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INCIDENCE OF ROOT ROTS ON FOREST STRIPS ALONG MOUNTAIN ROADS IN THE ALPS

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Abstract

The carrying capacity of forests growing along roads is continually threatened by human activities as well as environmental stress factors. Growth reduction and decline of trees near strip roads resulting from traffic pollutants, soil compaction and damaged roots. The role of rots in decreasing natural stability of these forest hedges managed in an environmental-friendly silviculture framework has been poorly analysed to manage this risk. To this purpose, road hedges of three mountain roads, SS50, SP620 and road SP16, and inner woodlands crossing some forest areas in the Italian Alps has been analysed. Sanitary conditions and presence of root and butt rot fungi have been assessed by visual inspection of the pathogens on fresh stumps *in situ* and by *in vitro* isolation and growing in pure culture. Also historical data were elaborated and compared. Main analysis were carried out on: frequency of stumps and trees attacked by root and butt rot; main fungal agents involved in the rots; comparisons between road edges *vs.* inner forests ; difference in the hedges attack as regard for classes of altitude and allocation side.
From the stumps survey the data shows an higher proportion of stumps with decay associated to fungi along the roads SS50 (35,5%) and SP620 (37,6) than in the respective inner forest (17,2 and 33%) nearby these roads. The road SP16 with 69,9% shows a very higher incidence of decay fungi compared with the SS 50 and SP620. However, the two forest hedges of SS50 and SP620 do not appear to be statistically different between them in terms of decayed and healthy stumps. The X^2 analyses shows highly significative differences among the four sites, inner and hedge forests of both SS50 and SP620. When are compared only inner and hedge forest for each road separately these differences are still significative. The comparison of three different ranges of elevation in both roads shows that the decay is decreasing significatively going from lower to higher elevation. Taken into account the road sides the decayed stumps were higher in the downward side, but significantly different only for the road SS50 and not for the road SP620.

Introduction

Woodlands sited along public roads are world-widely recognised as important even when they can hide permanent hazards with different level of risks in relation to specific targets. If one considers that almost all forests in Italy lie in mountain regions which constitute 35.2% of the whole land, the public road-network is a key factor for policies aiming to develop such areas, usually evaluated as marginal from the economical point of view (Branchi, 1991).
The carrying capacity of trees growing along roads is continually threatened by human activities as well as environmental stress factors (Leh, 1993). Growth reduction and decline of trees near strip roads result from traffic pollutants, soil compaction and damaged roots (Wasterlund, 1983; Majdi & Persson, 1989). A vulnerable root system is particularly critical

in the context of an adequate structural support and mechanical stability of these forest hedges. Physiological stresses, wounds, thinnings, cuttings, harvesting, logging and incorrect silvicultural practices represent important predisposition factors to develop and to epidemically widespread root and root rots in forests (Robek & Matthies, 1996). Also the role of storms, even when they do not produce root failures or stem breakages themselves, they can cause injuries at the base and on roots of apparently healthy and vigorous conifer trees. These injuries and cracks can form afterwards entry ports for rot fungi (Klein, 1995). Root rots are the main agents weakening the mechanical resistance of trees at level of both stem and roots (Anselmi, 1998). Furthermore, they are not always easily detectable in standing trees following traditional methodologies (Whitney, 1988). Several times, especially on Norway spruce and silver fir, the external symptoms are not always clear (Vollbrecht & Agestam, 1995). Visual approach (Mattheck & Breloer, 1994) integrated with monitoring of bio-auxometric tests (Rinn, 1990; Rinn *et al.*, 1996; Battistel *et al.*, 1998) are usually employed during the risk analysis. In doubtful cases Pressler's borer measurements can be an useful tool to supporting decisions (Rinn, 1990; Delatur, 1993).

Since '20s Italian forest policy-makers paid attention and classified the forest along roads as "forest under special conditions"(art. 8-10 of Royal decree-law 3267/1923). Forest managers have been closely involved in assuring to stakeholders a reasonable and effective compromise between social and private needs.

In the Alps wind-throws and snow-breakages represent for conifer forests all year long a not easily foreseeable hazard with sometimes serious consequences. Especially in areas with high tourist pressures, damages to road users (injuries, death), losses of private properties and public goods as well as civil and/or criminal liability of public and private forest owners are now getting priority attention in assuring safety as essential requirement. Under the present Italian forest law (act 752/1986 and follows) whoever road user receives damages from these forest edges, caused by their incorrect management, is allowed to complain to the public authority about the civil and penal responsibility in charge of road safety (art. 2043 and 2051 of the Civil Code). These rights find parallels in several other European countries (Gebhard, 1995; Hötzel, 1998; Gatterbauer, 1998) as well as in the European law (Cheminade & Alletto, 1982; Pampanini, 1990).

In Trentino, Eastern Italian Alps, damaging events caused by abiotic factors where recorded in the last three decades (Ambrosi, unpublished data). These events, mainly connected to wind and snow storms, weaken forest stability and compromise the delicate forest structure of this mountain area.

Assessment risk of root failure or stem breakage on the forest edges along 1350 and 6500 km respectively of main and forest Trentino's road network is considered very important taking into account of the increasing ageing of these ecotons and the eminent tourist attractiveness of the Province. The forest land in Trentino accessible by public and forest roads is very relevant with a density of 23 linear metres per forest land hectare. These strip forests are calculated to represent almost 15% of the total forest lands in Trentino with a theoretical number of about 25 millions of trees (data not shown).

Despite the local guidelines towards an environmental-friendly forest management of forest, sanitary monitoring has been neglected until '80s. No inventory of mechanical stability has been worked out; no risk analysis have been drawn down for parking or picnic areas so that there is no ranking of hazards along different roads or stretch of roads. At the beginning of 1990 the local Forest Authority, in order to estimate the failure risk and to reduce the fatal consequences, promoted a constant monitoring based on observation, collecting, diagnosis and reporting run by trained forest assistants and checking and elaboration by local experts (Ambrosi & Salvadori, 1998).

The role of rots and their causal agents in decreasing natural stability of these forest hedges managed in an environmental-friendly silviculture framework has been poorly analysed so that forest technicians can not properly considerate and manage this relative risk. Main fungal agents involved in rots processes in boreal conifer forests have been longer recognized as *Heterobasidion annosum* and *Armillaria* spp. (Holdenrieder, 1989).

Therefore, inner woodlands and road hedges crossing some forest areas in Trentino have been analysed. Sanitary conditions and presence of root and butt rot fungi have been assessed by visual inspection of the pathogens on fresh stumps *in situ* and by *in vitro* isolation and growing in pure culture.
Main objectives of the work are the following:
- frequency of stumps and trees attacked by root and butt rot;
- main fungal agents involved in the rots;
- comparisons between road edges *vs.* inner forests;
- difference in the hedges attack with regard for classes of altitude and allocation side (upward, downward).

Materials and methods

Forest hedges along three public roads were surveyed during some thinning operations carried out in 1998. All three forests were located in Trentino, East Italian Alps. The main ecological features and the species composition of the sites are summarized in Tab. 1. The three roads chosen were: the SS-50 (Strada Statale di Passo Rolle), the SP-620 (Strada Provinciale di Varena) and the SP-16 (Strada Provinciale di Alberè). The road borders were continuously covered by forest along all the surveyed roads length and only Norway spruce trees were interested by thinning operations. The stumps examined were considered belonging to strip along road if they were cut at a distance not higher than 25 m from each road side. For comparison, thinning strips of about the same size were also surveyed in the inner forest nearby SS-50 and SP-620. Except for the distance from the road, the ecological conditions of these two inner forest sites were similar to the respectively road strips, which they were compared to.
Fresh stumps were checked on for the presence of decay and fruit bodies. For comparison, two strips of the thinnings performed in the inner forest nearby SS-50 and SP-620 were also surveyed.

In cases where the visual observation of the decay symptoms *in situ* and presence of fruiting bodies did not permit an accurate determination of the fungal decay agent, a disk about 5 cm thick of decayed wood was collected from the rotted stump. Also from stumps on which small traces of decay were observed, samples of core roots were collected by using an increment borer. These woods were then wrapped in moist newspaper and incubated for 7-10 days at room temperature in a clean plastic bag used as a humid chamber. In some doubtful cases where this method did not clearly reveals the fungal species, cultures on malt extract medium (ME) were made from some decayed sample. These fungi, detected both by visual inspection of wood and by identification of pure culture *in vitro*, were defined and classified in three groups as: 1) *Heterobasidion annosum*, 2) *Armillaria* spp. and 3) other pathogen and saprotrophic fungi.

Detection of *Heterobasidion annosum*
Stumps along the roads were examined for the presence of basidiocarps, inspecting also the interior hollow part of the stumps. These stumps were surveyed around the root collar and along the bigger roots to check signs of the fungus. The diagnostic symptoms in Norway spruce, on collecting samples, were the characteristic white stringy rot in the roots and sometimes an ectotrophic mycelium white coloured, on the root surface. Sometimes conidial stage was visible with a hand lens on broken roots under debris on stumps, in insect galleries and in cavities formed by shrinkage of soft tissue at the bark-wood interface. Conidia of *H. annosum* were borne on swollen heads of unbranched conidiophores. Each head bears many spores and appears as a white speck, giving the colony a granular appearance.

Where conidia were not clearly visible on decayed stumps the search was performed on wood disks after humid chamber incubation. These disks were examined under a dissection microscope to search the conidia of *H. annosum*. Cultures on malt extract medium (ME) were made from any decayed regions where conidia of *H. annosum* had not been observed.

The occurrence of *Heterobasidion annosum* was confirmed by the presence of the imperfect state *Spininger meineckellus* (A.J. Olson) Stalpers, according to the methods described by Stalpers (1978).

Detection of *Armillaria* spp.

Under local conditions the presence of thick, fan-like whitish to cream mycelium between the bark and the wood, extending up to 2 metres above the ground on infected symptomatic or asymptomatic trees, is most diagnostic for *Armillaria*. General yellowing of the foliage accompanied by resinosis on the stem, root collar and lateral roots, especially on high risk sites, was generally indicative of infection. The patch-wise radial spread of the disease aids in identification. In advanced stages of infection and decay a white soft rot with dark zone lines was produced in roots and stumps. Rhizomorphs of the fungus produced on infected hosts, as well as basidiocarps, were collected when they were present.
Where typical mycelium or rhizomorphs were not clearly visible we proceeded also here with the humid chamber and in case it didn't succeed with the pure culture in Petri dish from decayed wood. The identification of *Armillaria* species was not done in this work.
To define statistical differences in the occurrence of decay fungi on stumps in comparisons among roads and between roads edge and inner forests and, along the same road, between elevation ranges and slope sides the X^2 analysis was used.

Results and discussion

Fruiting bodies of the fungi were rarely produced on infected hosts and *Armillaria* rhizomorphs were also not very common. Soil type, physiological state of the host, precipitation and temperatures are probably the major determinants of rhizomorph production. Reddish-brown sub-cortical cords are commonly observed underneath the bark of stems at ground level, in trees only in advanced decay, and usually several years after being killed by the fungus. The cords were usually not extended into the soil.
The monitoring data recorded in the last decade on the entire Province, show that root failures and stem breakages in Trentino caused by wind and snow appear rather high in comparison with other biotic and abiotic causes of damages (Fig. 1).

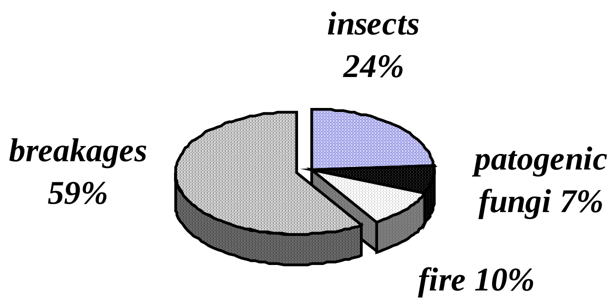

Fig. 1. Causes of damaged wood in Trentino 1990-99

The monitoring data reported (Fig. 2) show that unfavourable weather events causing stem breakage occur randomly along the years both in terms of quantitative impact and spatial distribution. Among the ten forest districts of the Province of Trento, the district no. 1 (Cavalese-Primiero) is the most vulnerable regards stem breakage. This is one of the reasons why two of the three roads selected for this study are located in this district. Some of the causes of this susceptibility may be related to the Norway spruce monoculture plantation that were established by the Austrians last century (Mazzucchi, 1998) and with the old age of the trees which favours heavy attacks by *Heterobasidion annosum* and *Armillaria* spp.

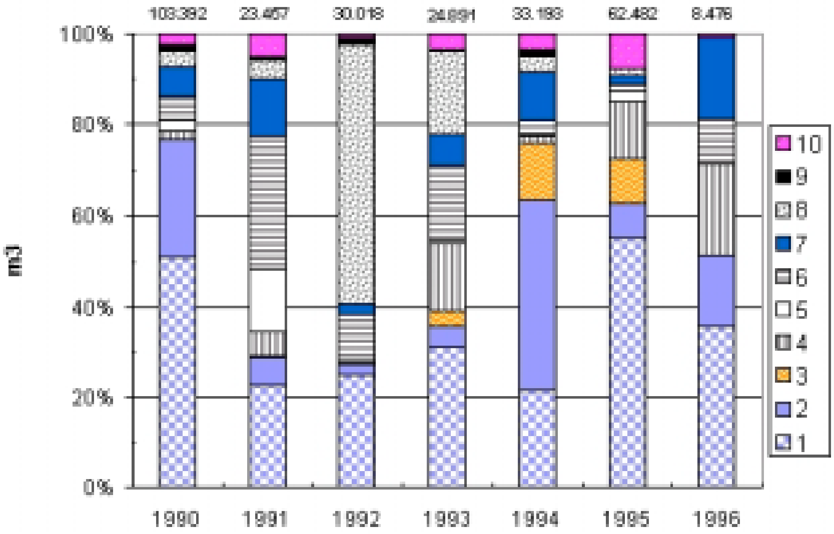

Fig. 2: Stem breakage in 10 forest districts in Trentino 1990-1996

The high amount of stem breakages recorded in 1990, shoved in both Fig. 2, were caused by the an exceptional event: the hurricane Vivian which provoked catastrophic breakages also in Switzerland, Austria and Germany (Kuhn, 1995).
Data from the stumps survey shows a higher proportion of stumps with decay associated with fungi along the roads SS50 (35,5%) and SP620 (37,6) than in the respective inner forest (17,2 and 33%) nearby these roads. The road SP16 with 69,9% shows a very higher incidence of decay fungi compared with the SS 50 and SP620 (Fig. 3).

Fig. 3: Example of cavities caused by *Heterobasidion annosum* butt rot along the road SP16.

However, the two forest hedges of SS50 and SP620 do not appear to be statistically different between them in terms of decayed and healthy stumps. The X^2 analyses shows highly significative differences, with p>0,01, among the four sites, inner and hedge forests of both SS50 and SP620 (Tab. 2). When comparing only inner and hedge forest for each road separately these differences are still significative with p>0,05 (Tab. 2) The comparison of three different ranges of elevation in both roads shows that the decay is decreasing going from lower to higher elevation with a X^2 highly significative (Tab. 2). Taken into account the road

sides the decayed stumps were higher in the downward side, but significantly different only for the road SS50 and not for the road SP620 (Tab. 2).
A partial explanation of the higher incidence of decay in the downward side of SS50 may be in relation of a heavy use of de-icing salt in this road during the winter and with the common preference in blow the gravel and the salt present on the road surface by the tractors on the adjacent downward side instead than the upward side. The effect of salt on the depression of mycorrhizal species and other microbiological traits of the soil (Majdi & Persson, 1989) and the deleterious direct effects on fine roots of trees like necrosis, Cl poisoning, Mg uptake, drought susceptibility, reduced resistance to decay fungi are quite well known in literature (Dobson, 1991). In addition, Norway spruce is a species particularly susceptible to salt damages (Kreutzer, 1977). Also stones and small material that can accumulate along the road over time are commonly removed on the downward side during the management operations of the road. This can also cause small wounds at the base of the standing trees acting as predisposing factor for the decay.
When the main pathogens *H. annosum* and *Armillaria* are considered, the road SP16 shows very evident differences between frequency of stumps with H. annosum (55,5 %) and Armillaria (10,4 %). The other two roads do not show a clear figure of dominance of any of the two fungi. Only slightly differences are in favour of *H. annosum* in SP620 and in favour of Armillaria in SS50. The same is the case for the inner forests of both roads. The differences that may be present should be made clearer from the analysis of a bigger number of stumps. The presence of both fungi in the same stump was quite limited ranging between 0,3% in the inner forest of SS50 and 2,6% in the road hedges of SP620. All other decay fungi are restricted in the range of 1,2% and 5,8% of the total cut stumps respectively SS50 inner forest and road hedges. This data confirm also for Trentino that *H. annosum* and *Armillaria* represent the main causal agents of the decay on Norway spruce and all other decay fungi together are in general of minor importance in the root and butt rots, ranging from 6,6 % and 16,4 % of the total decayed stumps. However they cannot be neglected because some of them can also play a central role in wood degradation and tree stability in particular environmental conditions (Schwarze *et al.*, 1997).
The results of the study suggest that the forest hedges along roads in mountain environment are subjected to higher susceptibility to root and butt rots than the inner forest and may reflect higher stability problem. The monitoring of the evolution of decays along these fragile ecosystems may contribute to contain the hazards for a better safety management practice. Results of this work may also contribuit to an experimental procedure for the economical estimation of the indirect damages to the forest edges by the construction and management of roads or power lines.
In the continuation of the work is planned to investigate the intersterility groups of *Heterobasidion annosum* and the different species of *Armillaria* that are present in these forests along roads and in the inner forests. In order to assess the number and extension of the fungal genotypes, a further study made by somatic incompatibility might gather a more complete view of the phenomenon.

References

Ambrosi P. & Salvadori C., 1998: Phytopathological monitoring of forests as mean for the silvicultural management: eight years of exploitation in Trentino. (Italian) Monti e Boschi 5, 9-12.
Anselmi N., 1998: Wood decay and stability in ornamental trees. Informatore Fitopatologico 48, 51-59.
Battistel G.A., Pollini C., Salvadori C., Deluca E. & Ambrosi P., 1998: Hazard tree analysis along the public road network in mountain areas. (Italian) Sherwood 36, 21-28.
Bethge K., Mattheck C. & Hunger E., 1996: Equipment for detection and evaluation of incipient decay in trees. Arboricultural Journal. 20, 13-37.
Branchi, F., 1991: 'Marginal' agricultural lands: understand them in order to utilise them. (I). Definition and distribution of marginal land. [Italian] Cellulosa e Carta. 42, 2-10.
Cheminade D. & Alletto F., 1982: Security - education - responsibility - route-making - rescue; Mountain accidents and law. International seminar on access to nature in mountain regions. Mont-Dauphin, France, 7-11 June 1982. Council of Europe, Strasbourg, France: 1982. 55-65.

Delatour C., 1993: A method for axenic sampling of wood from standing trees. European Journal of Forest Pathology. 23, 314-316.
Dobson M.C., 1991: De-iceing salt damage to trees and shrubs. For. Comm. Bull., UK, No. 101, 64 pp.
Gatterbauer H., 1998: Traffic tutelage and trees: the Austrian right approach. Sherwood 36, 35-40
Gebhard H., 1995: The visitor-safety obligation and the forest. Agrarrecht. 1995. 25: 12, 389-398
Holdenrieder O., 1989: *Heterobasidion annosum* and *Armillaria mellea* s.l.: current research on two old problems in forest pathology. [German] Schweizerische Zeitschrift fur Forstwesen 140, 1055-1067.
Hötzel H.J., 1998: Traffic tutelage and trees: the German right approach. (Italian) Sherwood 36, 41-43.
Klein E., 1995: Are storms the most important cause of heart rot in spruce. [German] AFZ, Allgemeine Forst Zeitschrift. 50, 819-821.
Kreutzer K., 1977: Injuries to forests by road de-icing salts. (German) Forstwissen-schaftliches Central-blatt. 1977. 96, 76-83.
Kuhn N., 1995: The site dependence of the windthrows caused by Vivian. [German] Information-sblatt des Forschungsbereiches Landschaftsokologie. 28, 1-3.
Leh H.O., 1993: Diagnosis of damage to street trees by abiotic stress factors. [German] Nachrichten-blatt des Deutschen Pflanzenschutzdienstes 45, 201-207.
Majdi H. & Persson H., 1989: Effects of road-traffic pollutants (lead and cadmium) on tree fine-roots along a motor road. Plant & Soil 119, 1-5.
Mattheck C. & Breloer H., 1994: Field guide for visual tree assessment (VTA). Arboricultural J. 18, 1-23.
Mazzucchi M., 1998: Why trees are felling? Technical and silvicultural aspects of this phenomenon. (Italian) Sherwood 36, 5-10.
Pampanini R., 1990: The EC law 269/79 and EC activity in forestry matters. [Italian] Annali della Facolta di Agraria Universita Degli Studi di Perugia. 42, 177-202.
Rinn F., 1990: Observations on the predictive value of methods for examining trees as regards the duty to ensure traffic safety. [German] Gartenamt. 39, 379-387.
Rinn F., Schweingruber F.H. & Schar E., 1996: Resistograph and X-ray density charts of wood comparative evaluation of drill resistance profiles and X-ray density charts of different wood species. Holzforschung 50, 303-311.
Robek R. & Matthies D. 1996: Soil and tree disturbances due to forest operations - an unresolved, interdisciplinary issue. Phyton (Horn). 1996, 181-186.
Schwarze F.W., Lonsdale D. & Fink S. 1997: An overview of wood degradation patterns and their implications for tree hazard assessment. Arboricultural Journal. 21, 1-32.
Stalpers J.A., 1978: - Identification of wood-inhabiting Anphyllophorales in pure culture. Studies in Mycology No. 16. Centraalbureau voor Schimmelcultures, Baarn. 248 p.
Vollbrecht G. & Agestam E., 1995: Identifying butt rotted Norway spruce trees from external signs. Forest & Landscape Research. 1, 241-254..
Wasterlund I., 1983: Growth reduction of trees near strip roads resulting from soil compaction and damaged roots - a literature survey. [Swedish] Sveriges Skogsvardsforbunds Tidskrift 81, 97-109.
Whitney R.D., 1988: The hidden enemy: root rot technology transfer. Great Lakes Forestry Centre, Canadian Forestry Service,Sault Ste. Marie, Ontario, Canada: 35 pp.

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Tab. 1 – Site characteristics of the three investigated roads included on the survey.

Road no. and locality	Geographic coordinates	Elevation Range (m)	Lenght (m)	Rainfall (mm/year)	Bedrock	Former soil use	Regeneration and Management	Stand age (years)	Tree species
SS 50 Passo Rolle	46º18'05" N 11º45'70" E	1.550-1.850	3.300	1350	Porphyry Marl	Forest	Natural regeneration Recreation and Protection	Even aged	*Picea abies* (96) *Pinus cembra* (2) *Larix decidua* (2)
SP 620 Passo Lavazè	46º20'10" N 11º28'60" E	1.300-1.800	5.300	1050	Rhyolite	Forest	Artificial plantation Protection	Uneven Aged	*Picea abies* (90) *Pinus cembra* (9) *Larix decidua* (<1)
SP 16 Alberè - Tenna	46º01'55" N 11º15'10" E	570-610	1.150	930	Dolomite	Agriculture	Artificial plantation Recreational Park	70	*Picea abies* (95) *Larix decidua* (5)

Tab. 2 Statistical X^2 tests calculated on the whole data set.

Comparison	G.L.	X^2	P	Significativity
Among the total 4 sites*	3	9,356	> 0,05	*
SS-50 vs. SP-620	1	1,090	> 0,1	n.s.
SS-50 Hedge *vs*. Inner forest	1	3,998	> 0,05	*
SP-620 Hedge *vs*. Inner forest	1	4,267	> 0,05	*
SS-50 Elevations	2	8,767	> 0,05	*
SP-620 Elevations	2	12,075	> 0,005	***
SS-50 Slope	1	4,439	> 0,05	*
SS-620 Slope	1	1,890	> 0,1	n.s.