ASSOCIATED WITH THE PRESENCE OF LETHAL CANKERS CAUSED BY CRYPHONECTRIA PARASITICA. THE DISTAL PORTION OF THE BRANCHES DESICCATES ABOVE THE POINT WHERE THE LESIONS OCCURRED (A). BRANCHES AND TWIGS ARE KILLED AND AND THE TREE REACTS BY EMITTING SHOOTS (B). IN THE WORSE CASE, THE TREE DIES COMPLETELY BECAUSE OF THE DISEASE (C).

FIGURE 17

HEALED CANKERS ON CHESTNUT SUCKERS FOLLOWING INFECTION BY CRYPHONECTRIA PARASITICA. THE LESIONS IN THE BARK AND UNDERLYING TISSUES ARE SHALLOW ALLOWING THE TREE TO REACT. AT THE BASE OF THE CANKER, NO SHOOTS DEVELOP. IN SOME CASES, A SWELLING OF THE SUCKER CAN BE OBSERVED IN ASSOCIATION WITH THE HEALED CANKER.

It is known that lethal and non-lethal, healed cankers are associated with two different types of *C. parasitica* strains, namely ***virulent*** and ***hypovirulent strains***. The hypovirulent strains are characterised by genotypic and phenotypic features that markedly differentiate them from virulent strains. Indeed, hypovirulent strains of *C. parasitica* are 'weakened pathogens' because they themselves have been infected with a virus called ***Cryphonectria hypovirus 1 (CHV1)***. The CHV1 virus attenuates the virulence of *C. parasitica*. Morphologically, in vitro cultures of the hypovirulent strains of *C. parasitica* show are whitish and display reduced sporulation compared to the virulent strains (**Figure 18**), which are generally orange. CHV1 can be transmitted from virus-infected hypovirulent strains to uninfected virulent strains. When virus transmission occurs, virulent strains undergo a conversion process, which makes them hypovirulent. This phenomenon (known as ***hypovirulence***) is based on ***complex biological mechanisms***, which form the basis of ***biological*** and ***silvicultural control*** guidelines against *C. parasitica* (see the dedicated chapter and **Box 3**). The fungus can also survive as a saprotroph and produce spores on ***chestnut stumps*** and ***branches*** on the ground (**Figure 19). I**n addition, *C. parasitica* can infect trees or colonise ***oak*** stumps and branches, on which the pathogen does not cause significant damage, but which may constitute a ***reservoir of infectious inoculum***. The ***life cycle*** of *C. parasitica* summarized later (**Figure 20**).

FIGURE 18
PHENOTYPIC DIFFERENCES BETWEEN VIRULENT AND HYPOVIRULENT STRAINS OF CRYPHONECTRIA PARASITICA. IN VITRO CULTURE OF A VIRULENT STRAIN OF THE PATHOGEN WHOSE MYCELIUM HAS NOT BEEN INFECTED BY CRYPHONECTRIA HYPOVIRUS 1 (CHV1): THE COLONY APPEARS ORANGE AND CONIDIA PRODUCTION IS ABUNDANT (A). THE SECOND IMAGE SHOWS A HYPOVIRULENT STRAIN OF C. PARASITICA INFECTED WITH CHV1: THE COLONY IS WHITISH AND CONIDIA PRODUCTION IS REDUCED (B).

18A

18B

19

FIGURA 19
CHESTNUT BRANCH INFECTED BY CRYPHONECTRIA PARASITICA COLLECTED FROM THE LITTER. THE FUNGUS STROMATA CAN BE OBSERVED.

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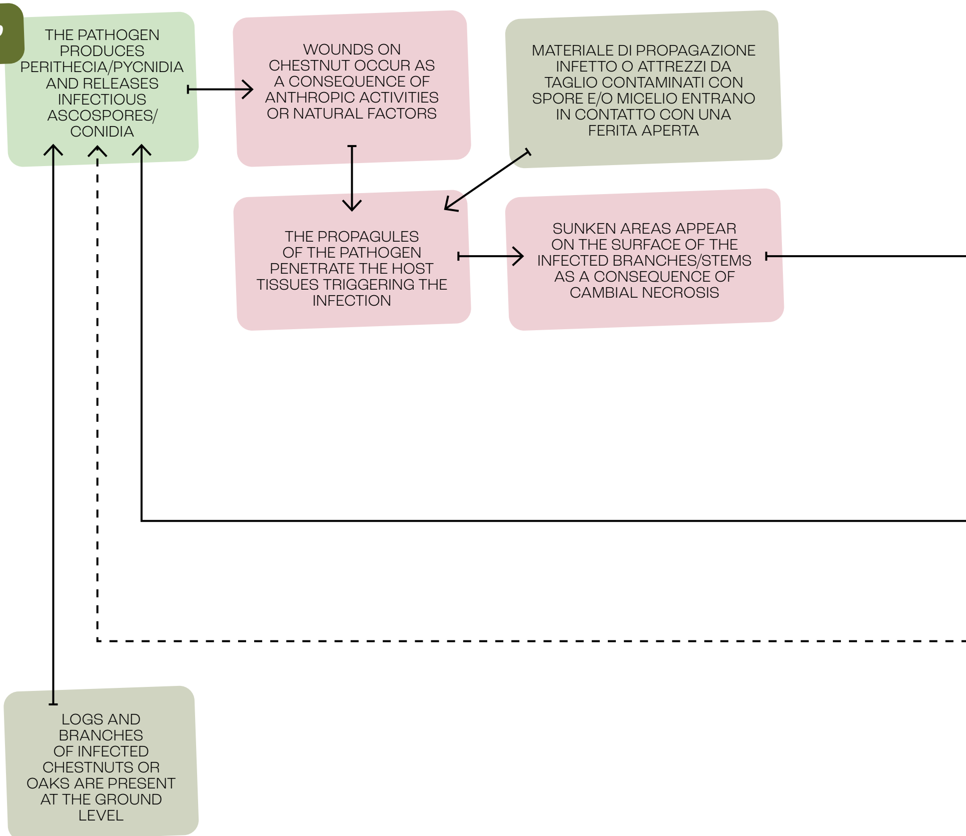

INK DISEASE

Ink disease can be considered as one of the ***main*** chestnut ***diseases*** in Europe. In Portugal, Spain and Italy it has been reported since at least the 18th century. Starting from the 1990s,, new outbreaks have increased considerably. Today, ink disease is mainly widespread in the southern range of the chestnut (Spain, Portugal, France, Switzerland, Italy, Greece, Romania, Macedonia, Turkey). However, countries further north such as Germany, Great Britain and the Czech Republic are also increasingly affected.

Trees affected by ink disease show ***defoliation*** and leaves smaller than regular ones. At the ***tree collar and base*** of the ***trunk***, infected trees show ***bark necrosis*** that can be associated with oozing of blackish liquid. Bark necrosis becomes evident after debarking (**Figure 21**). As the entire ***root system*** is affected, trees affected by ink blight are not able to develop new suckers.

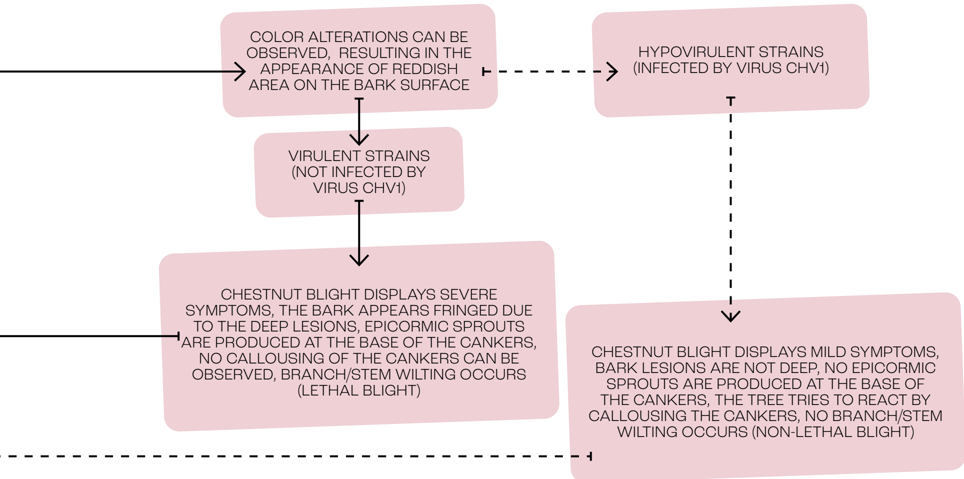

FIGURE 20
SIMPLIFIED DIAGRAM OF THE LIFE CYCLE OF CRYPHONECTRIA PARASITICA AND ITS RELATIONSHIP WITH SYMPTOMS ON CHESTNUT. THE GREEN BOX INDICATES THE CONVENTIONAL START OF THE CYCLE, THE BLUE BOXES ANY INCOMING VARIANTS, AND THE PINK BOXES DESCRIBE THE DIFFERENT PHASES. THE ARROWS INDICATE THE SUCCESSION OF EVENTS. CERTAIN PECULIARITIES ASSOCIATED WITH THE HYPOVIRULENT STRAINS OF THE PATHOGEN ARE CONNECTED WITH DOTTED LINES.

Ink disease is mainly caused by two species of oomycetes of the genus ***Phytophthora***, namely ***P. cinnamomi*** and ***P. x cambivora***. Oomycetes are microorganisms closely related to brown algae and diatoms. Both pathogen species ***live in the soil*** where they form a network of ***filamentous cells*** (hyphae). Under favourable weather conditions, e.g. heavy rainfall, they can produce asexual, biflagellate spores (***zoospores***) that can move actively in the circulating soil solution. When zoospores reach the roots of a chestnut tree, they lose their flagella, germinate and cause ***an infection*** that usually leads to ***lethal root rot***. Under unfavourable conditions (e.g. periods of drought), *P. cinnamomi* can also form another type of asexual spores (***chlamydospores***), which are important for its long-term survival. *P. cinnamomi* and *P. x cambivora* can also reproduce sexually and produce ***oospores***. Neither *P. cinnamomi* nor *P. x cambivora* ***are European species***. The former is probably native to Papua New Guinea, while the origin of *P. x cambivora* is not yet known. Through international trade in ***infected plant material***, they were rapidly spread around the world. Both pathogens can attack a very large number of host plants. With a spectrum of over 5000 plant species, *P. cinnamomi* is among the 100 most dangerous ***invasive species*** in the world. In addition to chestnut trees, in Europe it causes extensive damage to cork oaks (*Quercus suber*) and holm oaks (*Quercus ilex*) in the so-called '*dehesa*', the typical agroforestry system of the Iberian peninsula. In Central Europe, *P. x cambivora* is instead increasingly reported on beech (*Fagus sylvatica*). The main limiting factor for a wider spread of these two pathogens in Europe would appear to be temperature. In particular, *P. cinnamomi* is very sensitive to cold and has not yet been found in regions where minimum temperatures are below 1.4°C. In a chestnut stand affected by ink disease, the soil is infested by one or both pathogens and it is unrealistic to completely eradicate the disease. Control strategies therefore aim to ***reduce the incidence of the disease*** and ***to prevent its further spread***. A relatively simple and mostly feasible measure is to ***improve soil drainage***, e.g. by creating ***streams*** to dispose surface water. Indeed, moist soils with stagnant or slow draining water promote the formation and spread of zoospores that can actively move through water. Especially after heavy rainfall, they develop and are spread over a large area by rainwater, increasing the risk of infection. The transport of ***infested soil*** (simply through the soles of shoes or the tyres of forest vehicles) must be avoided, especially during and immediately after rainfall. As Asian chestnut trees are less susceptible to ink disease, Euro-Asian hybrids could be a viable alternative to the European chestnut tree in specific situations (e.g. in fruit orchards). In any case, seedlings and other propagation material should only be purchased from professional nursery operators and after careful inspection of the above-mentioned material.

FIGURE 21
TYPICAL SYMPTOMS OF INK DISEASE ON CHESTNUT. DEFOLIATION (A) AND NECROSIS UNDER THE BARK AT THE BASE OF THE TREE (B).

21A

21B

DISEASES CAUSED BY *GNOMONIOPSIS CASTANEAE*

Since the early 2000s, chestnut growers in countries including Italy and Switzerland began to complain of a significant increase in product losses in their chestnut orchards as a consequence of a high incidence of chestnut rot. Symptoms observed pre- and post-harvest at the endosperm level were not completely consistent with symptoms caused by the most common agents of fruit rot, including the ascomycete fungi *Ciboria batschiana* (Zopf) N.F., *Phoma* spp. and *Phomopsis* spp. Furthermore, the isolation assays conducted repeatedly yielded colonies whose peculiar macro- and micromorphological characteristics were peculiar. Following further studies and more in-depth investigations, it was ascertained that the causal agent of the resurgence of the fruit rot was a yet unknown species of ascomycete, which was first described in 2012 under the name ***Gnomoniopsis castaneae*** (**Figure 22**), synonym *G. smithogilvyi*. Since then, many other reports of the pathogen from Europe, Asia, Oceania and America have been published. The current geographical range of distribution of the pathogen is not yet fully known, while its origin is completely unknown. However, in view of the impact and levels of incidence and severity that ***chestnut rot*** (**Figure 23**) caused by *G. castaneae* has caused to date, the scientific community and experts in the chestnut sector agree that this pathogen represents one of the main threats to chestnut cultivation worldwide.

22

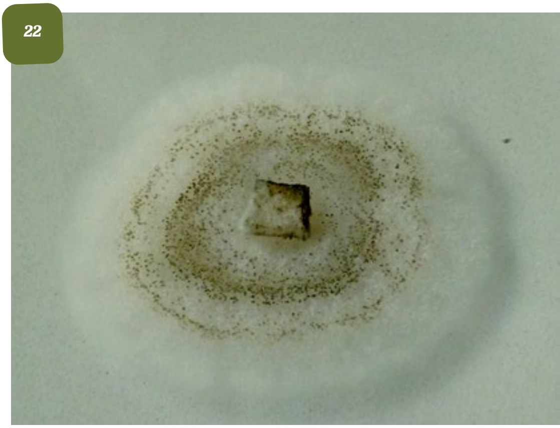

FIGURE 22
IN VITRO CULTURE OF THE PHYTOPATHOGENIC ASCOMYCETE FUNGUS GNOMONIOPSIS CASTANEAE.

FIGURE 23
CHESTNUT ROT CAUSED BY GNOMONIOPSIS CASTANEAE. THE MOST TYPICAL SYMPTOM IS A ROT THAT LEADS TO THE DEGRADATION OF THE ENDOSPERM, THE COLOUR OF WHICH TURNS TOWARDS SHADES OF BROWN (A), BUT THE FUNGUS CAN ALSO BE ASSOCIATED WITH DEHYDRATION OF THE FRUIT, WHICH TENDS TO TAKE ON A CHALKY CONSISTENCY AND A WHITISH COLOUR (B).

Fruit rot is an issue that is beyond the scope of this handbook, as it is not strictly related to forestry and to the main ecosystem services provided by the coppice. However, *G. castaneae* is not only an agent of chestnut rot, but has also been reported in association with other symptoms like ***bark cankers***. Although knowledge on the relationship between *G. castaneae* and bark cankers is at present still largely lacking, some indications suggest that the cankers induced by the pathogen are not too dissimilar to those caused by *C. parasitica*, to the extent that in many cases *G. castaneae* has been unexpectedly isolated during phytosanitary monitoring campaigns targeting *C. parasitica*. Tests conducted in a controlled environment by means of artificial inoculations have highlighted the pathogenicity of *G. castaneae* and its ability to reproduce symptoms of bark necrosis and cankers. In the forest, however, there are still no reliable estimates of the impact of cankers associated with *G. castaneae*. The practical difficulty in making such estimates depends on several factors. Firstly, distinguishing on a visual basis between cankers caused by *G. castaneae* and *C. parasitica* can be particularly difficult. Furthermore, *G. castaneae* is a particularly versatile fungus, being able to colonise chestnuts and green tree tissues as an ***endophyte***, i.e. as a micro-organism present inside host tissues that coexists with the host without inducing disease symptoms. Adding to the complexity of the picture is the fact that *G. castaneae* is also a ***saprotrophic fungus***, which can colonise substrates consisting of organic matter of plant origin present in the litter. Consequently, even if *G. castaneae* is isolated from symptomatic chestnut tissues, establishing a cause-and-effect association between the presence of the fungus and the symptoms could be challenging. Indeed, *G. castaneae* could be present in plant tissues as an endophyte, as a latent pathogen (i.e. a fungus capable of shifting from endophytic to pathogenic state), or it could have occurred as an opportunistic fungus after infection *C. parasitica*. Investigating the aetiology of *G. castaneae* canker is beyond the scope of the MONGEFITOFOR project, but monitoring the presence of the pathogen in the Italian-Swiss cross-border areas is essential in order to be aware of its presence, incidence and geographical distribution.

In relation to the ***biological cycle***, ***epidemiology*** and ecology of *G. castaneae*, the fungus produces the reproductive structures of the sexual form on the spines of burrs when they are mostly on the ground. In contrast, the reproductive structures of the asexual phase are produced on the surface of the chestnut burrs or on the galls of *D. kuriphilus*, if present. Ascospores and conidia infect the chestnut tree via the floral route during the anthesis period, leading to chestnut rot and ideally ending the cycle with falling of the burrs. However, it cannot be excluded that there are other modes of infection, especially in relation to cankers. In the north-western Alpine areas, *G. castaneae* is capable of releasing infectious inoculum (***ascospores*** and ***conidia***) throughout the year. Although no true seasonal trend is evident as in the case of *C. parasitica*, in ***winter*** the inoculum production of *G. castaneae* reaches a ***minimum***, while in the other seasons the values are statistically comparable (**Figure 24**).

FIGURE 24
SEASONAL TREND IN SPORE PRODUCTION OF GNOMONIOPSIS CASTANEAE IN THE NORTH-WESTERN ALPINE SECTORS (IN BLACK) EXTRAPOLATED FROM DATA REPORTED IN THE LITERATURE (LIONE ET AL. 2021). THE GRAPH SHOWS THE SIMULATED TREND FOR A 4-YEAR PERIOD (16 CONSECUTIVE SEASONS, 1 TO 16 IN ABSCISSA). FOR EACH SEASON (A: AUTUMN; I: WINTER; P: SPRING; E: SUMMER) AN EMPIRICAL SPORULATION INDEX (IN ORDINATE) IS SHOWN, INDICATING THE INOCULUM PRESSURE. WINTER MINIMA ARE EVIDENT, WHILE SPRING, SUMMER AND AUTUMN SHOW STATISTICALLY COMPARABLE VALUES. THE CURVES IN RED AND BLUE INDICATE THE UNCERTAINTY OF THE SIMULATION (95% CONFIDENCE INTERVALS).

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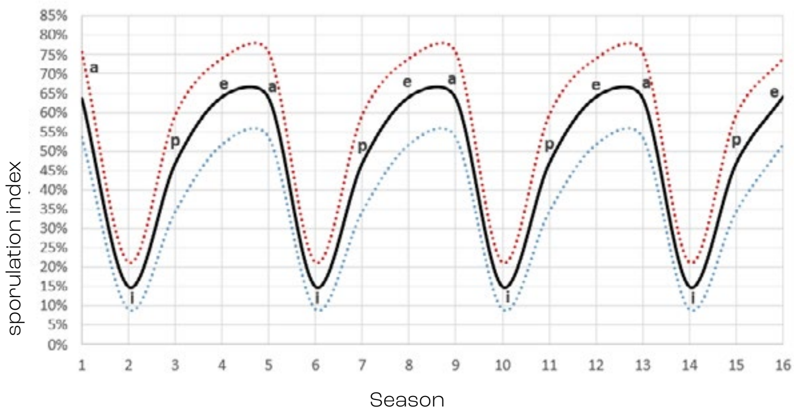


It has been established that ***milder temperatures*** are favourable not only to a ***higher incidence*** of fruit rot, but they also boost the inoculum pressure of *G. castaneae*, i.e. the production and release of infectious inoculum. ***Increasing levels*** of ***inoculum pressure*** are also positively correlated with the ***wind gusts***.

THE PHYTOSANITARY MONITORING OF CHESTNUT TREE IN AOSTA VALLEY

In the course of the MONGEFITOFOR project, a systematic ***phytosanitary chestnut monitoring*** campaign was conducted in the Aosta Valley through a series of ***forest surveys***, accompanied by the collection of ***biological samples*** and their ***analysis*** in the ***laboratory***. With reference to the previously described chestnut diseases and the target pathogens *C. parasitica*, *G. castaneae* and *Phytophthora* spp. the knowledge framework regarding their presence, distribution and impact was lacking for the Italian side of the cross-border areas bordering Switzerland. With the aim of acquiring precise information on this subject, through the activities of the MONGEFITOFOR project, the following objectives were identified:

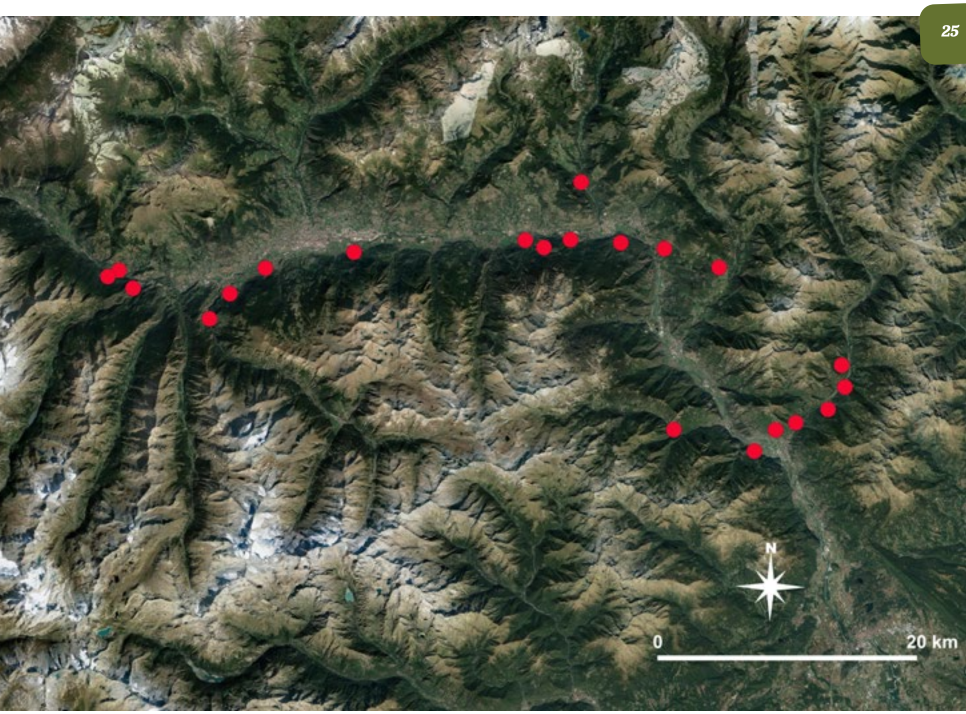
- to make a qualitative and quantitative assessment of the main chestnut diseases in coppices representative of the Italian-Swiss cross-border areas;
- to provide an estimate of the incidence and determine the spatial distribution of target pathogens;
- to check for other phytosanitary problems.

For site selection, a preliminary characterisation of the chestnut coppices was conducted on the basis of forest types and of the data held by the Forestry Corps of Aosta Valley. Further selection operations were conducted by adopting a series of criteria aimed at combining technical-scientific requirements with logistical and administrative aspects, focusing on sites:

- spread throughout the natural range of the chestnut in the Aosta Valley, both latitudinally and longitudinally;
- located at representative altitudes of the growing areas of chestnut in the region;
- balanced for aspect;
- located on slopes with different gradients;
- that are easily accessible because of the presence of roads;
- preferably with a public ownership.

The monitoring of the health status of the chestnut in the Aosta Valley was conducted over a two-year period (2020-2021) by performing field surveys in the summer months in 21 selected sites (**Figure 25**).

FIGURE 25
MAP OF SITES WHERE PHYTOSANITARY MONITORING WAS CONDUCTED ON CHESTNUT DURING THE MONGEFITOFOR PROJECT. ON THE MAP, THE SITES ARE HIGHLIGHTED IN RED. IN THE BACKGROUND, SATELLITE IMAGE OF THE ITALIAN-SWISS CROSS-BORDER AREAS INVOLVED IN THE PROJECT (SOURCE: GOOGLE MAPS, 2023).



A characterisation of the sites was performed in order to acquire dendrometric variables and data of phytopathological relevance (Figure 26). In particular, a visual analysis of the symptoms was performed.

During the surveys, biological samples were taken from woody tissues (Figure 26) of chestnut. The samples were subsequently transferred to the ***Forest Plant Pathology and Forest Biotechnology Laboratories*** of the Department of Agricultural, Forest and Food Sciences (DISAFA) of the University of Turin, where they were analysed using ***diagnostic techniques***. The analyses made it possible to verify the presence of the target pathogens and to quantify their incidence (Box 2).

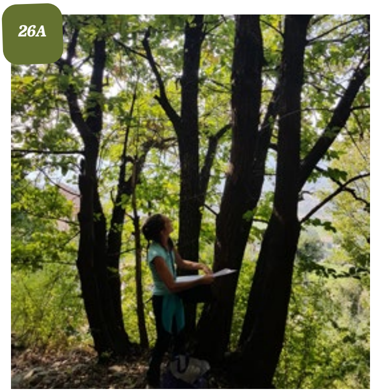


FIGURE 26

ACQUISITION OF DATA CONCERNING THE SIZE AND THE OVERALL HEALTH STATUS OF CHESTNUT TREES (A). TAKING SAMPLES OF WOODY TISSUES NEAR CANKERS (B). SAMPLING THE TREE COLLAR TO CHECK SYMPTOMS OF INK DISEASE (C). TO INK BLIGHT (C).

BOX 2

Laboratory diagnosis

Laboratory diagnosis allows the detection of the pathogen thereby confirming its identity. In the course of the MONGEFITOFOR project, laboratory analyses were conducted mainly based on classical microbiological and microscopy techniques, including isolation assays. Following the collection of plant tissue samples, work is performed in a sterile environment, under a biological hood, by placing a few fragments of the sample in culture on dedicated agarised substrates. The aim is to obtain in-vitro cultures of pathogenic microorganisms (**Figure 27**). The colonies of fungi or chromista obtained are subsequently subjected to microscopic or molecular investigations (e.g. PCR, real-rime PCR) to determine their identity at species level.

27A

27B

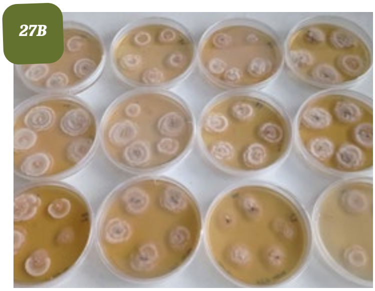


FIGURE 27
SOME PHASES OF THE LABORATORY TESTS CONDUCTED ON BIOLOGICAL SAMPLES OF CHESTNUT PLANT TISSUES. THE PICTURES SHOW SOME STAGES IN THE EXECUTION OF THE ISOLATION TESTS AIMED AT DIAGNOSING THE TARGET PATHOGENS. OPERATIONS CONDUCTED IN A STERILE ENVIRONMENT, UNDER A BIOLOGICAL HOOD, CONSISTING IN PLACING PLANT TISSUE FRAGMENTS IN CULTURE ON AGARISED SUBSTRATES (A). PETRI DISHES WITH FUNGAL COLONIES DEVELOPED FROM THE TISSUE FRAGMENTS PLACED IN CULTURE (B).

INCIDENCE, SEVERITY AND DISTRIBUTION OF CHESTNUT DISEASES AND TARGET PATHOGENS

The chestnut coppices monitored in Valle d'Aosta are located at altitudes ranging from 380 m above sea level to 1380 m above sea level. The majority of these (67%) are distributed in the lower valley, while the remaining in the middle (9%) and upper valley (24%), with slopes varying from approximately 3% to 78%. Dendrometric measurements have shown that chestnut trees tend to be mature or over-mature, although there are also sites with younger suckers. The average sucker diameters at breast height were approximately between 30 and 35 cm, but locally considerably larger diameters were recorded due to the presence of standard trees . Instead, average diameters of slightly more than 10-15 cm were found in a number of more recently coppiced sites.

Overall, ***symptoms of*** chestnut ***blight*** were detected ***in all the sites***, despite the fact that these differed widely in relation to many characteristics. Chestnut blight is widespread on trees of different age in sites with different environmental and management conditions. Symptoms of chestnut blight were found on both ***suckers*** and ***standard trees***, and both ***lethal and healed cankers*** were observed (**Figure 28**).

28B

28C

FIGURE 28
REPRESENTATIVE EXAMPLES OF SYMPTOMS OF CHESTNUT BLIGHT IN COPPICES ON THE ITALIAN SIDE. PRESENCE OF LETHAL (FOREGROUND) AND HEALED (BACKGROUND) CANKERS IN A COPPICE (A). DEPRESSED LESIONS ON THE BARK OF A YOUNG SUCKER (B). CRYPHONECTRIA PARASITICA STROMATA ON SYMPTOMATIC BRANCHES (C).

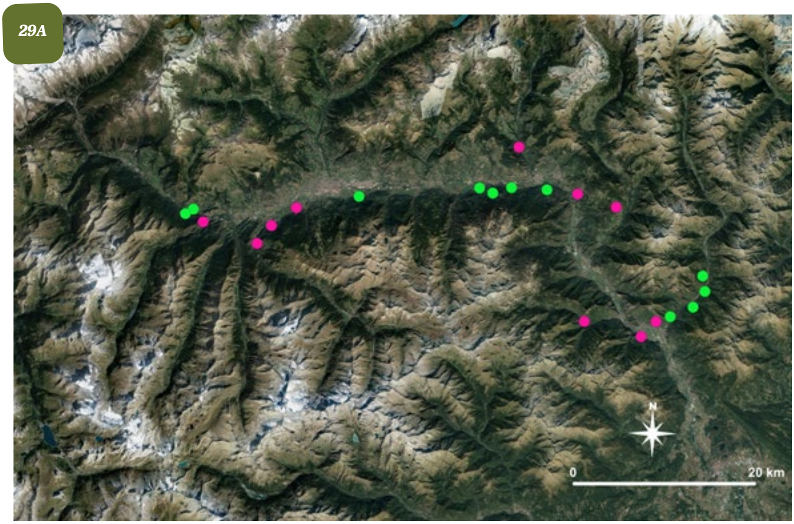
The percentage of ***desiccated branches*** is on average ***35%***, with a minimum value of 4% and a maximum of 64% depending on site. Overall, the percentage of desiccated branches was similar between the lower (30%) and upper valley (36%). Instead, the overall percentage of desiccated branches in the middle valley was as high as 62%.

Chestnut blight severity was estimated by adopting a class system, considering the first 5 metres of tree height from the collar and assessing the presence of 0-1, 2, 3, 4, 5 or more cankers (class 1, 2, 3, 4, and 5, respectively). On average, the sites monitored had a class ***score of 4***, with a minimum of 1.6 and a maximum of 5. The same score showed average values of 3.7 in the lower valley, while higher values were observed in the upper valley (4.4) and middle valley (4.8). Therefore, there seems to be a ***positive correlation*** (confirmed by a significant Pearson index of 0.71) ***between the incidence of desiccated branches*** and the ***severity of chestnut blight***, which is to be expected in light of the biology of the pathogen.

The diagnosis conducted in the laboratory from biological samples collected in the field revealed the ***presence*** of ***C. parasitica*** at 10 sites out of 21 (corresponding to a ***48% incidence***) and ***G. castaneae*** at 17 sites (corresponding to an ***81%*** incidence). Of these, 8 sites (38%) showed the presence of both pathogens, 2 (9.5%) exclusively of *C. parasitica*, 9 (43%) exclusively of *G. castaneae*, while for the remaining 2 (9.5%) sites no isolates of either species were obtained.

Based on the results of the surveys, the maps of the spatial distribution of *C. parasitica* and *G. castaneae* are reported below (**Figure 29**).

29A



29B

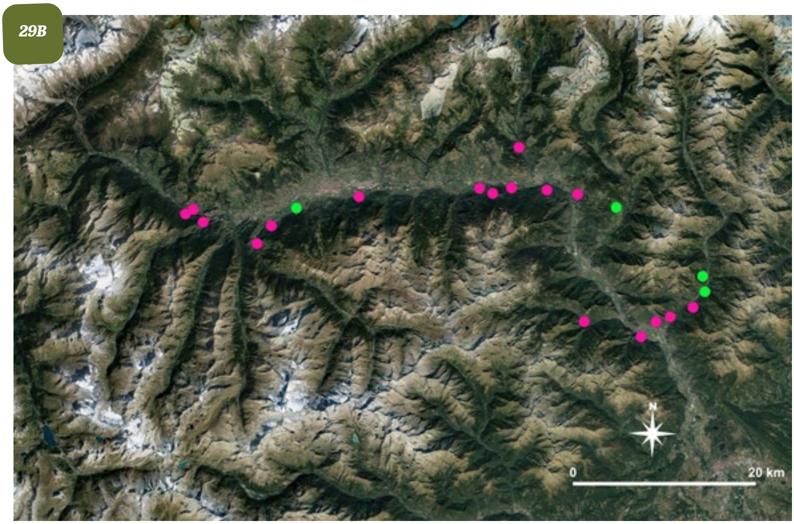


FIGURE 29
MAPS OF SITES WHERE CRYPHONECTRIA PARASITICA (A) AND GNOMONIOPSIS CASTANEAE (B) WERE DIAGNOSED AS A RESULT OF THE PHYTOSANITARY MONITORING CONDUCTED DURING THE MONGEFITOFOR PROJECT. THE SITES WHERE THE PATHOGENS WERE FOUND ARE SHOWN IN FUCHSIA, THE OTHERS IN GREEN. IN THE BACKGROUND, SATELLITE IMAGE OF THE ITALIAN-SWISS CROSS-BORDER AREAS INVOLVED IN THE PROJECT (SOURCE: GOOGLE MAPS, 2023).

At the ***site level***, where the pathogens were found to be present, their ***incidence*** (percentage of infected trees) averaged at ***62%*** for ***C. parasitica*** and ***57%*** for ***G. castaneae***, in both cases with minima and maxima of ***20-25%*** and ***100%***. The data seem to suggest that both pathogens are present and widespread in Aosta Valley. It is worth noting that in several stands where bark cankers were present, it was possible to isolate *G. castaneae*, but not *C. parasitica*. It is not possible to establish whether this result is a consequence of the aetiology of the canker, interspecific competition phenomena, or succession processes of the fungal communities associated with cankers. The presence of *G. castaneae* was also investigated in chestnuts and the results of the laboratory analysis showed that 11 out of 21 sites (52%) had infected rotten nuts. All factors considered, *G. castaneae* appears to be a present and abundant pathogen.

With regard to ***Phytophthora spp.***, symptoms of ink disease were not detected, with the exception of two sites in St. Marcel and Saint-Denis. However, a thorough inspection of symptomatic trees and subsequent isolation attempts were inconclusive on the presence of these pathogens.

The phytosanitary monitoring of chestnuts conducted during the MONGEFITOFOR project has thus highlighted how ***bark cankers*** and the phytopathogenic fungi ***C. parasitica*** and ***G. castaneae*** are present and ***widespread*** in Aosta Valley, affecting a large part of the chestnut distribution area in the region. The sites investigated are in fact located over an area extending approximately 57 km longitudinally and 21 km latitudinally, virtually covering a topographical area of almost 1200 km2 over a height difference of 1000 m.

However, it should be pointed out that the health status of the chestnut appears to be somewhat dynamic and it cannot be ruled out that the onset or resurgence of certain diseases occurs in connection with the increasingly frequent climatic anomalies experienced in recent years. Recent studies have highlighted, for example, the role that meteorological phenomena, such as ***hailstorms***, can play in fostering *C. parasitica* infections. Indeed, hail is an agent capable of causing injuries on bark-tissues that, by exposing the underlying cambium, facilitate infection and the onset of disease symptoms (**Figure 30**).

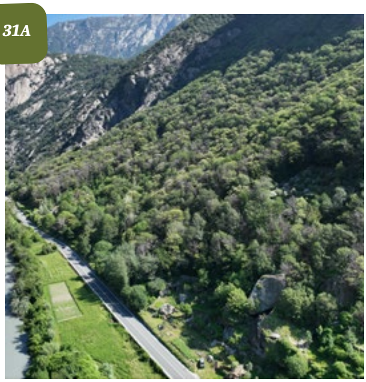
It is interesting to mention that, at the very end of the writing of this manual (June

FIGURE 30
CHESTNUT BRANCH SHOWING HAIL WOUNDS AND SYMPTOMS OF CHESTNUT BLIGHT.

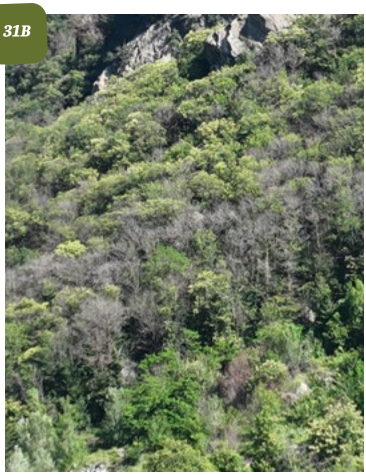
FIGURA 31
AERIAL IMAGES TAKEN BY DRONE FOLLOWING RECENT REPORTS OF CHESTNUT TREE DECLINE IN THE MUNICIPALITY OF HÔNE IN AOSTA VALLEY.

2023), a number of reports of extensive decline of chestnut were received from the lower Aosta Valley. The reports were verified by the Aosta Valley Forestry Corps and monitored with ***drones*** equipped with a video camera and camera suitable for aerial photography. Although clarifying the aetiology of these tree declines will require further diagnostic investigations, their sudden onset seems to indicate that ***continuous***, ***capillary*** and ***constant phytosanitary monitoring*** operations of the territory are fundamental for the ***protection*** of ***forests***. (**Figure 31**).

31A



31B



INK DISEASE MONITORING IN SWITZERLAND

Ink disease was officially reported for the first time on the Swiss side of the Italian-Swiss cross-border areas covered by the MONGEFITOFOR project in 1943 (in the canton of Ticino). However, a systematic survey of the distribution of the disease was only conducted from 2014 onwards on behalf of the cantonal forestry section, and continued in the years 2019-2021 within the framework of the project "Chestnut ink blight: favoured by climate change?" funded by the Federal Office for the Environment (Climate Change Adaptation Pilot Programme, Phase II). The ***MONGEFITOFOR*** project completed this monitoring campaign in Ticino and Val Bregaglia (Graubünden) by means of a series of forest surveys, accompanied by the collection of soil samples and their subsequent analysis in the laboratory. A survey of the cantonal forestry services identified chestnut stands potentially affected by the disease. Soil samples were then taken nearby symptomatic trees and analysed in the laboratory to confirm the presence of *Phytophthora* spp. using the baiting method (**Figure 32**).

FIGURE 32
ISOLATION OF PHYTOPHTHORA SPP. USING THE BAITING METHOD. SOIL SAMPLES TAKEN FROM THE BASE OF SYMPTOMATIC CHESTNUT TREES WERE PLACED IN PLASTIC BASINS AND SUBMERGED IN WATER. RHODODENDRON LEAVES WERE THEN ADDED AS BAITS FOR PHYTOPHTHORA SPP. FROM LESIONS DEVELOPED ON THESE LEAVES, COLONIES OF PHYTOPHTHORA SPP. WERE ISOLATED, GROWN IN VITRO AND IDENTIFIED.

32

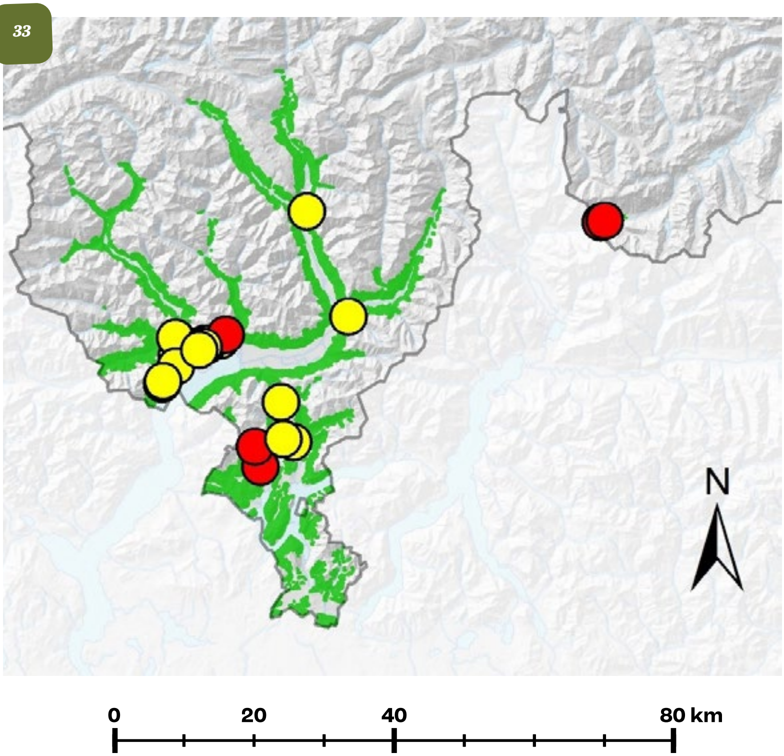
Sampling conducted from 2014 to 2021 ***confirmed*** the presence of ***ink disease*** in the Alps of Southern Switzerland. A total of 25 outbreaks were identified, most of them caused by ***P. cinnamomi***. In the Bergell valley (Castasegna), however, only ***P. x cambivora*** was found (**Figure 33**). In Canton Ticino, the outbreaks are not evenly distributed over the territory but are grouped in the Locarnese (from Brissago to Brione and Terre di Pedemonte) and in the Lugano area (Valle del Vedeggio). Both regions are characterised by a strong presence of man-made infrastructures, including residential areas, industrial areas and communication routes (railways, roads, motorways). Both aged coppices and old chestnut forests were affected by ink blight, regardless of the type of management implemented or the state of abandonment.

SILVICULTURAL AND PHYTOSANITARY INTERVENTIONS FOR THE MANAGEMENT OF COPPICES AFFECTED BY CHESTNUT BLIGHT

The presence of trees infected by *C. parasitica*, the potential role of *G. castaneae* as a canker-causing fungus and general health conditions of chesnut suggest the need to adopt appropriate technical measures to supplement the regular management practices previously described. The knowledge gained from an in-depth examination of the international scientific literature and the experience acquired during the MONGEFITOFOR project, also deriving from the ***exchange*** of expertise among the project partners, have made it possible to outline a number of ***management guidelines*** for ***silvicultural*** and ***phytosanitary interventions*** congruent with the functions and ecosystem services provided by chestnut coppices. In particular, the ***preservation of vigorous populations of, or with, chestnut trees*** is undoubtedly a priority, however its achievement is only realistic following a careful assessment of the health conditions of the tree, of the stand as a whole and of the foreseeable future prospects. Silvicultural management practised in the absence of appropriate measures taking into consideration the epidemiology of the pathogens associated with bark cankers may result in a modest outcome. While there is the possibility of implementing ***biological control*** *of Cryphonectria parasitica* based on the phenomenon of ***hypovirulence*** (**Box 3**), this option seems ***impractical*** in forestry due to technical-operational, logistic and economic constraints. Indeed, the biological control of *C. parasitica* is a complex intervention which is practised locally in particular contexts characterised by high profitability (e.g. valuable chestnut orchards) or by conservation value (e.g. varietal collection fields).

FIGURE 33
CURRENT DISTRIBUTION OF INK DISEASE IN THE SOUTHERN ALPS OF SWITZERLAND (CANTONS TICINO AND GRAUBÜNDEN). IN YELLOW THE OUTBREAKS DUE TO PHYTOPHTHORA CINNAMOMI AND IN RED THOSE CAUSED BY P. X CAMBIVORA.

33



BOX 3

Biological control of *Cryphonectria parasitica*

The CHV1 virus mentioned in the previous chapters is technically a large double-stranded ds-RNA (L ds-RNA), which can be transmitted via hyphal anastomosis under the control of a homozygous vegetative compatibility system involving 5 to 7 genetic loci (v-c loci). If two isolates have identical alleles at all loci then ds-RNA can transfer and, as a result of this transfer, a virulent strain becomes hypovirulent. This phenomenon, known as hypovirulence, is the basis for biological control strategies against chestnut blight. In order for intervention to be effective, one of the most established strategies involves the following steps: I) locally identifying healed and lethal cankers; II) locally taking symptomatic samples and laboratory isolation of the C. parasitica associated with the respective cankers; III) performing microbiological and molecular tests to identify virulent strains, hypovirulent strains and vegetative compatibility groups of the fungus; IV) selecting hypovirulent strains with the highest rate of vegetative compatibility with the local virulent strains; V) multiplying the inoculation of the selected hypovirulent strains; and VI) proceeding with their artificial inoculation in chestnut groves on lethal cankers (**Figure 34**). Bearing in mind that for the CHV1 virus horizontal transmission occurs via hyphal anastomosis, while vertical transmission occurs only via conidia, and only in a variable percentage of cases, it is evident that the conversion of virulent to hypovirulent strains is a biological process that takes a long time. In fact, the results of biological control can be visible at least ten years after the intervention takes place. The biological control option clearly imposes a number of constraints, as it requires technically and economically onerous analyses, the availability of well-equipped laboratories and highly specialised staff, and the operational possibility of performing the inoculations on branches and stems of chestnut trees that are not always easy to reach.

34

FIGURE 34
ARTIFICIAL INOCULATION OF HYPOVIRULENT STRAINS OF CRYPHONECTRIA PARASITICA AT THE MARGINS OF A LETHAL CANKER TO IMPLEMENT BIOLOGICAL CONTROL IN THE FIELD.

Although, for the above reasons, biological control in the strict sense is not always feasible in chestnut coppices, it is nevertheless possible to exploit the biological phenomenon of hypovirulence by adopting specific interventions, i.e. ***pruning***, ***thinning*** and ***removal*** aimed at ***mechanically removing lethal cankers*** and at the same time ***preserving healed cankers*** present. As lethal cankers are caused by virulent strains of *C. parasitica*, while healed cankers are associated with hypovirulent strains, removing lethal cankers may result in a partial eradication virulent strains. Proceeding in this way, the population of virulent strains tends to reduce, while that of hypovirulent strains may remain at the site and spread spontaneously. In the ***long term***, this dynamic should increase the likelihood that conversion of the remaining virulent strains will occur, resulting in a gradual ***remission of symptoms***. In practical terms, chestnut suckers and trees affected by lethal cankers should be removed, promising asymptomatic individuals and those mainly affected by healed cankers should be preserved.

During the execution of cuts, regardless of their purpose, it is advisable to ***disinfect*** the ***chainsaw chain*** and other tools intended to come into contact with tree tissues (e.g. hacksaws, shears, pruning shears). Products that can be used for this purpose include disinfectants based on ***quaternary ammonium salts***. Disinfection should be performed as frequently as possible before working on a new tree. The rationale behind this technical measure lies in the fact that, in the absence of disinfection, tools contaminated with spores and mycelium can inoculate the pathogen in healthy trees, or in still healthy branches of the same tree.

Operations must be performed adopting, as far as possible, all the necessary measures to ***reduce the likelihood of injuries*** to stumps, suckers, stems and branches during forestry works. This precaution, even if technically not easy to implement in the forest, is aimed at limiting the opening of wounds in the bark that represent pathways of penetration not only for *C. parasitica* but also for other wound pathogens, such as wood decay fungi. Accidental wounds and cut wounds could be usefully ***disinfected*** by adopting ***copper*** products effective against certain phytopathogenic fungi, taking care not to exceed the recommended doses (an excess of copper can be phytotoxic) and to carefully follow the legislative and regulatory ***prescriptions on phytosanitary matters***, thereby avoiding possible violations of the regulations in force. The choice of product should be oriented towards ***avoiding mastics*** that can form a ***thick film*** on the wound, ***hindering gas exchange***. These mastics can in fact cause a "***wet chamber effect***", creating an environment saturated with humidity favourable to the germination of spores or the ***development*** of mycelium of ***phytopathogenic fungi*** (**Figure 35**).

Following silvicultural interventions, it will also be advisable to ***remove logs and branches*** from the site, including those of any oaks present. As *C. parasitica* is able to produce infective inoculum on those substrates, removing them from the area of intervention may be useful in reducing inoculum pressure and, consequently, the risk of infection.

FIGURE 35
USE OF AN UNSUITABLE MASTIC AGAINST FUNGAL INFECTIONS. BY FORMING A THICK FILM, A MOIST ENVIRONMENT FAVOURABLE TO THE DEVELOPMENT OF CRYPHONECTRIA PARASITICA AND OTHER FUNGI MAY DEVELOP.

If the intention is to ***artificially*** plant seedlings because conditions are unfavourable to natural regeneration, it is recommended that a thorough ***phytosanitary inspection*** of the propagation material be performed, which is in any case required in the case of chestnut nurseries precisely to prevent the spread of *C. parasitica*. The inspection is essential not only to prevent the planting of seedlings that could quickly be killed by the disease, but also to protect the existing population from any ***resurgence*** of ***chestnut blight***. Transporting infected plant material to a site could result in the ***introduction of virulent strains*** of *C. parasitica* belonging to ***vegetative compatibility groups*** that are not present there, which drastically reduces the likelihood of those strains being naturally converted to hypovirulent.

Fertilisation may also be a useful intervention, in conjunction with ***mechanical weed control***, to increase the ***vigour*** of ***seedlings*** planted. A number of empirical observations suggest that ***potassium silicate*** products could also exert a limited protective action against *C. parasitica*. However, it must be pointed out that in-depth studies and specific research on this subject are still in progress.

Regardless of the operations planned on the forest site (planting seedlings, thinnings, cuttings, etc.), these should be performed when there ***has been no rainfall*** on the site ***during the 7 days preceding*** the operations. In the presence of rainfall, it is advisable to suspend operations and only resume them after at least 7 days without rain (especially if the amount of rainfall is between 1 and 10 mm per day).

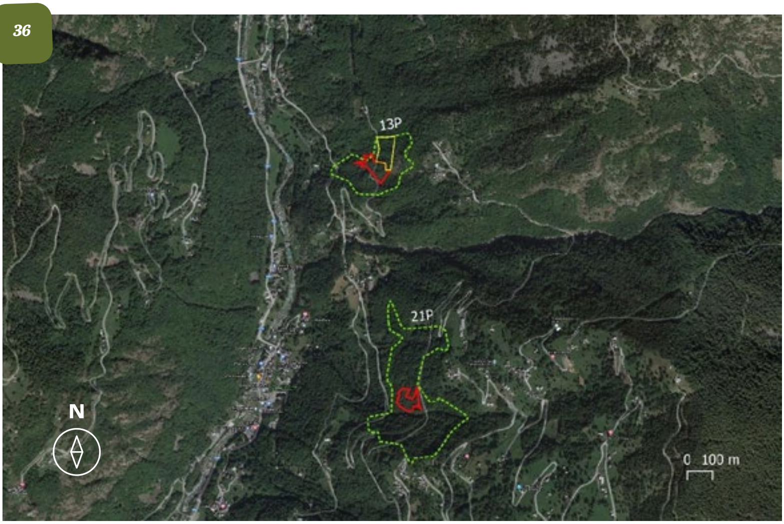
In addition to these guidelines, certain ***phytosanitary aspects*** relating to the safety and mechanical stability of standard trees and coppice must also be considered. In the presence of symptomatic and severely affectedchestnut trees, it may be necessary to pay attention to the presence of other adversities, such as wood decay-causing fungi. Indeed, threats to the mechanical stability of the tree may be significant when the chestnut trees growsin anthropised environments. In these cases, targeted ***phytosanitary fellings*** may be necessary to ***protect properties and people*** from tree failures.

APPLICATION EXAMPLES OF THE MONGEFITOFOR GUIDELINES FOR THE MANAGEMENT CHESTNUT STANDS

As part of the MONGEFITOFOR project, ***pilot forestry sites*** were designed and set up for the application and demonstration of ***silvicultural*** and ***phytosanitary*** management ***guidelines*** for chestnut coppices affected by chestnut blight.
The pilot sites involved two non-contiguous plots at a distance of approximately 500 m from edge to edge, located in the Municipality of Fontainemore, Frazione Boussolusa (plot 21) and Località Tetas (plot 13), at an altitude of approximately 1,000 m above sea level. The sites are characterised by western exposure and by high slopes, with rocks. The chestnut is only present on a small portion of the afore-mentioned plots, near points with coordinates 411598, 5056426 (plot 13), and 411776, 5055508 (plot 21) (UTM WGS84 reference system) (**Figure 36**).

FIGURA 36
CARTA GENERALE DELLE PARTICELLE (LINEA VERDE TRATTEGGIATA) E DELLE FASCE DI VEGETAZIONE A PREVALENZA DI CASTAGNO (LINEA ROSSA), O ASCRIVIBILI ALL'ACERO-TIGLIO-FRASSINETO (LINEA GIALLA), SELEZIONATE PRESSO IL COMUNE DI FONTAINEMORE PER L'ATTUAZIONE E LA DIMOSTRAZIONE APPLICATIVA DELLE LINEE GUIDA PER LA GESTIONE SELVICOLTURALE E FITOSANITARIA DEI CEDUI DI CASTAGNO AFFETTI DA CANCRO CORTICALE. SULLO SFONDO, IMMAGINE SATELLITARE DELL'AREA INTERESSATA (FONTE: GOOGLE MAPS, 2023).

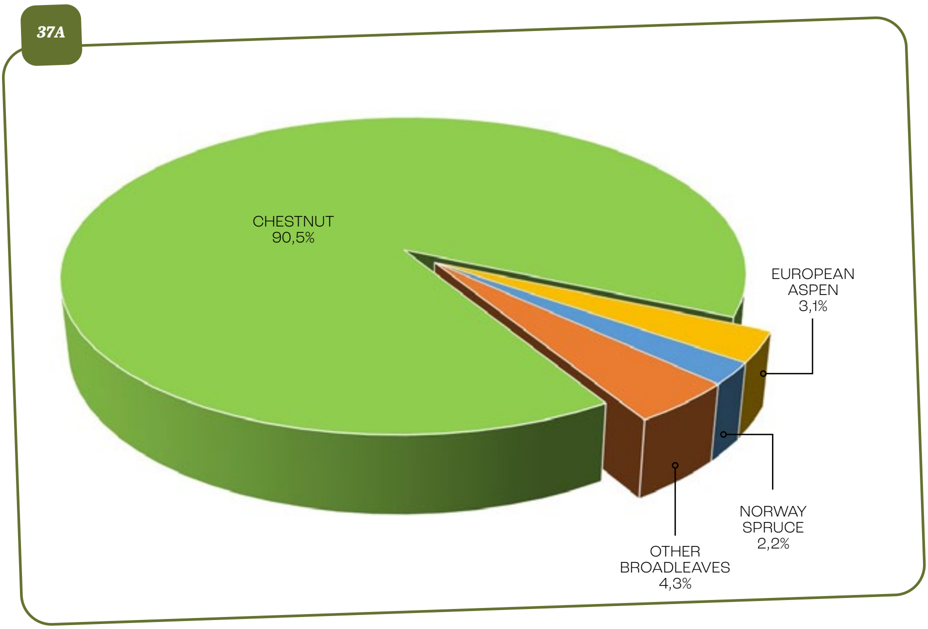
36



Overall, chestnut is coppiced, with sporadic presence of standard trees. The coppice is aged, in an abandoned condition, but not over-mature, and is characterised by stumps with varying numbers of suckers, with different diameters. The chestnut tree alternates with various broadleaves typical of the maple-lime-ash grove, with the sporadic presence of conifers. 15.2% of the chestnut trees show symptoms of chestnut blight; of these, 89.6% have lethal cankers, while the remaining 10.4% are characterised by healed cankers.

The basal area is slightly higher than the average found in similar formations, also due to the high number of chestnut suckers. The specific composition, distribution by diametric classes and details regarding basal area and density of the forest stand are reported below (**Figure 37** and **Table 2**).

FIGURA 37
GRAPH OF THE PERCENTAGE DISTRIBUTION OF THE SPECIES PRESENT (A) AND THEIR DISTRIBUTION BY DIAMETER CLASSES (B) IN PLOT 13 IN LOCALITÀ TETAS.



37B

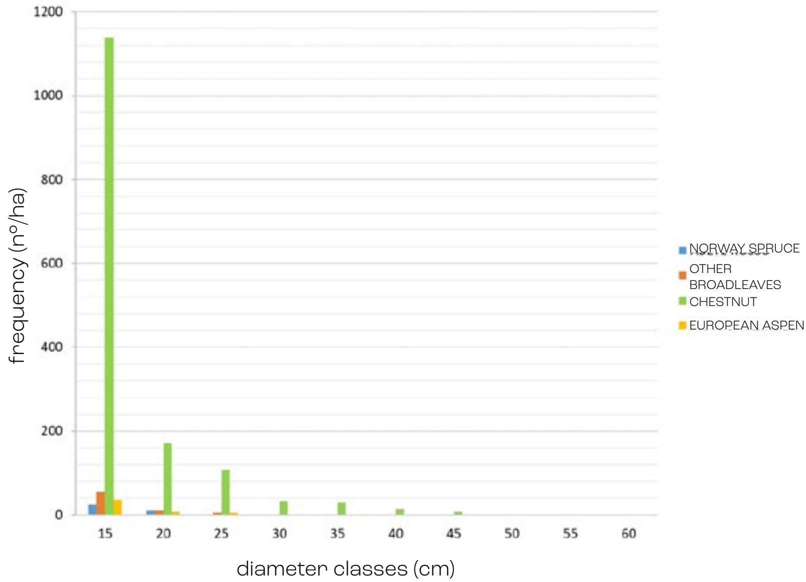


TABLE 2

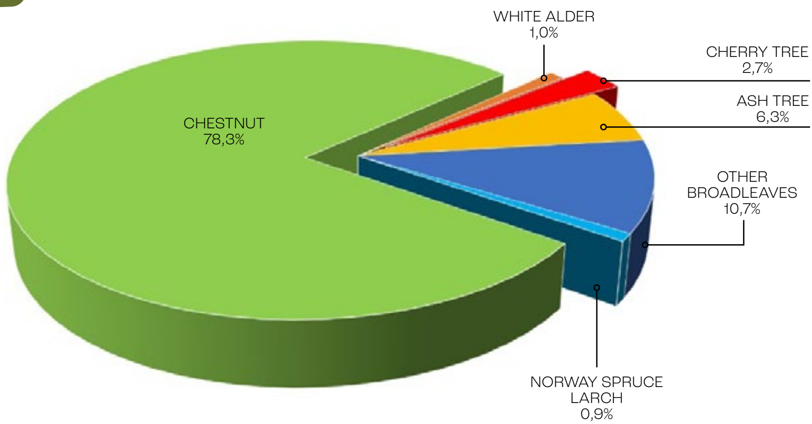
Specifications regarding the basal area and stand density in plot 13 in Località Tetas.

Species	Basimetric area m²/ha	Plant density/ha
CHESTNUT	28,03	1498
OTHER BROADLEAVES (sycamore maple, birch, ash, rowan)	1,10	71
EUROPEAN ASPEN	1,00	51
NORWAY SPRUCE	0,55	36
TOTAL	**30,68**	**1656**

Plot 21 in Frazione Boussolusa is a mesoneutrophilous chestnut forest type with Salvia glutinosa, variant with invasion broadleaf trees, including maple and ash. The basal area is higher than that found in similar stands, due to the high number of chestnut suckers and the abundant presence of other broadleaves. As in the case of the previous plot, tree species composition, distribution by diameter classes and details regarding the basal area and density of the forest stand are reported below (**Figure 38** and **Table 3**).

FIGURE 38
GRAPH OF THE PERCENTAGE DISTRIBUTION OF THE SPECIES PRESENT (A) AND THEIR DISTRIBUTION BY DIAMETER CLASSES (B) IN PLOT 21 IN FRAZIONE BOUSSOLUSA.

38A



38B

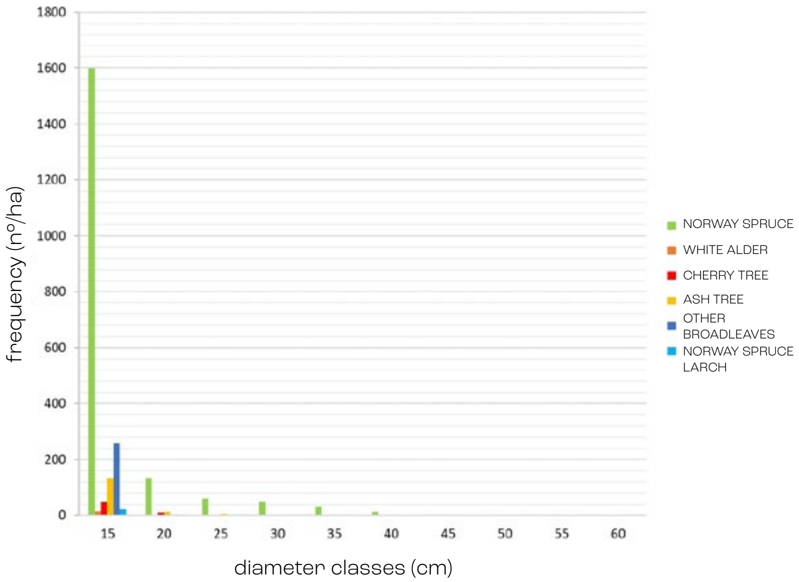


TABLE 3

Specifications regarding the basal area and stand density in plot 21 in Frazione Boussolusa.

Species	Basimetric area m²/ha	Plant density/ha
CHESTNUT	31,09	1886
OTHER BROADLEAVES (birch, beech, downy oak, rowan)	2,92	258
ASH	2,14	152
CHERRY	1,38	66
ALDER	0,63	24
NORWAY SPRUCE / LARCH	0,25	22
TOTALE	**38,41**	**2408**

The pilot sites were implemented to exemplify some points of the guidelines outlined for the management of coppices affected by chestnut blight, with particular reference to

- ***selection and marking of trees*** (**Figure 39**) aimed at performing the subsequent ***phytosanitary cutting*** (**Figure 40**) for the mechanical removal of suckers with lethal cankers and the preservation of those showing healed cankers present on the site. In plot 13 in Località Tetas, 313 trees and suckers out of 911 (36.4%) were removed resulting in a removed volume of 36.44 m3 out of 68.16 m3 (53.5% removal in volume). In plot 21 in Frazione Boussolusa, 444 plants and suckers were removed out of 1218 (36.8% s) resulting in a removed volume of 28.96 m3 out of 57.33 m3 (removal of 50.5% in volume);
- thorough ***disinfection of the chainsaw chain*** (**Figure 41**) and other cutting tools intended to come in contact with tree tissues with a solution of quaternary ammonium salts;
- ***disinfection of wounds*** with a copper product (**Figure 42**);
- ***chipping*** of branches, ***removal*** of ***logs*** and ***wood chips*** from the site (**Figure 43**);
- careful ***phytosanitary inspection*** of the seedlings in the nursery and their subsequent ***planting*** and ***fertilisation*** (**Figure 44**). These operations are aimed at establishing ***plants for planting*** to increase the abundance of chestnut in areas dominated by other broadleaves. Seedling inspection aims to avoid the planting of infected propagation material and the possible introduction of virulent strains of *C. parasitica* from outside, while fertilisation aims to increase the probability of seedling establishment and vigour;
- In the event of ***rainfall***, the workers were instructed to ***suspend operations*** and only resume them after ***at least seven days without rain*** to reduce the risk of infection.

Some phases were filmed for the production of thematic videos of the MONGEFITOFOR project, which are available on dedicated multimedia channels (see **Box 1**).

39

FIGURE 39
THE SELECTED AND MARKED FOR CUTTING (YELLOW PAINT) SHOWS EARLY SYMPTOMS CHESTNUT BLIGHT.

FIGURE 40
SETTING UP OF THE PILOT FORESTRY SITE FOR THE CHESTNUT WITH APPROPRIATE BANNERS OF THE MONGEFITOFOR PROJECT (A) AND OPERATIONAL PHASES OF THE PHYTOSANITARY CUTS PERFORMED ON THE SUCKERS PREVIOUSLY SELECTED FOR CUTTING (B).

40A

40B

41

42

FIGURE 41
CHAINSAW CHAIN DISINFECTION WITH A SOLUTION OF QUATERNARY AMMONIUM SALTS

FIGURE 42
WOUND DISINFECTION WITH COPPER PRODUCTS.

FIGURE 43
CHIPPING OF BRANCHES (A) AND REMOVAL OF LOGS (B).

FIGURE 44
PHASES OF INSPECTION OF PROPAGATION MATERIAL IN THE NURSERY, PRIOR TO TRANSPORTATION (A) AND SUBSEQUENT PLANTING AND FERTILIZATION OF SEEDLINGS (B).

43A

43B

44A

44A

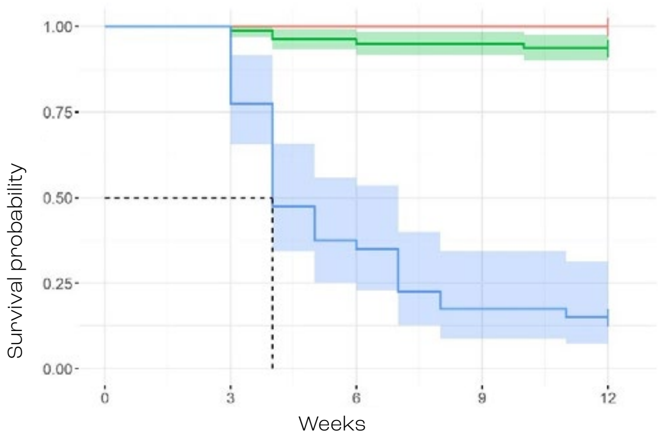
STRATEGIES FOR THE MANAGEMENT OF INK DISEASE

The management strategies outlined are mainly derived from the activities conducted on the Swiss side, in view of the relevant incidence and spread of ink disease there. ***Local varieties*** of tree species have been selected over the centuries on the basis of certain phenotypic characteristics. Selection has been mainly oriented towards optimising production profiles and finding individuals that are more tolerant to various diseases that can affect the chestnut tree. In Castasegna, Val Bregaglia, the chestnut tree is very abundant and its historical and cultural values are recognised and appreciated at the confederation level. The chestnut tree in that area of the canton of Graubünden is unfortunately significantly affected by ink disease, in this case caused by *P. x cambivora*. In view of the many calls at local level and beyond for the preservation of chestnut, a ***pilot site*** was set up to ***test the susceptibility of local varieties*** to various species of the *Phytophthora* genus present in the Alpine region. Indeed, more tolerant varieties could be introduced or favoured in chestnut stands affected by ink disease. For this purpose, seedlings of five Bregaglia chestnut varieties

(*Lüina, Marun, Rossera, Temporiva* and *Vescuf*) were inoculated in special greenhouses at the WSL with isolates of P. *cinnamomi, P. x cambivora, P. cactorum, P. cryptogea* and *P. plurivora*. Currently, observations indicate that the ***highest mortality*** was caused by ***P. cinnamomi*** (**Figure 45**). The differences in susceptibility to *P. cinnamomi* among the tested chestnut varieties do not appear to be substantial, however, the *Lüina* variety would appear to be the most promising.

FIGURE 45
PROBABILITY OF SURVIVAL OF TWO-YEAR-OLD CHESTNUT SEEDLINGS INOCULATED WITH PHYTOPHTHORA CINNAMOMI (IN BLUE) AND WITH P. X CAMBIVORA, P. CACTORUM, P. CRYPTOGEA AND P. PLURIVORA (IN GREEN) DURING THE FIRST 12 WEEKS POST-INOCULATION. CONTROL SEEDLINGS NOT INOCULATED ARE SHOWN IN RED

45



In the southern Alps of Switzerland, the chestnut forms extensive stands that fulfil several functions. On one hand, they are a typical element of the local landscape with a strong ecological and cultural-historical significance. On the other, especially in valleys characterised by steep slopes, they protect human infrastructure from rockfalls, landslides and erosion. In stands affected by ink disease, chestnut is really at risk. Therefore, it may be strategically appropriate to guide successional dynamics towards a multi-species forest cover. Silvicultural choices should also be guided by ***phytosanitary principles*** and should therefore favour ***other tree species***, resistant to *P. cinnamomi* and *P. x cambivora*. The tree species will also have to be adapted to the climatic conditions that are likely to affect the Italian-Swiss cross-border areas in the near future. As part of a research project conducted for the Federal Office for the Environment (FOEN), a modelling approach was developed to determine the suitability of native tree species to replace or accompany the chestnut in the future. The potentially suitable species included ***maples*** (*Acer platanoides*, *A. pseudoplatanus*), ***linden*** (*Tilia platyphyllos*), ***hornbeam*** (*Ostrya carpinifolia*) and ***rowan*** (*Sorbus aria*). On a more general level, the main and well-established ***control guidelines*** aimed mainly at preventing new outbreaks and at containing existing ones, include:

- the maintaining of ***good*** stand ***conditions*** to give vigour to the trees and improve their reactivity to the disease. In coppices, cutting rotations should be optimal, avoiding ageing and excessive competition among suckers;
- ***avoiding*** or ***limiting*** operations that could cause ***injury to the roots***;
- Implementing effective ***drainage*** and ***channeling*** of ***surface water***, such as to avoid water stagnation and/or runoff from infected areas;
- Avoiding the circulation of ***vehicles*** along roads immediately ***after heavy rainfall***, at least during the growing season, in order to avoid ***splashes*** of contaminated water. ***Removal of soil residues*** from tractors or other vehicles (particularly ***tyres***) that could host infectious inoculum before entering chestnut stands;
- In areas with a high risk of infection, ***buffer strips*** with herbaceous, shrub or tree species that are not susceptible to *Phytophthora* spp. can be usefully created at the margin of roads;
- if feasible, proceeding with

phytosanitary cuts aimed at removing ***dead or infected individuals***, removing stumps and large roots by taking care of not spreading contaminated soil or other material.

CONCLUSIONS AND PERSPECTIVES

In the framework of the ***MONGEFITOFOR*** project, Italian and Swiss institutions and research bodies, supported by European Union funding - Territorial Cooperation Programme ***INTERREG*** V-A Italy-Switzerland 2014/2020, cooperated to monitor the health status of cross-border forests and designed sustainable strategies for their management and protection. In particular, this ***technical-scientific handbook*** is dedicated to the ***management of chestnut coppices*** affected by ***diseases*** caused by phytopathogenic fungi and chromista, including ***chestnut blight*** and ***ink disease***. By examining the main biological traits of the target ***pathogens Cryphonectria parasitica, Gnomoniopsis castaneae*** and ***Phytophthora spp.***, the handbook aims to summarise the results obtained during the project in a practical manner, providing the user with ***silvicultural*** and ***phytosanitary guidelines***.

Thanks to the results obtained from the phytosanitary monitoring and the related diagnostic analyses, it was possible to quantify the incidence and severity of the major chesnut diseases in the study area. Chestnut coppices require careful and targeted management, to be implemented with a multidisciplinary approach that integrates traditional ***silviculture*** with ***phytosanitary*** interventions based on solid scientific evidence. The key objective of the MONGEFITOFOR project was to outline this approach and at the same time to create suitable tools for the dissemination of ***knowledge*** and ***know-how*** relevant to chestnut management, for the benefit of owners, managers and administrators of forest resources, as well as technicians, practitioners and other stakeholders.

Looking forward, the MONGEFITOFOR project sets the foundations for more ***sustainable*** forest management of chestnut, providing technical-scientific tools whose application can contribute to increasing the ***resilience of forest ecosystems***.

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