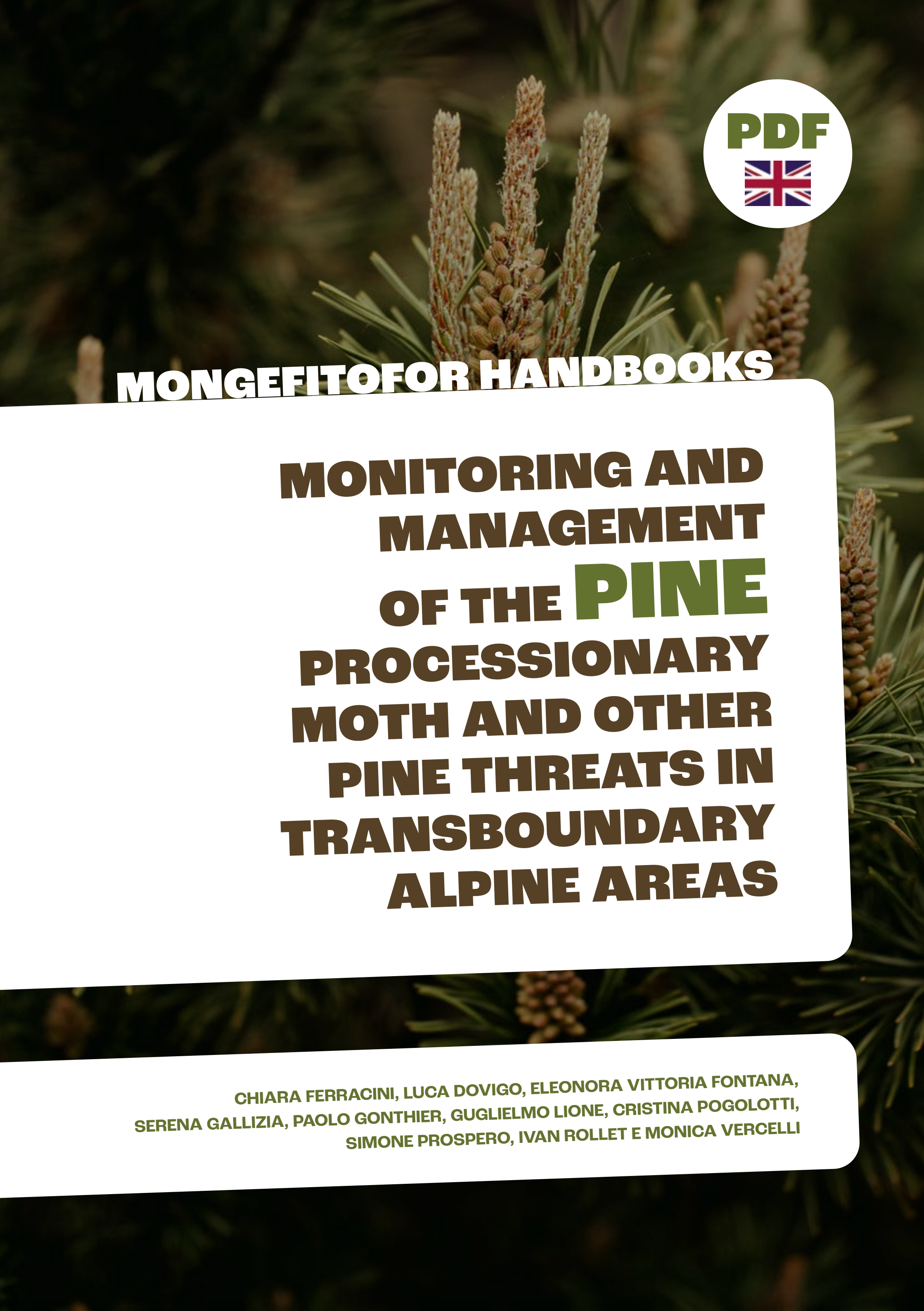


MONGEFITOFOR HANDBOOKS

MONITORING AND MANAGEMENT OF THE PINE PROCESSIONARY MOTH AND OTHER PINE THREATS IN TRANSBOUNDARY ALPINE AREAS

CHIARA FERRACINI, LUCA DOVIGO, ELEONORA VITTORIA FONTANA, SERENA GALLIZIA, PAOLO GONTHIER, GUGLIELMO LIONE, CRISTINA POGOLOTTI, SIMONE PROSPERO, IVAN ROLLET E MONICA VERCELLI

PDF

MONITORING AND MANAGEMENT OF THE PINE PROCESSIONARY MOTH AND OTHER PINE THREATS IN TRANSBOUNDARY ALPINE AREAS

Series: “MONGEFITOFOR HANDBOOKS”

Authors

Chiara Ferracini [1], Luca Dovigo [2], Eleonora Vittoria Fontana (1), Serena Gallizia [1], Paolo Gonthier [1], Guglielmo Lione [1], Cristina Pogolotti [1], Simone Prospero (3), Ivan Rollet [2], Monica Vercelli [2]

Scientific Coordination

Chiara Ferracini [1], Paolo Gonthier [1], Guglielmo Lione [1], Simone Prospero [3]

[1] University of Turin, Department of Agricultural, Forest and Food Sciences (DISAFA), Largo P. Braccini 2, 10095 Grugliasco (TO), Italy.
[2] Regione Autonoma Valle d’Aosta, Assessorato Agricoltura e Risorse Naturali, Corpo Forestale della Valle d’Aosta, Loc.La Grande Charrière 14, 11020 Saint-Christophe (AO), Italy.
[3] Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Zürcherstrasse 111, 8903 Birmensdorf, Switzerland.

Recommended form of citation

Ferracini C., Dovigo L., Fontana E. V., Gallizia S., Gonthier P., Lione G., Pogolotti C., Prospero S., Rollet I., Vercelli M. (2023). Monitoring and management of the pine processionary moth and other pine threats in transboundary Alpine areas. Series: “MONGEFITOFOR handbooks”. Autonomous Region of Valle d’Aosta.
ISBN 9791280561329

INDEX

PREFAZIONE

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, including the pine processionary moth and other phytosanitary issues of pines. This handbook presents the results of a phytosanitary monitoring aimed at investigating the spread and incidence of the insect pest and the factors potentially associated with the Scots pine decline to propose operational strategies for their management in the forest standsof cross-border alpine areas. Indeed, this handbook was created thanks to the knowledge gained in the cross-border area, reporting the results of the synergy between the project partners who shared experience, knowledge and skills during the various activities.

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 pines in the Alps.

The Councillor for Agriculture and Natural Resources
Marco Carrel

THE MONGEFITOFOR PROJECT

MONGEFITOFOR (the Italian acronym standing for "Guidelines for the Monitoring and Management of Phytosanitary Emergencies in the Forests of the central-western Alps") is a project financed 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 cooperated to monitor the ***health status*** of cross-border ***forests*** and propose sustainable strategies for their management and protection, thus promoting their ***resilience***. The project is led by the Struttura Corpo Forestale della Valle d'Aosta (IT) and has as partners the University of Turin - Department of Agricultural, Forestry and Food Sciences (DISAFA) (IT), the Federal Research Institute for Forest, Snow and Landscape WSL (Birmensdorf) (CH), Canton Grisons - Office for Forests and Natural Hazards (CH) and Canton Ticino - Forestry Section (CH).

The project lays its foundation on the fact that forests are an essential element of the ***landscape*** of the Alpine valleys and have a multifunctional value that is realised not only in the ***production*** of timber but also in the maintaining of ***biodiversity***, in the ***hydrogeological protection*** of slopes and in 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 the adversities of ***Scots pine***, in particular the ***pine processionary*** moth, and the ***decline*** associated with abiotic and biotic factors, including ***climate change*** and ***fungal infections***, critical issues to which this ***technical-scientific handbook*** is dedicated. The handbook is intended to support not only owners, managers, and administrators of forest resources, but also technicians and practitioners who wish to expand their knowledge and improve their skills.

BOX 1

Insights into the MONGEFITOFOR project

The **MONGEFITOFOR** project, which started in 2019 until 2023, focuses on the monitoring of emerging phytosanitary issues of tree species that play a key role in the hilly and low-mountainous forest formations of the Italian-Swiss cross-border areas: **chestnut** (*Castanea sativa*), **common ash** (*Fraxinus excelsior*) and **Scots pine** (*Pinus sylvestris*), to which specific technical-scientific handbooks of the series "**MONGEFITOFOR HANDBOOKS**" are dedicated. In addition to the handbooks, the MONGEFITOFOR project also offers multimedia content for technical information and in-depth analysis, 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 SCOTS PINE: GENERAL OVERVIEW OF THE SPECIES

Scots pine (*Pinus sylvestris L.*) is a forest species that forms floristic-vegetation consortia in which it is present as a dominant species or as an accessory species, occupying a vast geographic range from the Iberian Peninsula to the Ochotsk Sea and from the Scandinavian regions to the northern portions of Turkey. In Italy, Scots pine colonises large portions of the Alpine area, descending southwards as far as Emilia Romagna region and beyond where, however, its presence tends to be sporadic and distributed in disjointed areas of varying extent. In Switzerland, Scots pine is widespread in almost the entire confederal territory from the hilly to the subalpine plane.

A tree that can reach heights of up to 30-40 m, the Scots pine is a long-lived evergreen, with microphylls up to around 6 cm long grouped in pairs in bundles and with asymmetrical female cones, also generally no more than 6 cm in size along the axis of greatest development. The winged seeds carried by the wind or animals ensures the natural regeneration of the species. Easily recognisable in the forest, Scots pine is characterised by grey-brown bark in the basal portion of the trunk, where plaques and cracks are evident, while towards the top the colour changes to ochre, yellowish or reddish depending on the ecotype and origin (***Figure 1***). Canopy architecture, branching development and stem conformation can be highly variable, depending on environmental, cultural, genetic and chorological factors. Some estimates put the number of ***ecotypes*** or ***geographic types*** attributable to Scots pine at over 70, each with its own morphological specificities, growth, longevity, and wood characteristics.

The Scots pine's ***root system*** is ***deep***, robust, with a solid taproot and an articulated system of multiple superficial roots that explore the soil, helping to secure the tree's anchorage.

The autoecology of this species is variable due to the high differentiation between ecotypes,

FIGURE 1

NUCLEUS OF MATURE SCOTS PINES IN THE FOREST. IT IS POSSIBLE TO SEE THE CLEAR COLOUR DIFFERENCE OF THE BARK, GREY-BROWN IN THE BASAL PORTION, REDDISH IN THE MIDDLE-HIGH PORTION OF THE STEM.

but it has several recurring characters. Scots pine is typical of mountainous plains, it is ***pioneer*** and ***heliophilous***, able to adapt with high ***plasticity*** to eco-pedological conditions that range from not very powerful and skeleton-rich soils to more fertile and evolved soils, in situations where the pH can be indifferently acid or basic. Soil texture is not a particularly limiting factor for this forest species, which grows both in well-drained environments and in contexts in which water stagnation may occur because of the level of compaction of the horizons. Considered to be xerophilous or ***meso-xerophilous***, Scots pine prefers ***subcontinental*** or continental climates and is able to tolerate significant temperature ranges, provided that the summer period is not excessively cold. Although drought tolerance is favoured by the architecture of the root system and physiological peculiarities, prolonged and/or frequent episodes of ***water stress*** associated with the absence of rainfall may adversely affect Scots pine's growth. The autoecological requirements of Scots pine can be summarised by means of a series of quantitative indices, which outline its salient characteristics (***Table 1***).

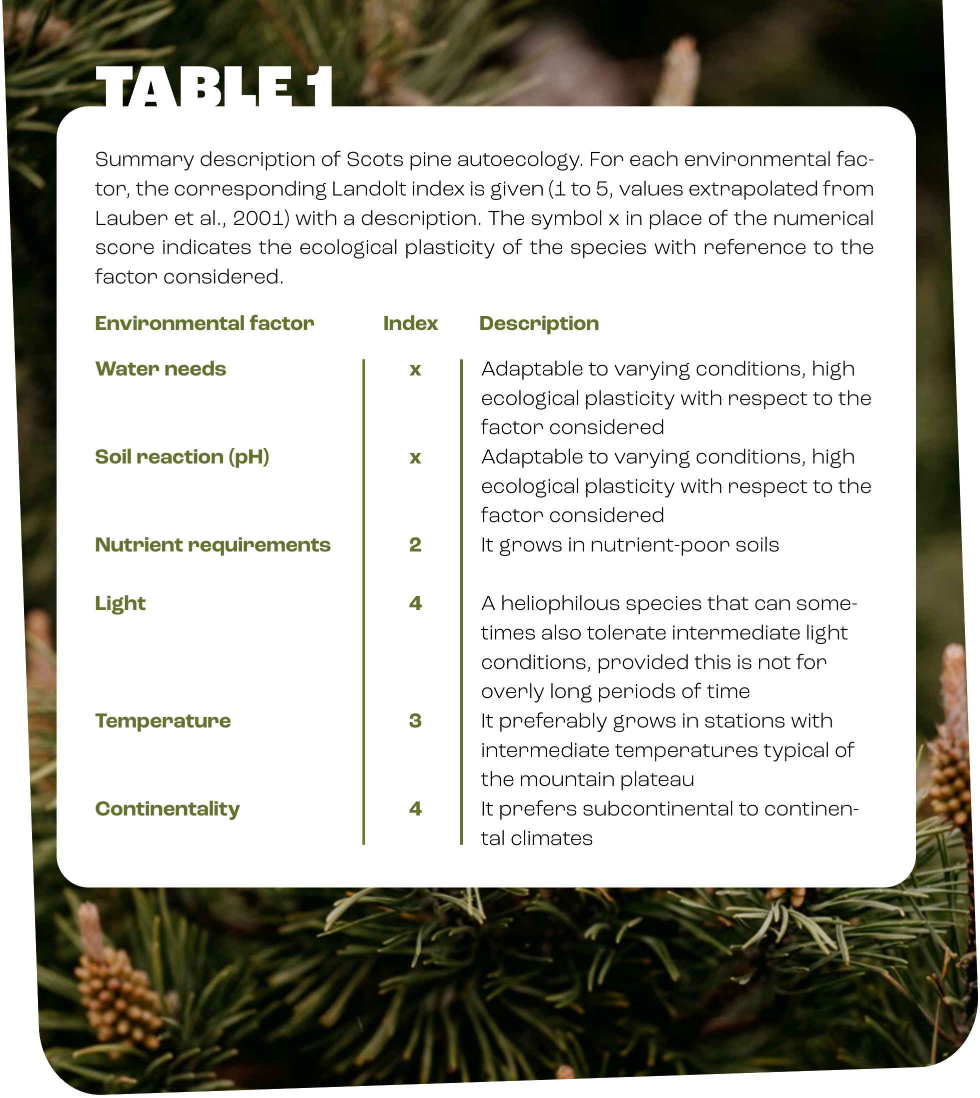


TABLE 1

Summary description of Scots pine autoecology. For each environmental factor, the corresponding Landolt index is given (1 to 5, values extrapolated from Lauber et al., 2001) with a description. The symbol x in place of the numerical score indicates the ecological plasticity of the species with reference to the factor considered.

Environmental factor	Index	Description
Water needs	**x**	Adaptable to varying conditions, high ecological plasticity with respect to the factor considered
Soil reaction (pH)	**x**	Adaptable to varying conditions, high ecological plasticity with respect to the factor considered
Nutrient requirements	**2**	It grows in nutrient-poor soils
Light	**4**	A heliophilous species that can sometimes also tolerate intermediate light conditions, provided this is not for overly long periods of time
Temperature	**3**	It preferably grows in stations with intermediate temperatures typical of the mountain plateau
Continentality	**4**	It prefers subcontinental to continental climates

TABLE 1
SUMMARY DESCRIPTION OF SCOTS PINE AUTOECOLOGY. FOR EACH ENVIRONMENTAL FACTOR, THE CORRESPONDING LANDOLT INDEX IS GIVEN (1 TO 5, VALUES EXTRAPOLATED FROM LAUBER ET AL., 2001) WITH A DESCRIPTION. THE SYMBOL X IN PLACE OF THE NUMERICAL SCORE INDICATES THE ECOLOGICAL PLASTICITY OF THE SPECIES WITH REFERENCE TO THE FACTOR CONSIDERED.

SYNECOLOGY AND CHARACTERISATION OF FOREST FORMATIONS WITH SCOTS PINE

In the Italian-Swiss cross-border areas, Scots pine constitutes forest stands in which it is the ***dominant*** species (***Figure 2***) or, at least, it is among the most represented, but it can also be present as an accessory element in various floristic-vegetation consortia (***Figure 3***). Some inventory estimates indicate that in Valle d'Aosta the Scots pine is the third conifer in terms of distribution, constituting 16% of the total number of trees while in Switzerland the species is associated with an empirical relative frequency score of 52% on a scale from 0 to 100%, thus being among the species classified as abundant. The ecological plasticity of Scots pine allows the species to settle in different forest contexts, making it complex to delineate an unambiguous and exhaustive typological picture. Some of the main formations in which the species plays a key, constitutive role are referred to as ***Scots pine forests***, including for transboundary ranges:

- acidophilic mesalpine pine forests;
- mesoxerophilic endalpine pine forests;
- basophilic endalpine pine forests;
- acidophilic endalpine pine forests.

2

FIGURE 2
SCOTS PINE-DOMINATED FOREST IN ITALIAN-SWISS CROSS-BORDER AREAS.

3

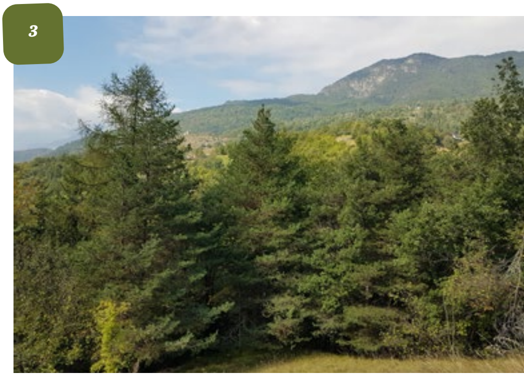


FIGURE 3
MULTI-SPECIFIC FOREST WITH THE PRESENCE OF SCOTS PINE ASSOCIATED WITH OTHER CONIFERS AND BROADLEAF TREES.

Alternatively, other ways of framing Scots pine-dominated populations have been identified which propose a classification for the same areas that identifies:

• primitive cliff pine forests;
• primitive pine forests on serpentine silicate substrates;
• typical mesalpic/endalpic pine forests on carbonate substrates;
• pine forests typical of serpentine silicate substrates;
• pine forests of submontane and montane silicate substrates;
• secondary pine forests.

In general, some of the main forest tree species that may be associated or consociated with Scots pine include spruce, larch, aspen, downy oak, chestnut and other broadleaved and coniferous trees, including other species of the genus Pinus.

ECOSYSTEM FUNCTIONS AND SERVICES PROVIDED BY SCOTS PINE

Scots pine, and more generally the forest formations in which it is present, exert a wide range of ***functions*** and provide various ***ecosystem services***, including:

• production of ***wood assortments***;
• production of non-woody secondary products;
• ***hydrogeological protection*** and slope consolidation;
• provision of services related to ecological-environmental function (e.g., support for ***biodiversity***, sequestration of atmospheric carbon dioxide and ***carbon stocks***, contribution to biogeochemical cycles);
• participation in formations that play an important role as ***landscape*** elements, providing suitable spaces for ***tourism*** and recreation.

The physical-mechanical and technological properties of the wood make Scots pine a suitable and valued species for the ***production*** of beams or beads for cladding. Indeed, the resinous wood of Scots pine has an attractive appearance, is moderately durable and has clearly visible annual rings, making it suitable for uses for which this characteristic may represent a benefit (***Figure 4***). Instead, lower ***quality*** assortments are used in carpentry, to make boxes or to obtain pulp for the paper industry. Whether or not quality wood assortments can be obtained depends not only on the cultural and environmental characteristics of the Scots pine forest but also on the peculiarities associated with the genotypic and ecotypic ***variability*** of the species. In certain areas, the conformation of the

trunk, the pronounced branching and the general architecture of the tree prevent a profitable productive use, which in other geographical contexts may be more interesting.
Numerous ***non-wood products*** can be extracted from Scots pine which serve different supply chains, for example in the pharmaceutical and cosmetic sectors. In fact, the needles, buds and resin can undergo extraction processes to obtain balsamic essential oils used in the preparation of phytotherapeutic products, perfumes, air fresheners and food products (Figure 4).

4A

4B

FIGURA 4
WOODY ASSORTMENTS AND NON-WOODY PRODUCTS DERIVED FROM SCOTS PINE. SPECIMEN OF SCOTS PINE WOOD FROM A XYLOTHEQUE: THE CLEAR DEMARCATIONS BETWEEN THE GROWTH RINGS AND THE LONGITUDINAL (FRONT), TRANSVERSE (TOP) AND RADIAL (RIGHT SIDE) SECTIONS OF THE STEM ARE VISIBLE (A). LABEL OF A PHYTOTHERAPEUTIC PREPARATION TO SOOTHE SYMPTOMS ASSOCIATED WITH COUGHS AND IRRITATION OF THE UPPER RESPIRATORY TRACT: THE REPORTED INGREDIENTS INCLUDE THE PRESENCE OF BALSAMIC SCOTS PINE ESSENTIAL OILS (B). REFERENCES TO TRADEMARKS HAVE BEEN INTENTIONALLY REMOVED.

Scots pine, while retaining productive values, is particularly well suited in Alpine areas to perform a fundamental slope protection function, acting as a natural limiter of ***hydrogeological risk*** and helping to consolidate slopes and escarpments. Indeed, Scots pine forests, like other protective forests, contribute to the defence of settlements, infrastructures and other man-made structures from the risks associated with rock falls, landslides and avalanches (***Figure 5***). In fulfilling this important function, Scots pine and its associated plant communities constitute an important piece of the mosaic of ***forest landscapes*** that characterise the high hills and mountains of the Italian-Swiss cross-border areas, creating recreational spaces and environments suitable for ***tourism*** (***Figure 5***). Moreover, Scots pine participates in the constitution of ecological networks and ***habitats*** that favour animal, plant and microbial biodiversity.

5

FIGURA 5
SCOTS PINE STANDS CONSOLIDATING THE UPSTREAM AND DOWNSTREAM SLOPES OF A ROAD USED BY TOURISTS, BIKERS AND HIKERS, IN THE FRAMEWORK OF THE ALPINE LANDSCAPE OF THE ITALIAN-SWISS CROSS-BORDER AREAS.

SILVICULTURAL AND MANAGEMENT ASPECTS

Ordinary silviculture of Scots pine is generally oriented towards ***conservation*** of the species, except for interventions aimed at guiding the dynamic processes of population ***evolution*** towards a multi-species composition in balance with the environmental characteristics of the station, mainly adopting the rules of naturalistic silviculture or systemic silviculture. In any case, given the heliophilous and pioneering nature of the species, interventions must be congruous and maintain a population density compatible with its ecological needs, allowing seedlings to establish and take root, and allowing ***natural regeneration***. This can be hindered by the presence of herbaceous, shrub or tree species that exert excessive competition. When such a scenario occurs, it is possible to implement ***artificial plantation*** or to proceed with fellings that favour a ***guided succession*** of the population in favour of other species that are more suitable for the site. In forest stands with a mixed composition, it is necessary to plan and size interventions carefully to avoid triggering a recession process in which Scots pine regresses in favour of other species that are much more tolerant of shade (e.g., Norway spruce, silver fir).
Historically, particularly when the productive function of the pine tree was considered prevalent, interventions based on clearcutting were quite common. Nowadays, among the proposed interventions, ***successive fellings*** are instead favoured. Some silvicultural schemes suggest high-intensity fellings (60-70% of the volume), conducted on small areas (between 0.1 and 0.25 ha), in order to create favourably exposed and uniformly distributed gaps in the area of intervention, with a regeneration period of approximately 10 to 30 years. Interspersed fellings may be recommended but only when production needs are a priority. The above-mentioned interventions can be considerably reduced in intensity when there is a risk of favouring other species, not in line with the wanted tree species composition and structure or when the current dynamics seem suitable to guarantee the perpetuation of Scots pine. In this case, it is indeed possible to ***limit interventions*** to a minimum to facilitate the natural regeneration dynamics in place. For situations in which

the conditions are adverse or even in cases where fertility is low, the option of non-intervention may be considered as a prelude to ***free evolution***.

The silvicultural indications provided in this chapter are valid for stands in which Scots pine does not show evident alterations ascribable to phytosanitary issues. In the presence of such issues, it is advisable to supplement good silvicultural practices with appropriate interventions that take into account the presence and impact of damage caused by ***insect pests and pathogens***, or ***decline*** associated with biotic and abiotic agents (e.g. ***fungal disease*** agents, anomalies linked to ***climate change***).

The MONGEFITOFOR project, by monitoring and investigating the phytosanitary threats of Scots pine and by making use of a solid scientific basis, therefore aims to outline possible forest management guidelines to be applied to situations in which diseases or insect infestations may require silviculture oriented towards a ***phytosanitary control***.

DISTRIBUTION AND BIO-ETHOLOGY OF THE PINE PROCESSIONARY MOTH

Thaumetopoea pityocampa (Denis & Schiffermüller, 1775), commonly known as the pine processionary moth, is a lepidopteran insect belonging to the Notodontidae family. This insect is a ***defoliator*** widespread in the regions of the Mediterranean basin, from southern France to Hungary and Bulgaria, and in North Africa, as well. In Italy, it is present throughout the peninsula, in Sicily and the smaller islands; in Sardinia it was accidentally introduced in 2006. Although *T. pityocampa* is a thermophilous species, it adapts easily to low temperatures and reacts quickly to climate change. This is why in recent years it has extended its distribution area northwards and is found at increasingly higher altitudes in the mountain (***Box 2***).

The **host plants** include all species of pine, mainly P. *sylvestris* and *Pinus nigra*, and *Pinus mugo, Pinus halepensis, Pinus pinaster, Pinus pinea* may represent suitable secondary

BOX 2

Climate change

The pine processionary moth responds rapidly to climate change and is considered a **key species**. Rising temperatures due to global warming have led to a change in the life cycle and a decrease in mortality of the overwintering larvae. There is also a shift in altitude and latitude of the species' range. The **distribution limit**, in fact, advanced **867 km** northwards between 1972 and 2004, while the altitudinal limit increased by **230 m** between 1975 and 2004 on the southern slopes (**Figures 6-7**).

6

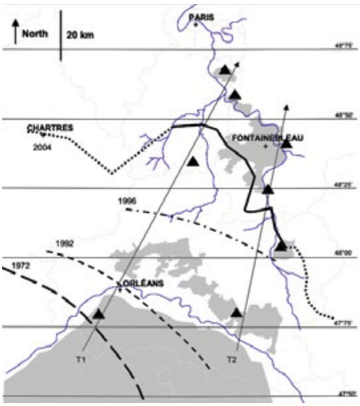


FIGURE 6
GEOGRAPHICAL EXPANSION OF THE PINE PROCESSIONARY MOTH IN THE PARIS BASIN (FRANCE) FROM 1972 TO 2004 (BATTISTI ET AL., 2005).

7

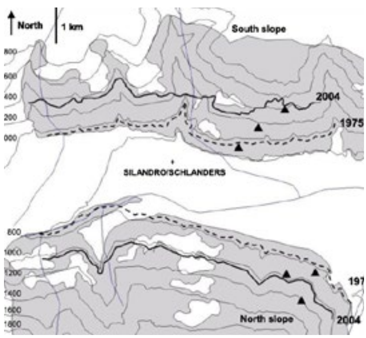


FIGURE 7
GEOGRAPHICAL EXPANSION OF THE PINE PROCESSIONARY MOTH IN VAL VENOSTA.

hosts, as well. Among the exotic plants belonging to the Pinus genus that are used in reforestation, P. radiata should be mentioned as a host for the defoliator. In case of huge infestations, this species can also feed on larch trees while in urban green areas it can damage cedars.
T. pityocampa performs ***one generation*** per year and has a ***crepuscular-nocturnal*** behaviour (***Figure 8***). It overwinters at the larval stage, inside silky nests built on the branches of the host plants (F***igure 9***).
The name of the species is because the caterpillars, when abandoning the nests, walk in a single row forming ***long processions***, initially along the trunk and then on the ground, in search of a suitable burial site to pupate in the soil (***Figure 10***).

8

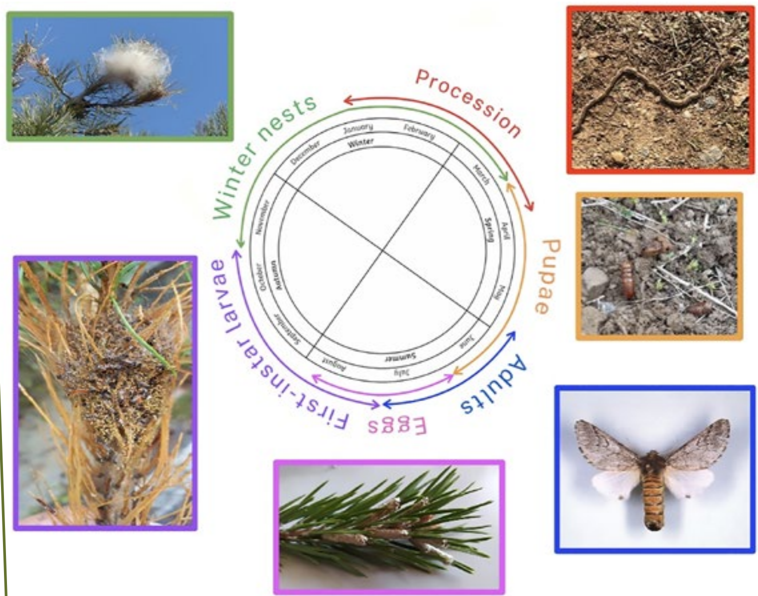


FIGURE 8
LIFE CYCLE OF THE PINE PROCESSIONARY MOTH.

FIGURE 9
WINTER NEST OF THE PINE PROCESSIONARY MOTH.

FIGURE 10
TYPICAL PROCESSION OF THAUMETOPOEA PITYOCAMPA CATERPILLARS BEFORE PUPATION.

11

During these movements, the larvae produce a ***silky thread*** and a ***pheromone trail***. Pupation occurs between February and April, usually at the edge of the forest, in clearings on sunny slopes with soft soil. *T. pityocampa* buries itself to a depth of 5-15 cm and ***pupates*** inside a ***silky cocoon*** (**Figure 11**).
Adult ***emergence*** occurs after approximately 2-4 months, mainly between ***June and July***, but part of the population may enter a ***prolonged diapause***, which generally may last from one to three years (***Figure 12***). ***Adults*** have a ***very short life span***, 2-3 days, during which mating occurs. Mated females lay from 70 to over 300 eggs in ***batches*** approximately 30 mm long, wrapping a pair of needles (**Figure 13**). The ***eggs*** are covered with ***scaly hairs*** from the female's abdomen, which have the task of cementing the eggs together, making them indistinguishable from one another, and protecting them from potential parasitoids and/or predators.
The ***eggs*** are roughly spherical in shape, about 1 millimetre in diameter and are ***grey-white*** in colour. After 30-45 days, depending on the temperature conditions, the eggs begin to hatch and the newly-hatched ***larvae*** immediately begin to ***feed on the needles*** of the host

pine tree, building ***temporary nests*** with their silky threads in preference to the sunniest and highest parts of the crown. The larvae have a ***gregarious behaviour,*** undergoing through five developmental instars and, from the third instar onwards, they present ***urticating hairs*** along their body (**Figure 14**) (**Box 3**).

In ***October***, the larvae produce their definitive ***winter nests***, much larger and thick than the summer nests, oblong or rounded in shape, always positioned in the most exposed and sunny parts of the crown. Several hundred larvae may overwinter inside these nests.

12

13

14

FIGURE 11
PUPAE OF THE PINE PROCESSIONARY MOTH.

FIGURE 12
ADULT OF THAUMETOPOEA PITYOCAMPA.

FIGURE 13
EGG BATCH OF THAUMETOPOEA PITYOCAMPA.

FIGURE 14
DIFFERENT LARVAL INSTARS OF THAUMETOPOEA PITYOCAMPA.

BOX 3

Not all caterpillars have urticating hairs as the pine processionary moth

In the spring and summer months, there are frequent reports of larvae with long hairs feeding on various broad-leaf trees, in both urban and forest environments. These larvae are often confused with the urticating larvae of the pine processionary moth, causing much concern among citizens and stakeholders.
Below some information and pictures of insect species often confused with the pine processionary moth are reported. These species present caterpillars **that do not have urticating hairs** and therefore do not pose a danger to humans and domestic animals, rarely causing disturbance in particularly sensitive individuals (*Figures 15-17*)..

15

16

17

FIGURE 15
LARVA OF THE FALL WEBWORM, HYPHANTRIA CUNEA.
FIGURE 16
LARVA OF THE GIPSY MONTH, LYMANTRIA DISPAR, CHARACTERISED BY THE TYPICAL BLUE AND RED SPOTS.
FIGURE 17
GREGARIOUS LARVAE OF THE LACKEY MOTH, MALACOSOMA NEUSTRIA.

In addition to the pine processionary moth, other two species present urticating hairs at the larval stage: the oak processionary moth (Thaumetopoea processionea) and the brown-tail moth (Euproctis chrysorrhoea), also capable of causing rashes, itching, redness, eye irritation and in severe cases even breathing difficulties (Figures 18-19).

18

19

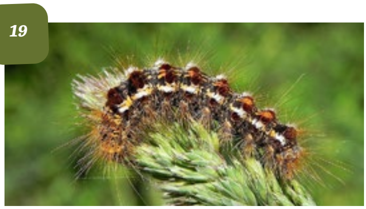


FIGURE 18
GREGARIOUS LARVAE OF THE OAK PROCESSIONARY MOTH ,THAUMETOPOEA PROCESSIONEA.

FIGURE 19
GREGARIOUS LARVAE OF THE LACKEY MOTH, MALACOSOMA NEUSTRIA.

PHYTOSANITARY, SANITARY AND VETERINARY IMPLICATIONS

The trophic activity of the young larvae during the autumn generally causes modest damage, with erosion and ***yellowing*** of the needles. Conversely, during spring mature larvae are much more voracious, and this can lead to a ***complete defoliation*** of the plants within few weeks. This action reduces the growth of the pines and weakens them, so they are more vulnerable to attack by secondary ***insect pests, such as bark beetles*** (**Figure 20**).

FIGURE 20
EVIDENT DAMAGE DUE TO THE TROPHIC ACTIVITY OF THAUMETOPOEA PITYOCAMPA LARVAE ON HOST PLANTS.

20

However, in pre-alpine areas, repeated defoliations play a very important ecological role in the succession of black pine forests by encouraging the entry of native broadleaf trees into the forest.
In pine forests with a landscape value or frequented for tourist-recreational purposes, infestations entail not only an ***aesthetic alteration*** of the forest due to defoliation, but also a serious ***sanitary and veterinary risk*** due to the urticating hairs released into the environment by the larvae from the third instar onwards. These hairs, located in thousands on precise areas of the larval body defined as 'mirrors', possess a harpoon-like conformation with terminal tips and contain a soluble protein, released when the hairs break, called ***thaumatopoein***. These characteristics make the hairs capable of causing ***skin reactions*** following direct contact with the larvae or by the simple dispersal of their hairs in the environment (**Figure 21**).
These effects may affect not only humans, but also ***domestic animals*** that often, attracted by the long procession of caterpillars heading for the ground, encounter them, showing allergic reactions, and often needing a rapid veterinary intervention.

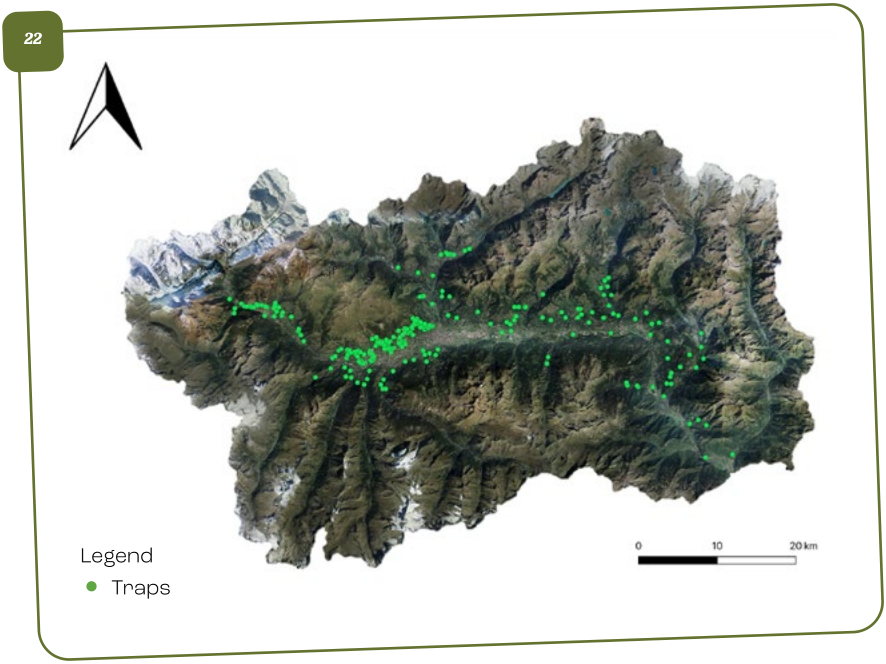
FIGURE 21
SKIN REACTION DUE TO THE CONTACT WITH THE URTICATING HAIRS OF THAUMETOPOEA PITYOCAMPA LARVAE.

21

PINE PROCESSIONARY MOTH MONITORING

As part of the MONGEFITOFOR project, to obtain a precise picture of the distribution, incidence and severity of T. pityocampa infestation in the Valle d'Aosta territory, an ***extensive monitoring*** was conducted placing ***277 georeferenced funnel traps*** loaded with the specific sexual pheromone in permanent study areas (**Figure 22**).

FIGURE 22
LOCATION OF TRAPS LOADED WITH THE SPECIFIC SEXUAL PHEROMONE FOR THE MONITORING OF THAUMETOPOEA PITYOCAMPA IN VALLE D'AOSTA.



The traps, controlled every 7 to 10 days, catch male individuals attracted by the female sexual pheromone, allowing to determine the ***period of flight*** of the adults, the peak of the flight, and the degree of intensity by the insect pest (**Figure 23**).

The monitoring, performed over ***large regional areas*** using ***specific protocols***, made it possible to predict the degree of ***infestation*** for the following year based on the number of nests and the rate of ***defoliation*** of pine forests recorded in winter and spring, respectively. Monitoring was scheduled throughout the life cycle of the target species, from 2020 to 2023, and will continue with long-term surveys after the end of the project, as well. Monitoring was integrated with ***citizen science*** activities and the involvement of ***stakeholders***, i.e., those actively involved in the project (**Box 4**).

FIGURE 23
FUNNEL TRAP USED FOR THE MONITORING OF THAUMETOPOEA PITYOCAMPA.

BOX 4

Citizen science

Citizen science is a set of activities involving the voluntary involvement of the general public in scientific research. Through such activities, it is possible on the one hand to improve data collection and on the other to raise awareness and educate the general public on environmental and ecological issues (**Figure 24**).
For this reason, the '**Report a phytosanitary threat**' platform on the MONGEFITOFOR project website was made available to citizens, easily accessible via QR-Code, to report the presence of phytosanitary issues in the area (**Figure 25**)

24

25

FIGURE 24
OUTLINE OF PLANNED CITIZEN SCIENCE ACTIVITIES.

FIGURE 25
QR-CODE CREATED TO REACH THE 'REPORT A PHYTOSANITARY THREAT' PLATFORM ON THE MONGEFITOFOR PROJECT WEBSITE.

APPLICATION OF CONTROL STRATEGIES

In the Western Alps, the pine processionary moth represents a serious threat for both the pine forests, which are severely defoliated, and for users, tourists and animals because of the problems caused by the urticating hairs of the larvae. For these reasons, the control strategies against this pest were made ***compulsory*** as early as the 1920s with the Italian Ministerial Decree 138 of May 20 1926 and subsequently with the Royal Decree 1700 of October 12 1933, later amended by the Royal Decree 2504 of December 2 1937. More recently, provisions for controlling this pest were established in the Italian Ministerial Decree of April 17 1998, reiterated by the Italian Ministerial Decree of October 30 2007. At present, the mandatory control of this species was repealed with the publication of the Italian Ministerial Decree of December 6 2021. Control strategies applied under the MONGEFITOFOR project have been intended to maintain the pest population at low level, to safeguard both forest stands and the health of human users and animals. In particular, the type of site was considered: infestation level, and presence of infrastructures of tourist-recreational interest and settlements.
The most effective techniques available, adopted in relation to the different stages of the pest life cycle and the characteristics of the infested forest stands, were used.
Under the MONGEFITOFOR project, different control methods were evaluated in experimental ***pilot sites*** for

three consecutive years, including: ***microbiological***, ***biotechnical***, ***mechanical*** and ***chemical control***, giving priority to ***sustainable*** techniques, also to adhere to European and National regulations (**Box 5**).

BOX 5

Pilot Sites

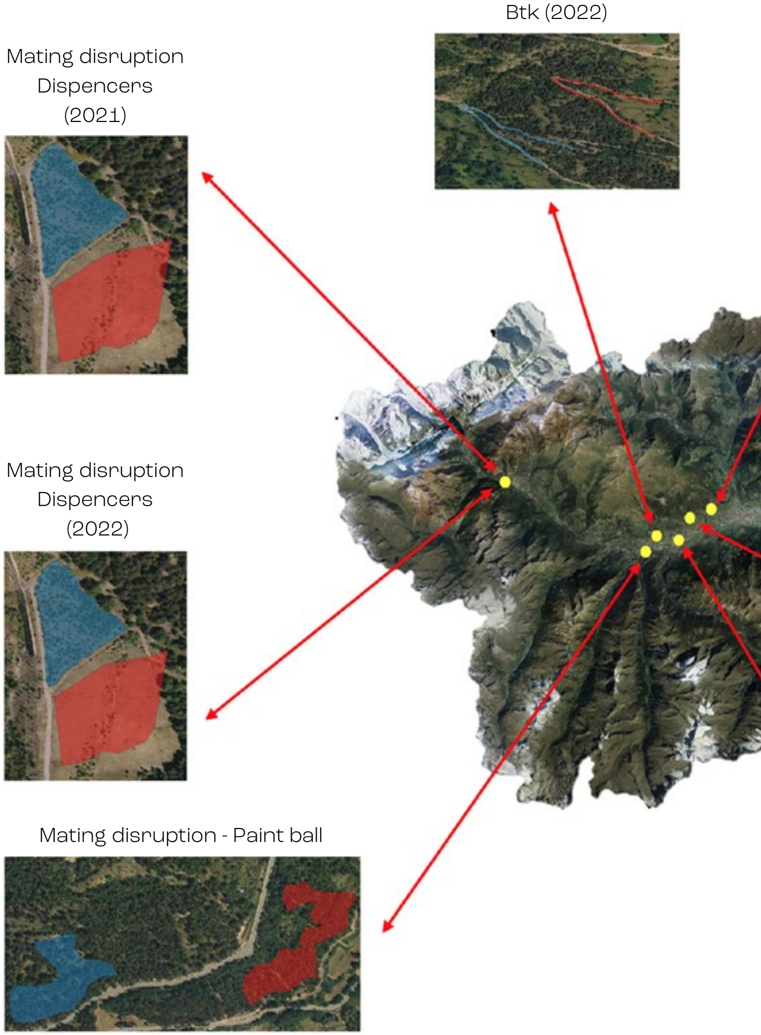
Pilot sites were selected to compare different control methods and their effectiveness, and to evaluate their environmental and economic sustainability. These experimental areas comprise homogeneous plots, both treated and untreated, monitored with targeted and periodic surveys and sampling.
Within the MONGEFITOFOR project, **eight** experimental **pilot sites** for the containment of the pine processionary moth were selected and set up by the project's operational team to promote the natural increase in resistance and resilience of forest populations (**Figures 26-28**).
Low-impact control strategies were applied at the pilot sites:

- **microbiological control**: *Bacillus thuringiensis var. kurstaki* (*Btk*) (2 sites);
- **biotechnical control**: confusione sessuale (erogatori, paint ball) (3 sites);
- **mechanical control**: bande adesive e collari al tronco (1 site);
- **chemical control**: endoterapia (2 cantieri).

FIGURE 26
STAFF INVOLVED DURING THE SELECTION OF A PILOT SITE.

FIGURE 27
STAFF INVOLVED IN THE APPLICATION OF THE TRUNK INJECTION TECHNIQUE IN A SECONDARY SCHOOL.

28


Btk (2022)
Mating disruption
Dispencers
(2021)
Mating disruption
Dispencers
(2022)
Mating disruption - Paint ball

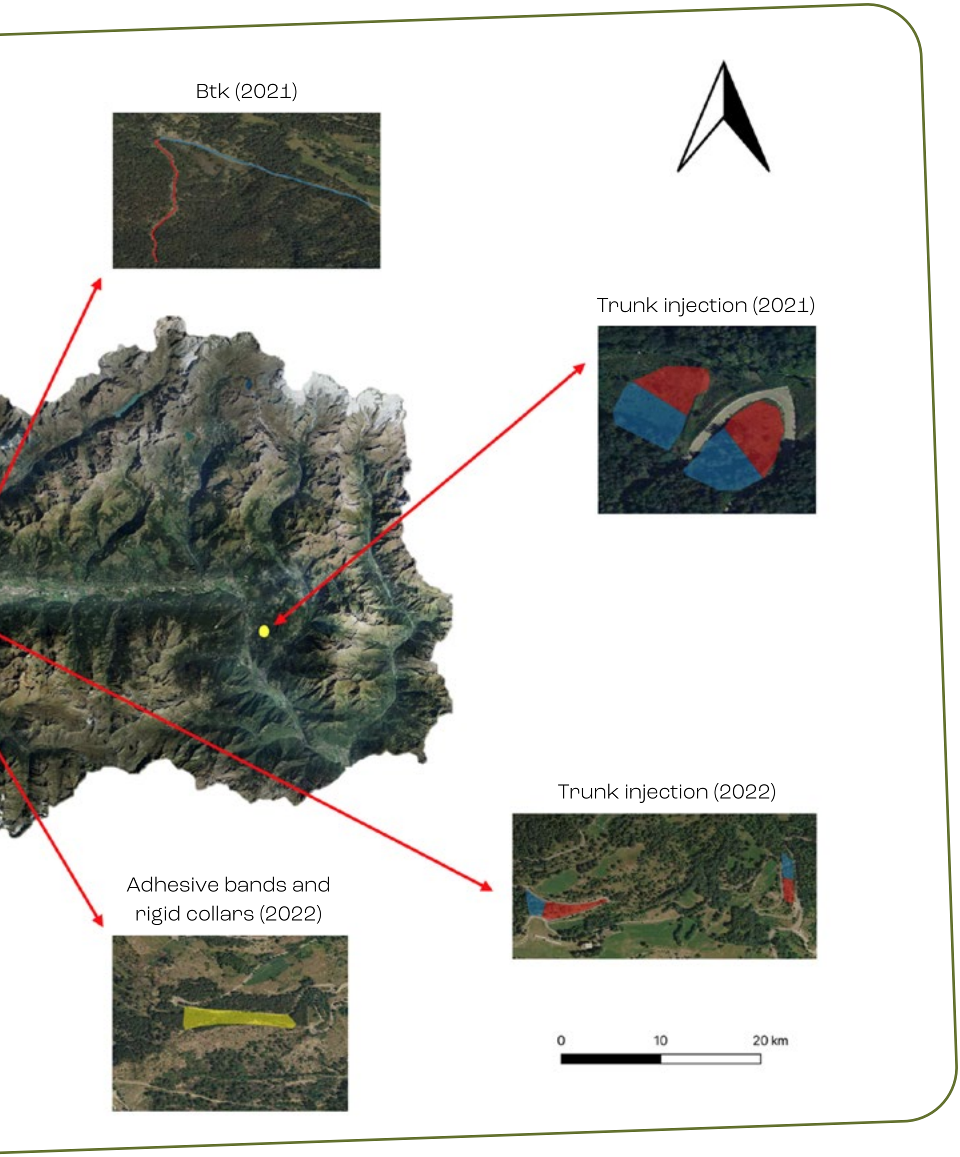


FIGURE 28
MAP REPRESENTING THE LOCATION OF THE PILOT SITES (YELLOW DOTS ON THE MAP). TREATED AND CONTROL SITES ARE SHOWN IN BLUE AND RED, RESPECTIVELY. THE AREA WHERE THE ADHESIVE BANDS AND COLLARS WERE PLACED IS SHOWN IN YELLOW.

MICROBIOLOGICAL CONTROL

This control strategy is part of the broader concept of biological control, which involves the use of biotic control agents such as viruses, bacteria, fungi, and nematodes. In the experimental areas of Sarre and Saint-Pierre (AO), and in other urban and forest areas, a registered product based on the ***entomopathogenic bacterium***, *Bacillus thuringiensis* var. *kurstaki (Btk)*, widely used against lepidopteran larvae, was distributed on the plants by means of ground-based applications. Treatments were performed in early September when the damage by the pest was still limited. Btk is a naturally occurring, aerobic, sporigenous bacterium acting by ingestion and causing the death of young caterpillars (mainly 1st and 2nd instar larvae), thus reducing the extent of the infestation. As *Btk* is easily degraded in environment by ultra violet light, the treatments were performed in the twilight hours (**Figure 29**).

The effectiveness of this treatment was evaluated by counting the number of nests after the treatment in the winter months. In all the treated plots, the number of winter nests was significantly lower than in the untreated plots, showing a good efficacy of this control method.

29

FIGURE 29

GROUND-BASED APPLICATION WITH THE ENTOMOPATHOGENIC BACTERIUM BACILLUS THURINGIENSIS VAR. KURSTAKI.

BIOTECHNICAL CONTROL

Biotechnical techniques involve the use of substances, such as ***sexual pheromones***, affecting insect behaviour, and the use of genetic techniques. Synthetic female sexual pheromones are used for monitoring and capturing of large numbers of male individuals (mass trapping), as well as for ***mating disruption***. This technique involves the uniform spread of sexual pheromones in the environment just before adult emergence. Males, being the environment saturated of synthetic pheromones, can hardly detect the pheromones naturally released by virgin females, making the search for females more difficult. ***High concentrations*** of pheromones cause saturation of the males' antennal receptors, decreasing their ability to respond to such stimuli. The consequence is a lower ***mating rate*** and thus a lower oviposition.
The pilot site was set up in Morgex (AO) where the 'traditional' method was applied in a selected area placing ***dispensers containing synthetic female pheromones***. This area was compared with a control area (without dispensers). Pheromone traps were placed in both sites in order to capture, and count, the attracted male individuals (**Figure 30**).

FIGURE 30
SEXUAL PHEROMONE DISPENSER USED TO APPLY THE MATING DISRUPTION TECHNIQUE.

30

Furthermore, the innovative 'Pine T Pro ball' method was tested in Saint-Pierre (AO). This method consists of 'shooting' small spheres containing 0.1 g of a suspension of sexual pheromone microcapsules, by means of air compressed paint ball rifle, targeting the tree branches. One application per year before the adult emergence is required. The preliminary results have shown how this technique can be promising in reducing the infestation of this pest, in terms of lower captures of male individuals in the traps (**Figure 31**). Further field investigations will be conducted after the end of the project to evaluate its effectiveness over a longer period.

31

FIGURE 31
APPLICATION OF THE SEXUAL CONFUSION TECHNIQUE USING THE INNOVATIVE 'PINE T PRO BALL' METHOD.

MECHANICAL CONTROL

Mechanical control methods involving the ***removal of nests*** from mid-autumn to the end of January are feasible on ***small areas***, on isolated trees and in public parks and/or gardens, but not in forests and do not ensure an effective population control. Uncertain results are also achieved by breaking up nests using firearms (ballistic control). In addition to these techniques, the mechanical removal of larvae can be performed. Specifically, in a pilot site in Sarre (AO) ***adhesive bands and rigid collars*** were applied to the trunk to form a ***barrier*** against mature larvae descending down after overwintering (**Figure 32**). The effectiveness of these traps was monitored by counting the captured larvae. The use of rigid collars allowed a greater capture of larvae than the adhesive bands, which were often overtaken by the caterpillars, especially at high population densities.

FIGURE 32
ADHESIVE BANDS AND RIGID COLLARS PLACED ON THE TRUNK TO INTERCEPT THE LARVAE AS THEY DESCEND ALONG THE TRUNK..

32

CHEMICAL CONTROL

Because of the risks to health, as well as toxicity to other non-target animals such as natural enemies and pollinating insects, insecticides cannot be applied by spraying on the foliage, but by ***trunk injections***. The trunk injections involve the direct introduction of small amounts of a registered ***systemic insecticide*** that can be slowly translocated to the crown by the plant's own lymphatic circulation, causing the death of the larvae feeding on the pine needles. Such a kind of treatment is commonly used on ornamental plants, located in schools and in public and private parks.

For two consecutive years, in the pilot sites of Montjovet and Sarre (AO), the '***New Corradi Method®***' was tested, involving a manual injection into the plant trunk, by means of a specific syringe with a pressure system, using ***abamectin*** as systemic active ingredient (**Figure 33**).

This technique provides ***high efficacy***, ***low phytotoxicity*** in a short time, and is environmentally, operator and public friendly. Treated and untreated sites were chosen according to the following parameters: presence of temporary nests, presence of larvae, and even-aged plants to ensure the use of the same amount of insecticide. This method provides a low pressure level during the introduction of abamectin, avoiding damage to the plant's vascular system. The treatment efficacy, by assessing the larval mortality, revealed a ***higher mortality rate of larvae*** taken from the temporary nests of abamectin-treated plants than those in untreated plants (**Figure 34**).

The use of various pest control methods made it possible to highlight the best results achieved in all the pilot sites, to suggest a control plan based on the most functional strategies, in relation to the environment as well.

FIGURE 33
TRUNK INJECTION USING THE NEW CORRADI METHOD®.

FIGURE 34
ACTIVITIES IN THE LABORATORY TO EVALUATE THE EFFECTIVENESS OF THE TESTED CONTROL TECHNIQUES.

33

In addition to the applied and tested control strategies, the importance of biological control agents against *T. pityocampa* has been highlighted. The processionary moth has a remarkable complex of ***natural enemies***. These include ***parasitoid insects*** (*Trichogramma* spp., *Ooencyrtus pityocampae*, *Baryscapus servadeii*, *Phryxe caudata*, *Villa brunnea*), ***predatory insects*** (*Xathandrus comtus*, *Calosoma sycophanta*), ***insectivorous birds*** (hoopoe, great tit) and ***viral and fungal diseases*** affecting larvae and pupae.
No biological control measure is usually performed against the pine processionary moth, but ongoing research on the

34

biology and behaviour of natural enemies may provide useful perspectives.

Specifically, in a biological control perspective, large-scale surveys were carried out in the Aosta Valley region, both in the field and in the laboratory, to identify potential parasitoids of the pine processionary moth. Particular interest was addressed to the richness and abundance of the ***egg parasitoids*** associated with the processionary moth. For this purpose, processionary moth eggs were collected from black pine and Scots pine forest stands at an altitude of 800 to 1300 m a.s.l., brought to the laboratory, cleaned of protective scales (**Figure 35**) and placed in glass tubes to monitor the emergence and to identify them (**Figures 36-37**).

35

36

37

FIGURE 35
REMOVAL OF PROTECTIVE SCALES FROM EGG BATCHES.

FIGURE 36
PARASITOIDS EMERGED FROM AN EGG BATCH IN A GLASS TUBE.

FIGURE 37
A NEWLY-EMERGED PARASITOID AND ITS EMERGENCE HOLE.

Morphological and molecular analysis of the individuals emerged allowed the identification of several species of oophagous parasitoids, among which the most representative were Trichogramma sp. (**Figure 38**) and Ooencyrtus pityocampae (**Figure 39**), while to a lesser extent individuals of Baryscapus servadeii and Anastatus bifasciatus were identified.
As part of the project, a ***cross-border task force*** (task-force EFIS - Phytosanitary Emergencies Italy-Switzerland) was established to provide support for forest defense activities in the project study area against ***new phytosanitary issues*** (**Box 6**).

38

39

FIGURE 38
ADULTS OF TRICHOGRAMMA SP.

FIGURE 39
EMERGENCE OF AN ADULT SPECIMEN OF OOENCYRTUS PITYOCAMPAE.

BOX 6

Task force

The **cross-border task force** developed within the project aims to identify and infestations and diseases caused by invasive organisms that could also cause problems in the Aosta Valley and in the cantons of Grisons and Ticino. The project areas show a high vulnerability to the pathogenic fungus *Dothistroma septosporum*, a worrying agent of pine canopy decline and defoliation. Similarly, invasive exotic insects such as the Japanese beetle *Popillia japonica* and the Asian longhorn beetles *Anoplophora chinensis* and *Anoplophora glabripennis* may also represent a potential phytosanitary emergency in the study area, having already been reported in several regions of northern Italy. Other possible threats are represented by the following species:
Agrilus planipennis, a buprestid affecting ash trees that is included in the **A2 list** by the **European and Mediterranean Plant Protection Organisation (EPPO)**, currently recorded in Russia and Ukraine and continuously expanding its range.
Bursaphelenchus xylophilus, a nematode carried by long-horn beetles included in the A2 list by EPPO, so far observed in Spain and Portugal, but not yet in Italy.
Dendroctonus valens, a bark beetle included in the **A1 list** by EPPO, a quarantine insect pest not yet present in the EPPO area.
Toumeyella parvicornis, a species listed in the EPPO **Alert List**, affecting the genus Pinus and currently reported in some regions of Italy (Abruzzo, Campania, Lazio, Apulia and Tuscany).

GENERAL OVERVIEW OF SCOTS PINE DECLINE

The ***decline of Scots pine*** is a well-known phenomenon throughout Europe. In the Alps, it is especially severe in the valleys oriented east-west trend with a more continental climate, such as the Rhone valley in Valais, the central valley of the Aosta Valley and the Susa valley in Piedmont. The decline of Scots pine in the ***Alps***, which has also been investigated in the past in the Aosta Valley in the framework of an Interreg Italy-Switzerland project, ***manifests itself chronically*** with the ***desiccation***, after a phase of progressive weakening, of ***single trees***

(**Figure 40**) or small ***groups of trees*** randomly distributed in the stands, especially in those sites on south-facing slopes. This syndrome, which reveals itself more intensely in forests below 1000 m a.s.l., is considered to be the effect of a complex series of factors, including climate, competition with other tree species, for example the downy oak, the presence of parasites such as mistletoe, sapwood nematodes, xylophagous insects and pathogenic fungi.

FIGURE 40
CHRONIC DECLINE OF INDIVIDUAL SCOTS PINE SPECIMENS. SAINT DENIS (AO)

40

41

42

Such decline phenomena have little in common with an ***acute type of generalised desiccation*** of Scots pine that occurred in the past in pine stands on former agricultural soils on the north-facing slope of the central valley of the Aosta Valley (**Figure 41**).
In its most acute phase, generalised decline consists of ***discolouration*** (reddening) of the ***foliage*** followed by complete ***desiccation*** of the individual tree. Needle drop proceeds from the inside of the twigs outwards, i.e. from the oldest needles. As a consequence, the terminal twigs often show ***lion's tailing*** (**Figure 42**). Needle browning, which follows reddening, is a fairly common symptom..
Although signs of the presence of phytophagous insects and phytopathogenic fungi were found on these Scots pines, including the longhorn beetle *Acanthocinus aedilis*, the *buprestid Phaenops cyanea*, the fungi *Cenangium ferruginosum, Cyclaneusma minus, Sclerophoma pithyophila* and *Truncatella hartigii*, these do not justify the overall symptomatology and the death of trees.
Climatic investigations and retrospective comparative analyses with other episodes of acute decline of pine trees in the Aosta Valley allowed identifying a climatic origin

of these phenomena. Indeed, at least ***two consecutive years*** characterised by ***anomalies in the summer ombrothermal index*** (the ratio between precipitation in mm and temperature in °C from the month of May to the month of August) would favour the onset of ***acute decline*** (**Figure 43**).

Acute decline mainly occurs in stands on the north-facing slopes rather than on south-facing ones, as in the latter the plants tolerate periods of prolonged drought better, due to a series of adaptations to compensate and reduce the transpiration water flow.

43

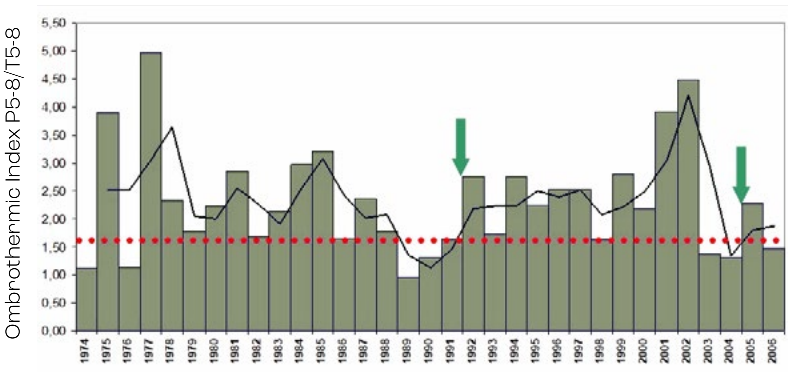


FIGURE 41
ACUTE GENERALISED DIEBACK OCCURRING IN 2005-2006 IN PINE FORESTS GROWING ON FORMER AGRICULTURAL SOILS IN THE NORTH-FACING SLOPE OF THE CENTRAL VALLEY OF THE AOSTA VALLEY . GRESSAN (AO).

FIGURE 42
DETAILS OF THE CROWN OF A SCOTS PINE AFFECTED BY ACUTE DECLINE. NOTE THE LION'S TAILINGOF THE TERMINAL PARTS OF THE SHOOTS.

FIGURE 43
HISTORICAL SERIES AND MOVING AVERAGE OF THE SUMMER OMBROTHERMAL INDEX, CALCULATED ON RAINFALL AND TEMPERATURE DATA FROM ST. CHRISTOPHE. IN RED A HYPOTHETICAL MINIMUM THRESHOLD FOR THE TRIGGERING OF ACUTE DECLINE OF SCOTS PINE. NOTE THAT THE ACUTE DECLINE OF SCOTS PINE OCCURRED AFTER A MINIMUM OF THIS INDEX.

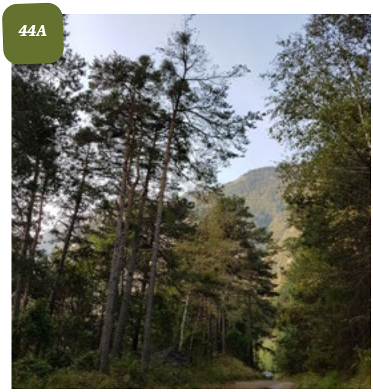
The selectivity of the phenomenon to Scots pine may be due to a complex series of factors, including climate, soil, the age of the plants and the architecture of their root system. In soils of medium depth, Scots pine develops a relatively deep root system, unlike other species such as spruce. While species with a shallow root system are able to intercept and make use of rainwater even when it is not abundant, species with a deep root system, being almost completely dependent on the water table, may suffer when this goes deeper in the soil. This is particularly true in the case of adult trees, which are unable to compensate the situation by significantly emitting new roots and modifying their root architecture. Although these phenomena may be reversible and do not necessarily lead to the death of forest stands, the consequences on the landscape are very significant, as is the risk of subsequent forest fires.

MONITORING SCOTS PINE DECLINE

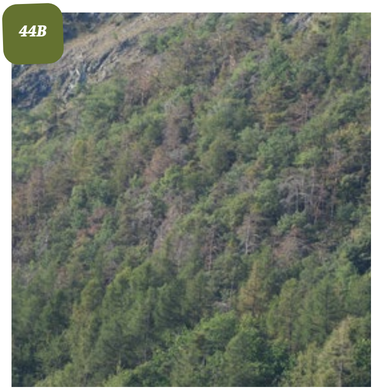
Over the last few years and during the implementation of the MONGEFITOFOR project, the Forestry Corps of the Autonomous Region of the Aosta Valley and the University of Turin have cooperated to collect and analyse new ***reports*** of Scots pine decline phenomena. Surveys were conducted in different plots
The overall examination of the health status of Scots pines was conducted using a variety of methods of ***phytosanitary monitoring***:
• Deployment of personnel actively patrolling the affected forest plot;
• Inspections with the aid of binoculars and digital cameras with high-performance optical zooms to assess the conditions of the stands, even when these werenot directly accessible;
• Deployment of personnel as in the previous points, but in

this case equipped with ***drones*** with a video camera and camera suitable for aerial filming (**Figure 44**).

44A



44B



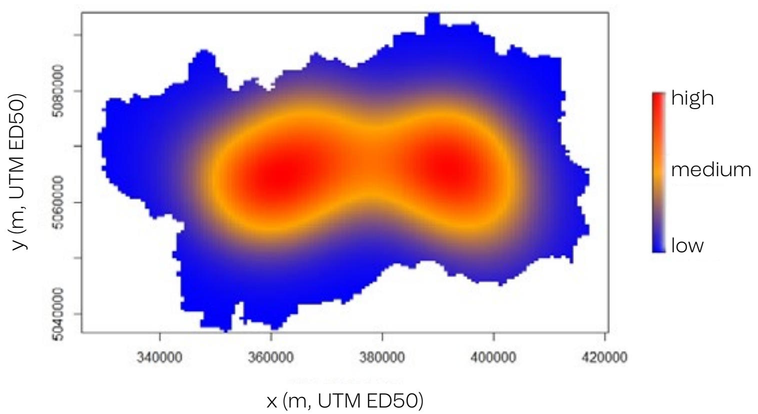
44C

FIGURE 44
TECHNIQUES FOR MONITORING SCOTS PINE DECLINE. ASSESSMENT OF SYMPTOMS IN SITU (A), REMOTELY (B) AND WITH DRONES (C).

The monitoring methods described above made it possible to conduct real-time and delayed assessments of the health of pine forests by analysing the footage and photographic material acquired. The sites for which reports of Scots pine decline were received were identified cartographically and a ***thematic map*** was produced to assess the level of concentration of reports, limited to the Aosta Valley. It was possible to verify that the concentration of reports of decline is highest along the main valley and has two peaks, the westernmost between Gressan and Avise, the easternmost between Saint-Vincent and Nus (**Figure 45**).
At some sites, samples were taken from symptomatic Scots pine branches and female strobili, taken up to 3 metres in height. The samples were analysed in the laboratory using: humid chambers to induce the differentiation of multiplicative or reproductive structures by any phytopathogenic ascomycete fungi present in the host tissues; microbial isolation assays aimed at obtaining in vitro cultures of fungi potentially involved in the decline; optical microscopy preparations set up to conduct the identification of the isolated species; in-depth diagnostics conducted with

FIGURE 45
MAP OF THE CONCENTRATION LEVEL OF REPORTS OF SCOTS PINE DECAY IN VALLE D'AOSTA. THE COORDINATES REPRESENT LONGITUDE (X) AND LATITUDE (Y) IN METRES, IN THE UTM ED50 COORDINATE SYSTEM.

45

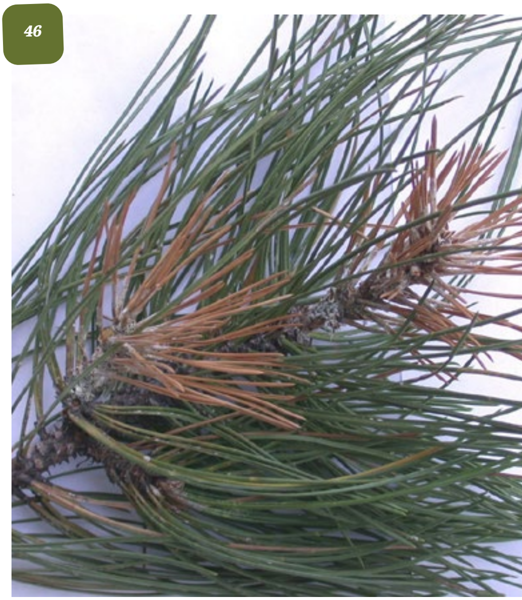


molecular techniques based on the extraction and analysis of genomic DNA (e.g., PCR). As a result, in ***70%*** of the cases approximately, the samples were positive for the presence of the mitosporic fungus ***Sphaeropsis sapinea***. A more in-depth look at this pathogen, the symptoms it induces in the host and possible containment strategies is provided in the next chapter.

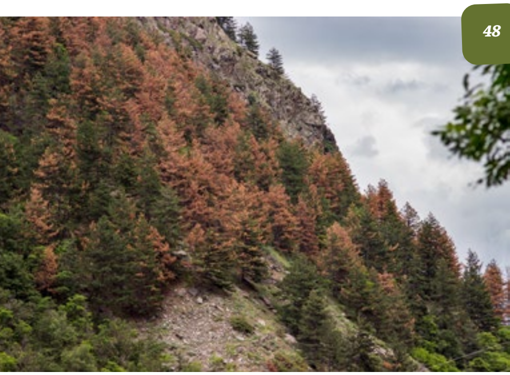
SPHAEROPSIS SAPINEA TIP BLIGHT OF PINES

Sphaeropsis sapinea (Fr.) Dyko & Sutton is a fungus that causes a blight of the current year's shoots of Scots pine, black pine and occasionally also spruce and other species of the Pinaceae family.
The fungus tends to be more ***aggressive in warm climate areas***, where it can kill branches of a certain size. However, the greater virulence of the fungus in these areas depends on certain factors that limit host resistance, such as ***drought***. The disease has recently made its appearance in a number of Alpine valleys, including the Aosta Valley, even at altitudes around 1,000 m a.s.l., probably taking advantage of the rise in temperatures and of water stress phenomena affecting the trees. Symptoms appear in spring as a ***blight*** of the year's ***shoots*** (**Figure 46**).

FIGURE 46
INITIAL SYMPTOMS CAUSED BY SPHAEROPSIS SAPINEA AT THE APEX OF PINE SHOOTS.



47



48

FIGURE 47
DIAGNOSIS OF SPHAEROPSIS SAPINEA IN THE FIELD: INSPECTIONS WITH A MAGNIFYING GLASS FOR THE PRESENCE OF FRUITING BODIES OF THE FUNGUS.

FIGURE 48
SPHAEROPSIS SAPINEA TIP BLIGHT OF PINES. AVISE (AO).

FIGURE 49
BLACK PUSTULES REPRESENTING SPHAEROPSIS SAPINEA FRUITING BODIES ON THE SCALES OF THE FEMALE STROBILUS OF A SCOTS PINE.

Infection of the shoots begins before the needles are completely developed and results first in the appearance of resin exudate on the shoot, then in the reddening of the infected needles which remain shorter than the green ones. Then, the needles turn ash-grey-brown and ***black pustules*** appear on them, especially at the base, representing the fruiting bodies of the fungus (**Figure 47**). Such pustules may also appear on the bark of dead twigs. The ***damage*** can be considerable in the case of infections occur significantly over consecutive years and in the case of epidemic development. The disease affects tree growth and, in young trees, can be ***lethal*** (**Figure 48**).
The fungus can also cause blue stain, a bluish-grey discolouration of wood. The black pustules (fruiting bodies of the fungus), which generally form in the spring of the year following the year of infection, produce asexual ***spores*** that are ***spread*** during the warmest and ***rainiest periods*** from March to October, with an optimal period from April to June, during the growth of the shoots. Overwintering of the fungus occurs in needles on the ground or on those still attached to branches, on the bark or on strobili. The latter can constitute an important

inoculum reservoir, as the fungus is able to fructify considerably on them (Figure 49). The fungus can also survive, behaving as a saprophyte, on trunks and branches on the ground. Intense hailstorms as well as high levels of relative air humidity can predispose trees to infection.

Regarding ***disease control***, the removal of infected branches, strobili and other material, even from the ground, could mitigate the severity of the disease, but this is generally not feasible in the forest. If action is taken in the early stages of pathogen establishment in the forest with pruning aimed at removing affected branches, this should be performed during very dry periods to prevent the wounds resulting from pruning to become infected. Although there is currently a lack of experimental evidence, the ***modulation*** of tree ***density***, through appropriate silvicultural techniques, could ***reduce the risk*** of spread of the disease.

49

ACKNOWLEDGEMENTS

This handbook has been produced in the framework of the activities of the MONGEFITOFOR project (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 - ID 540693), funded by the European Union through the Territorial Cooperation Programme INTERREG V-A Italy-Switzerland 2014/2020..
The authors would like to thank Davide Cadario for his support in the field activities and Francesca Brescia for her assistance at the DISAFA's Forest Pathology Laboratory, as well as the Agents, Officials and Personnel of the Forestry Corps of the Aosta Valley who took part in the activities to identify the pilot sites.
Special thanks go to the many stakeholders who supported the MONGEFITOFOR project.

ESSENTIAL BIBLIOGRAPHY

Auger-Rozenberg M-A.; Barbaro L.; Battisti A.; Blache S.; Charbonnier Y.; et al. 2015. Ecological responses of parasitoids, predators and associated insect communities to the climate-driven expansion of the pine processionary moth. In Processionary Moths and Climate Change: An Update. A. Roques. pp. 427. Dordrecht, Neth, Springer.

Battisti A.; De Battisti R.; Faccoli M., Masutti L.; Paolucci P., Stergulc F. 2013. Lineamenti di zoologia forestale. Padova University Press, Padova.

Bernetti G. 1995. Selvicoltura speciale. Torino: UTET. ISBN 9788802048673

Bernetti G. 2005. Atlante di selvicoltura. Dizionario illustrato di alberi e foreste. Bologna: Edagricole. ISBN 9788850646654

Camerano P.; Terzuolo P.G.; Varese P. 2007. I tipi forestali della Valle d'Aosta. Arezzo: Compagnia delle Foreste.

Capretti P.; Santini A.; Solheim H. 2013. Branch and tip blights. In: Infectious forest diseases, Gonthier P. and Nicolotti G. (eds.). Cab International, Wallingford, UK., pp. 420-435.

Del Favero R. 2004. I boschi delle regioni alpine italiane. Padova: CLEUP. ISBN 9788867870820.

Ferracini C.; Saitta V.; Pogolotti C.; Rollet I.; Vertui F.; Dovigo L. 2020. Monitoring and management of the pine processionary moth in the northwestern Italian Alps. Forests 11: 1253-1265.

Ferracini C.; Saitta V.; Rondoni V.; Rollet, I. 2023. Variables Affecting the Pine Processionary Moth Flight: A Survey in the North-Western Italian Alps. Forests 14(1): 31.

Gonthier P.; Giordano L.; Nicolotti G. 2010. Further observations on sudden diebacks of Scots pine in the European Alps. The Forestry Chronicle, 86(1), 110-117.

Lauber K.; Wagner G.; Gygax A. 2001. Flora Helvetica. Bern: Haupt Verlag. ISBN 9783258077000.

Masutti L.; Zangheri S. 2001. Entomologia generale e applicata. CEDAM, pp. 978.

Pogolotti C.; Vercelli M.; Fontana E.V.; Ferracini C. 2022. Management strategies to control pine processionary moth outbreaks in North-Western Italian Alps. Book of Abstract of the IUFRO Conference Division 7 – Forest Health Pathology and Entomology Lisbon, 6-9 September 2022, pp. 74.

Pollini A. 2013. Manuale di entomologia applicata. Edagricole, pp. 1462.

Regione Piemonte, Regione Autonoma Valle D'Aosta 2008. Il deperimento del pino silvestre nelle Alpi occidentali: natura e indirizzi di gestione. Arezzo: Compagnia delle Foreste, pp. 128.

November 2023
Printed by Tipolitografia Botalla s.r.l. - Gaglianico (BI) - Italy

This handbook has been produced in the framework of the activities of the MONGEFITOFOR project (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 - ID 540693), funded by the European Union through the Territorial Cooperation Programme INTERREG V-A Italy-Switzerland 2014/2020.

Interreg
Fondo Europeo di Sviluppo Regionale
ITALIA SVIZZERA - ITALIE SUISSE - ITALIEN SCHWEIZ
UNIONE EUROPEA
MONGEFITOFOR

Région Autonome Vallée d'Aoste
Regione Autonoma Valle d'Aosta
DISAFA
Università degli studi di Torino
ti
WSL

PROGETTO GRAFICO: ANDREA DALLA FONTANA | ÉQUIPE ARC-EN-CIEL

ISBN
9791280561329