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Institute for Plant Protection in Horticulture, Braunschweig

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Preface

Today a large section of the world's human population already lives in urban and periurban areas. The way of living has increasingly changed from a nature-related one to an urbanistic one. During the recent century the number of human beings who contribute to the feeding of the human population by basic horticultural and agricultural food production has dramatically decreased in relation to the number of people fed. Agricultural production and cultivation no longer determines the life style of most inhabitants of industrialized countries, but the design and development of high technology products, industrial productions, business in the service sectors, in particular for urban subsocieties, and the development of electronic communication systems. The more this comes true the stronger is the need of urban dwellers for compensation. This is manifested by leisure activities and the desire for urban green areas, gardens and recreation parks. In Germany, the regular federal horticultural exhibitions bear eloquent witness to these needs.

Besides publicly laid out and tended green areas and tree plantations which at one hand are made for the use of everybody, on the other hand, however, are difficult to protect against misuse and destruction because of their anonymity, private gardens find lively interests especially for families. In addition, urban and periurban centres of professional horticultural productions and services have established, which offer their goods and services directly to the urban markets. All these components represent what we call urban horticulture. They significantly characterize and determine urban and suburban life.

The manyfold functions of urban horticulture have been described in detail in relevant publications. The central importance of the components of urban horticulture - e. g. parks, lawns, tree plantations, flower beds, avenue trees, suburban productions, private gardens, roof gardens - for climatization, air quality, architectural planning and forming of city compartments, ecological networks and biodiversity in urban areas and, last not least, the well-being of urban dwellers has been greatly recognized. There are, however, still many questions to be answered. People, for instance, plant trees in streets for more than 350 years, however, with unsatisfactory success. Too many stress factors still damage these trees in different ways. Although scientific efforts made significant progress in recent years, lots of problems can be observed in practice and integrated concepts for maintaining plant's health are badly missing. Many biological interactions and relationships need to be examined. Valid procedures and methods, which are suitable to keep these important living components of urban areas healthy and able to function, still have to be developed. Integrated concepts are necessary to guarantee a sustainable function of the manyfold elements of urban horticulture. How can we combine components of integrated plant protection, plant care, purposeful architectural planning and implementation to lasting solutions? Efforts to answer such questions are part of these proceedings. The International Symposium on Plant Health in Urban Horticulture is meant to be a platform to discuss integrated methods and concepts of plant protection and plant care, to answer open questions and to create new scientific questions in order to approach the aim of a sustainable development in urban green areas.

Braunschweig, May 2000

Georg F. Backhaus

Hartmut Balder

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1. Introduction

Whoever is dealing with urban green and its future role has to realize the presumable circumstances of future social development, within the frame of which it will be placed. In the last century many European cities have continuously enlarged their urban green in terms of quantity and quality. They therefore now possess a considerable number of green areas representing a large social financial value. In the city of Berlin for example 2.592 public green and recreation areas exist. To 4 square meters of built-up or sealed surfaces corresponds about 1 square meter of green space. The total area amounts to 5.053 hectares - not included 692 hectares of graveyard areas, 23 hectares of “framing green“ in 79 permanent allotment garden areas, 907 hectares of green space on street land as well as 400.600 street trees.

To maintain, care for and develop the public urban green is the genuine task of the municipal horticultural departments. To cope with this task means more and more to manage the “permanent economical deficiency“. In accordance with the motto that “green always grows“ it is frequently being tried - within the frame of landscape building measures - to reduce the cost, with the consequence of having them - years later in the field of maintenance and care - increase enormously.

These facts described here - rather simplified -are closely connected to the change of our cities. Therefore the future development of urban green has to be re-organized. At the same time the scientific progress must be used for a determination of the special problems at each single location in order to obtain long-lasting green spaces satisfying modern requirements, with little need for care.

2. Changing cities

Looking at the transformation and modernization processes of economy and society at the transition of the 20th to the 21st century it is obvious that in contrast to earlier processes the actual development in the city has to be organized according to criteria of quality. Spatially the process could happen mainly as inner development between periphery and center, in the urban area already developed in terms of infrastructure. The fact that this is not yet sufficiently the case but that more areas are being rendered impervious has to be the starting-point for urban and open space policy. The cities have to be regained for urban society and this concerns especially urban public space.

For urban green in European cities having experienced this change in parallel, the situation is the following:

- In the time after World War 2 the reconstruction of the destroyed cities had top priority. In the first post-war years public green therefore received little attention.
- Up till the 70s urban planning preferred the "dispersed“ and individual traffic oriented city. The historical structures of the cities were often disregarded. New roads with sometimes oversized cross-sections of 50 to 100 meters cut neighborhoods in two and dissolved the evolved centers of the cities.
- In many places clearly defined public and private spatial structures got lost in favor of fluid spaces without defined boundaries.
- Only later urban open space planning developed extensive nets of green belts interpreting also broad green median strips on reserved routes marked-out for traffic as necessary biotope connections.
- The guiding line of modern age in the following brought a considerable increase in green areas, which today from an ecological point of view are judged to be particularly precious.

- Green throughout the cities and the permanent increase in green areas were regarded as signs of quality; aesthetics, gardening quality and the functional demands in the city remained largely unconsidered.
- Especially in the 70s and 80s, as a counter reaction to intensive industrialization and motorization, a social political consciousness for the protection of environment and nature arose. A sensitization for the cautious handling of urban green, precious biotopes and the natural resources soil, water and air occurred.
- As current development in many places the urban developmental effects of the transformation process from the industrial society to a service and information society is becoming apparent. This radical change in which a great part of former industrial and infrastructural locations become unnecessary, offers the opportunity for an inner structural change. Old industrial sites - sources of air and soil pollution - can become locations of the modernization of economy and society.

The task modern urban developmental policy is confronted with today therefore does not consist so much in the broad expansion of the city (construction of residential estates, factories), but the socially urban- economically and ecologically reasonable re-use of already developed urban areas. Many European cities therefore face a radical change in perspective. The future lies in inner renewal and modernization, in the reorganization of the existing, in the fitting-in of new uses in existing structures. Already for reasons of the availability of areas (in the stock of the centers), quality instead of quantity will determine the strategy for the future.

3. Requirements for a future open space policy

A future open space policy has to be oriented to the current situation. Especially important factors are here:

- The limited public funds:

  The economical situation of many local authorities and cities is very tensed so that the provision of green and recreation areas including care and maintenance as part of the so-called voluntary municipal amenities at the moment can be financed only selectively.

- The extensive, but qualitatively little satisfying stock of green areas:

  The continuous request for more green did not lead to that cities became greener. The constant demand for ecological compensatory areas instead frequently resulted in an urban open space system emerging from a random principle. The numerous green spaces originating from this can be landscaped only scarcely with the consequence of an even more rapid neglect.

- The current definition of the function of green spaces:

  By many users of public green areas urban green is not regarded any more as something exceptional and precious, but as natural common property and correspondingly they treat it without care. At the same time green areas have to adapt to people's quickly changing leisure time requests. At the moment the fringe groups of society increasingly retreat to public open spaces. Social control frequently does not occur in these places. Conversely the further differentiation of individual living styles leads to a process which could be described as “cocooning“, because other parts of the urban population retreat more and more to private spheres.

- The ecologicalization of public green as - up to now - a matter of prime importance:

  The requested type of open space “biotope“ from character and pretension is anti-urban and only with great difficulties can be integrated into urban green areas without giving immediately the impression of “non-care“ to the uninformed observer and user.

  From this characterization of the initial situation of urban open space policy four main stressing points for the work in the near future derive:

- Quantity:

  The issues of urban development in the 21st century do not lie in the proceeding consumption of space, but in the change of use and structure of already used areas. In many places this does give the possibility of integrating additional parks in the cities, at the moment though it seems more reasonable to carry out a first stock-taking of the existing green areas and having a rather differentiated look at the demands for "more and more“.

- Quality:
  An increase in the quality of green areas is necessary and a definition of clear spatial structures. Within the context of an urban development incorporated in the tradition of the European city the basic elements of inner-urban open space systems (block, parcel, house - municipal park, street, courtyard) according to the urban structure have to be formed and rendered discernible in their different character. Also the often exaggerated arrangements of the last years have to be replaced by structurally rather minimalistic models, which in the tradition of the simple gardening solution accept the place and herewith gives it the power of identity.

- Responsibility:
  A clear assignment to either private or public spaces has to be effected. The areas described as half-public spaces are often originating from the open city structures and there comprise the function of distance holder and framing green, leading to a situation where it is not apparent any more, to whom these areas belong. Furthermore a clear assignment would make the municipal responsibility for public areas in the urban space more obvious and in the end also discharge public households of areas, which are used an actually should be maintained privately.

- Management:
  The open space system of public green areas has to be ordered hierarchically according to the value for the public, meaning that green areas with representative functions have to be discriminated from other areas. Apart from this new approaches for a green space management have to be considered. One possible way would be to give a share of the maintenance cost for green areas to investors, organizations or the citizens themselves.

4. Summary

The provision of cities with green spaces has always been submitted to permanent change. Demands concerning the use and problems resulting from location must lead more intensely to an open space planning with the quality of public green spaces as a central concern. A sustainable improvement of structure synchronously has to be measured by its economical dimensions.

The continuous growing-together of Europe facilitates a direct comparison between the different approaches of the cities to this subject.

Considering the different traditions in the handling of urban green we can learn a lot from each other - with the objective to adapt open space planning even more effectively to the requirements of sustainable urban development doing justice to developmental history of the European city oriented to urban qualities, and giving it the ability to manage future.

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Contributions of phytomedicine to a sustainable development in urban horticulture

1. Introduction

Man has a close relationship to nature, which, although he has not totally lost it, he looks at from a rather emotional view. Especially the city dweller does not anymore have a particularly close relationship to nature, unlike the farmer or gardener, who are dependent on natural and environmental conditions. Therefore he has a perspective of nature that is more or less diametrically opposed to the one of the producer of agricultural and horticultural goods. Thus urban people picture nature and its vegetation as unpolluted as possible, a scenario where plant or animal production are regarded as nuisance if not even denouncement, as under those influences cannot develop in that way as the urban resident thinks it should be. However, growth of plants including those in towns and cities are exposed to urban influences, which are the result of the coexistence of humans and their way of behaviour and acting. These influences and their effects are by now recognised and one seeks to avoid their disadvantages or, in case of their existence, improve their condition. In any case one has to remember that a tree in a woodland is affected by very different conditions than one in a city. (Fig.1)

Forest		Street
ecosystem	plants	single tree/ avenue
complete	cycle of nutrients	interrupted
natural structure	soil	artifical substrate
natural cycle	water condition	reduced infiltration
undisturbed	gas replacement	disturbed
balanced	climate	higher temperature
		lower humidity

(BALDER u.a., 1997)

Fig. 1: Comparison of Forest Grown and Urban Grown Plants

2. The function of green in cities

There is evidence that the temperature in major settlements often is by 0.5-2.0 °C higher than in the surrounding countryside. Plants have the characteristic that they burn more than 60 % of the energy, in form of light from the sun, through evaporation and metabolism. According to Bernatzky (1988) due to a 70 m wide rampart surrounding the inner city of Frankfurt, the temperature is reduced by approximately 3.5 °C. This reduction in temperature, however, is also a result of the effect of shading by plants, especially trees. The reason for this is the reduced conductivity and capacity to hold temperature of the vegetated spaces as opposed to built up areas, which on the other hand act as energy saver and thus result in a flow back into the atmosphere in periods of colder weather. Because of these differences in temperature there are continuous air currents, which constantly change the composition of the air.

An important role play trees and bushes for the filtering of the air. Wooded areas do not supply any dust at all apart from pollen. Instead the blown in dust is fixed. In a park with a combination of grassland and wooded areas, 85% of the dirt can be filtered out; road trees can filter 60 %. These are obviously only very general data, as the filter effect is dependent on the leaf biomass, which in turn is dependent on the species. Besides the filtering effect the vegetation, especially woodlands, is an important oxygen supplier, with is essential for man, animals and plants. To meet the needs of oxygen of one person, 150 m^2 of leaf area are needed. It is assumed that a mature birch plantation of an area of 1 ha provides 9.5 t of oxygen per year, a woodland of the same size of beech would provide 15.6 t/year. If this is then translated to the needs of urban population, 30-40 m^2 of plantations is needed inside cities (Bernatzky 1988).

In relation to this, the carbon dioxide has to be taken into account, too. The process of photosynthesis and the generation of energy, the plant constantly takes up carbon dioxide. Thereby dangerous concentration levels are avoided, which otherwise would be the result of fuel and petrol burning. As can be seen green spaces create a balance for effective oxygen-carbon dioxide levels, which equally benefits man, animals and plants.

Apart from these positives aspects of the general welfare of the city dwellers the value of vegetation in cities has to be seen in the reduction of noise pollution. Although often over estimated, a reduction in noise by 10-12 dB can be obtained, depending on the plant species and the density. In general frequencies between 1000-11200 Hz, with a maximum at 8000 Hz are reflected best. Figure 2 shows different plant species resulting in different levels of noise reduction.

	Reduction of noises by tree species (dB)
4-6	*Tilia cordata*, *Betula pendula*, *Alnus incana*
6-8	*Fagus sylvatica*, *Quercus robur*, *Carpinus betulus*
8-10	*Tilia platyphyllos*, *Populus berolinensis*
10-12	*Acer pseudoplatanus*

Fig. 2: Value of trees for diminishing of noises

The aesthetic value of plantations has already been mentioned. Rows of trees and small woodlands are an important architectonic element to structure over-dimensional urban spaces and to harmonise uniform or differing building styles. In this way parks are deliberately used to enhance and contribute to the townscape and rows of trees serve a better and clearer traffic guiding. Hereby through knowledge of growth pattern, height, and habitat requirements of the used plant species is essential. Especially roadside habitats pose unfavourable conditions. The parameters of habitat characteristics are shown in Figure 3.

parameter		**effects**
growth conditions	(substrate, water, nutrients et al.)	vital - delicate condition
ecology	(pathogens, beneficial organisms et al.)	wide - narrow condition
micro climate	(temperature, humidity, radiation, wind)	heat/dry - cool/humid
strain	(emission, wind et al.)	low - high
horticultural interventions	(removal of leaves and twigs, tree care, weed control et al.)	slight - extensive

(BALDER, unpublished)

Fig. 3: Stand Situation of Street Trees

3. Stress factors on the vegetation in inner city areas

If these parameters are not taken in to account, the plants do not show optimal growth and die. Usually, however, these parameters take effect by themselves, which is reflected in the tree pattern of certain cities (Fig. 4). As the stress factors are similar in many cities, the use of tree species is related. However, the habitats of different locations can be rather different, e.g. the planting of Ash in the town of Augsburg, a species which is characteristic for the woodlands along the river Lech in that region.

	Berlin (West)	**Berlin** (total, 1998)	**Hannover**	**Kassel**	**Frankfurt**	**Augsburg**
number	143 135	400 965	26 820	9 887	31 628	16 012
	%	%	%	%	%	%
Tilia	41,7	36,4	30,5	24,6	13,5	31,0
Acer	16,1	18,5	16,1	21,5	11,6	27,0
Platanus	5,2	6,1	7,6	11,3	20,5	2,0
Robinia	3,9	-	3,3	6,0	14,5	2,0
Quercus	7,5	8,4	14,5	7,4	3,1	0,5
Aesculus	7,1	5,3	4,9	7,8	11,3	7,0
Fraxinus	1,8	-	1,1	3,4	1,1	14,0
Betula	3,6	-	3,1	1,1	3,1	4,5
Populus	1,8	-	2,1	2,6	7,9	4,5
Sorbus	3,5	-	5,0	6,7	2,8	2,0
Carpinus	-	-	1,7	0,9	0,5	0,5
Ulmus	1,3	-	3,7	1,0	0,8	1,0
miscellaneous	6,5	-	6,4	5,7	9,3	4,0

(KUNICK, 1988, changed)

Fig. 4: Existence of street trees in towns in Germany (1988)

If these attitudes of urban dwellers particularly refer to areas outside the town, the inner town greens of course have to be seen in a different light, because this serves aesthetic values, is used for recreation and improves the living space. For long it has been known that people cannot live in conglomerations of houses without any green spaces. It is true that medieval towns, especially those cities, which were centres of commerce in central Europe, did not have parks within the city walls, however, usually those towns were comparatively small and the urban population had their allotments outside the walls. Nowadays urban green is impeded in its growth and development due to the high building density and roads and the sealing of soil. As much as one appreciates the green spaces along streets and although it still is applied, it is nonetheless used rather scarcely: they are restricted by kerbstones, canals, underground cables, sealing of the soil etc (Fig. 5)..

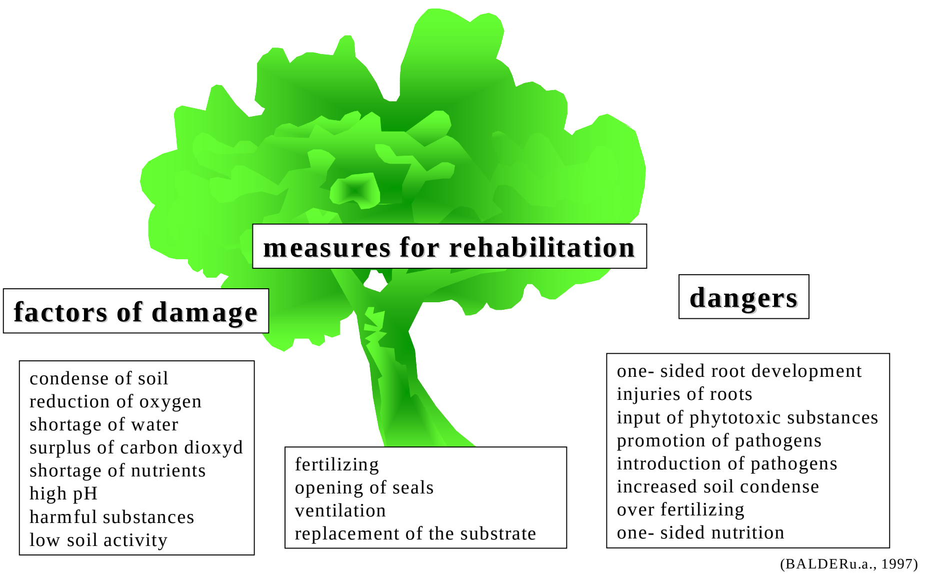


FIG. 5: Damages and Dangers of Urban Trees

Further limits are car parks (limited or unlimited in time) and particularly cobble stones and paving. All these limitations, in addition to which you also find various pollutants, as well as the dry climate (due to the high housing density), lead to predispositions that do not favour natural growth and development of trees, shrubs, herbaceous and annual plants. Especially in warm seasons the temperature can be extremely high in cities.

Many of our trees naturally grow in woodlands. Therefore it is necessary to create similar conditions to their original habitats in the built up environment. If those criteria are not taken into consideration, predispositions are created, which will expose the plants to the increased influence of abiotic and biotical disadvantaging factors (Fig. 6).

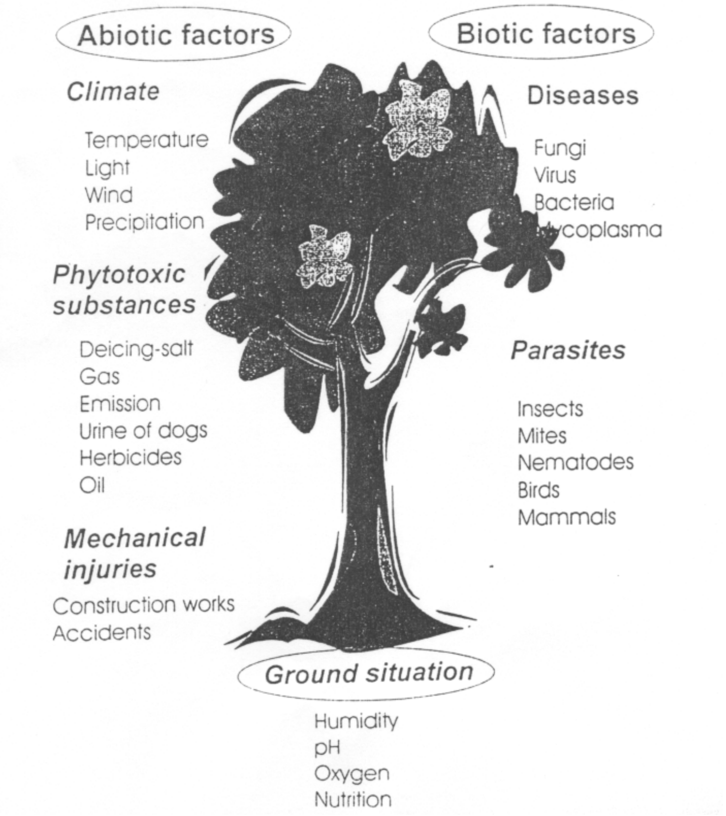


Fig. 6: Damage of urban trees

Some of these abiotic factors are climate, pollutants such as grit, gas, dog fouling, air pollutants etc. but also mechanical damage caused by traffic or building activities. The high influence of soil characteristics have already been mentioned. With this regard it is important to mention soil compaction with negative attributes such as oxygen deficiency, change in pH and a change in water and nutrient availability.

The biotic influences are equally diverse and arise under the respective predispositions. These are pests of different kinds of organism that are rather related to the plant kingdom, with the exception of viruses. The measures that we take, to avoid the above-mentioned adverse factors damage, can in turn cause harm if applied improperly, and this damage might hardly be related to the original cause of the harm.

A particular problem hereby are the injuries to trees, either intentionally through pruning or coppicing or unintentionally through construction work or traffic, which can have far reaching impacts on the development of the trees (Fig. 7), which can result in the dying of roots, development of rottenness in the tree trunk and in the end the removal of the tree. There are also situations in which a tree had considerable shoot growth however suddenly stops growing and shows symptoms of infection. In those cases the phytopathologists are asked to find the reasons for the symptoms. Trees in an urban environment, however, are subject to many influences that can result in a complex course of disease which makes an exact diagnosis very difficult. Yet only an exact diagnosis can lead to an effective disease control.

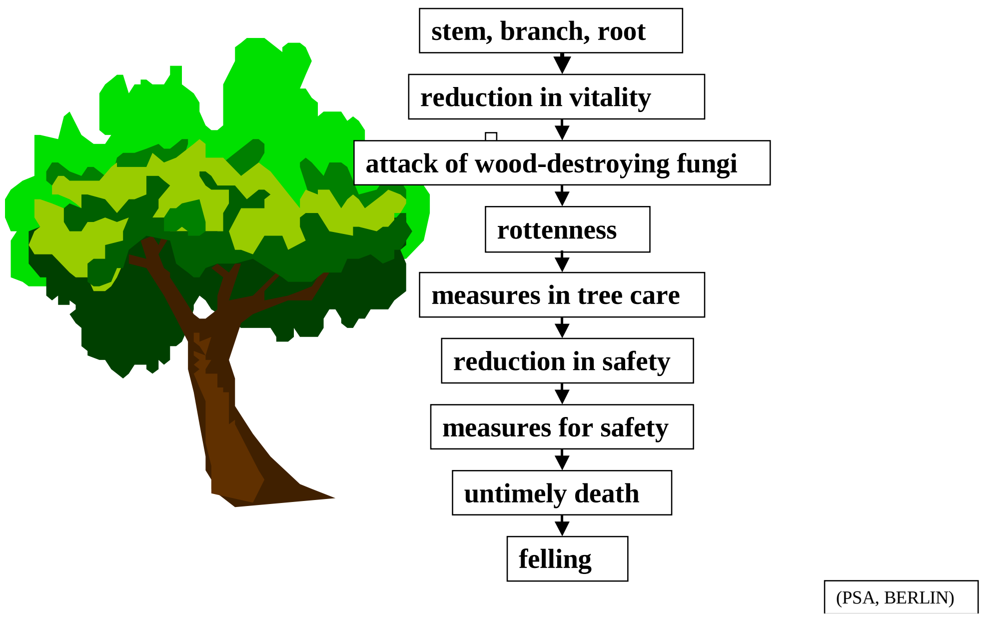


Fig. 7: Series of Effects after Injuries of Trees

4. Requirements for the urban green in the future

Even with regard to urban greens integrated plant protection should be applied. Figure 8 introduces possibilities of such measurements. These include obviously considering the special habitat requirements in an urban environment and the stress to be expected. Therefore mainly plants that can take best the stress of traffic, dogs, climate and similar factors should be planted. It is not very useful to place a nearly mature tree in a big hole, if then the tree needs several years to continue growing normally. A younger tree with an intact root system will soon overtake such an old tree. The younger tree will in any case develop healthier than a several years old tree, which will due to its sub optimal growth suffer from a number of diseases and pests, which in their complexity are difficult to diagnose.

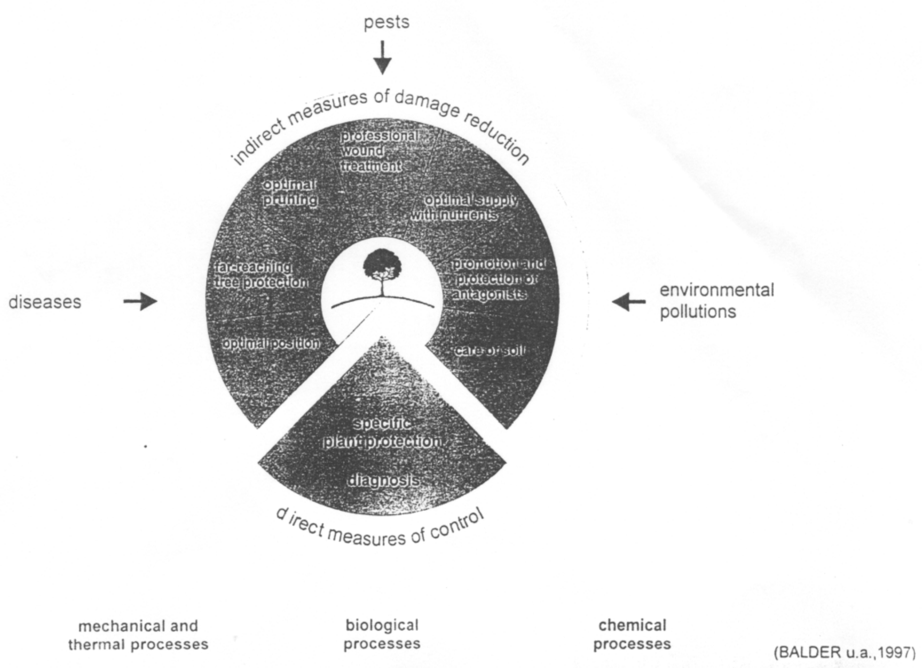
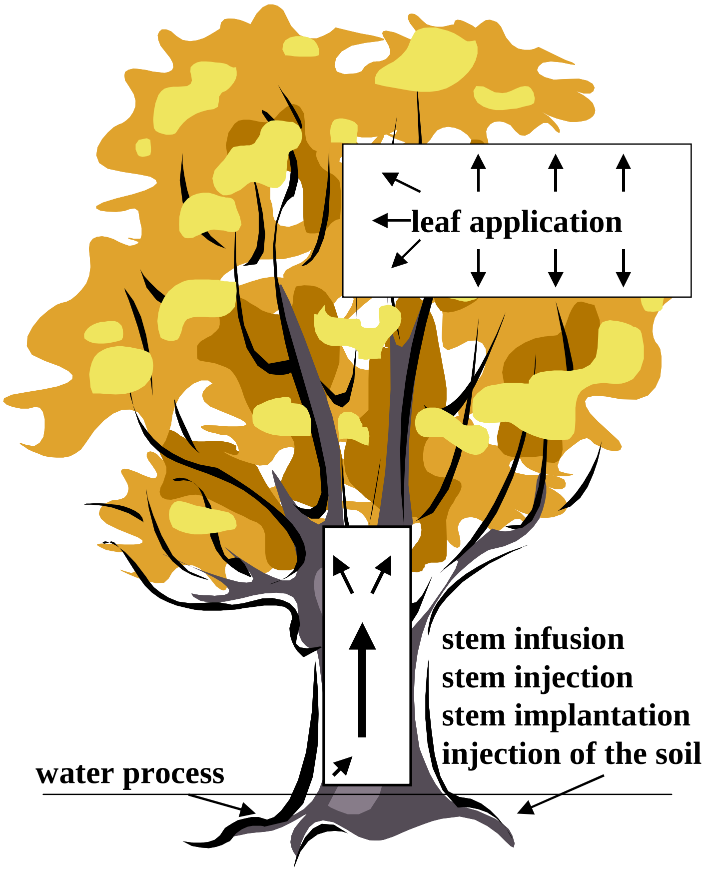


Fig. 8: Integrated Pest Control in Tree Care

Hence a closer co-operation between communal institutions should be aimed for: road construction engineers should not decide on the fate of trees alone. In this case decision makers have to gather information about species selection, planting, maintenance, generally about the possibilities of optimising growth and development of parks and greens, and not only about the interest of civil engineers and construction workers. As theoretically everything is governed and ruled centrally in a district or county, all this should be possible- unfortunately reality tells a different story. It should be in particular being aimed for the elimination of growth restriction factors. Often the problem is the acute existence of an infection of a several year old tree. In this case direct control measurements are necessary, which can be carried out comparatively easily if they are of mechanic, thermic or biologic nature. The application of a chemical pesticide, however, often meets considerable opposition, at least if it is sprayed. Injections of pesticides into the soil can be used with young trees, as well as infusions into the tree trunk (Fig. 9), these again result in an injury of the bark.



(Offical Bureau of Plant Protection Berlin)

Fig. 9: Application Technology of Pathogens on Trees

Those have not shown any considerable success though e.g. against *Cameraria ohriella*. Either one has to live with it or apply insecticides at times when the town is quiet.

Concluding one has to draw the consequences for the stress factors of the urban plantations; initially to prevent abiotic damages by reducing the influence of pollutants as well as the elimination of pollutants (Fig. 10), then removal or reduction of biotic causes of damage by using vigorous and resistant plants and/or the use of symbionts and possible useful biological enemies or antagonists (Fig. 11). Only when the consequences from all the errors and mistakes done in the past with regard to planting and their maintenance are drawn, the point will be reached, where one can speak of a healthy and suitably adopted planning and planting strategy in the urban environment.

prevention of entry

- reduction/ prevention of output (for example ban of deicing
- safety in operation (for example gas pipes)
- protection of the roots (for example deicing salt, urine of dogs)

elemination

- replacement of soil (deicing-salt, heavy metals, gas etc.)
- specific ventilation (gas)
- fertilizing, correction of pH to fix harmful substances

Fig. 10: Reduction of the Pressure on the Environment caused by harmful Substances (Balder, 1998)

Increase of Stress Tolerance of Tree Plantings

- breeding of resistance
- cultivation of vital plants
- equipment with essential
  - symbiotic organisms
  - beneficial organisms

Fig. 11: Increase of Stress Tolerance of Tree Plantings

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Review of research and knowledge on urban forests and urban trees in Europe

1. Introduction

Urban forests and trees are primarily characterised by their specific growing conditions. They are situated in often harsh, high-pressure environments. It mostly takes considerable structured efforts to establish, maintain and manage trees on urban sites for the benefit of the local population.

During recent decades, several approaches have been developed for enhancing urban forest and urban tree establishment, conservation and management. Perhaps most notably among these approaches has been the urban forestry approach, developed in North America, but strongly rooted in European traditions of urban green management. Urban forestry encompasses the planning, design, establishment and management of trees and forest stands with amenity values in or near urban areas (e.g. Meyer 1982; Shigo 1991; Watson and Neely 1993; Miller 1997; Harris et al. 1999). Recently, this multidisciplinary approach has found wider application also in Europe (e.g. Randrup and Nilsson 1998; Forrest et al. 1999).

The urban forestry approach may act as a framework for a better coordination of both research and practice related to urban forests and trees. Thus the large task of meeting the specific and high demands of urban environments can be met in a more effective and efficient way, if only by the exchange of experiences and the limitation of duplication of efforts.

Until only a few years ago, coordinated research and development initiatives directed towards urban tree resources were rather limited at the European level. Traditionally, studies on urban forests and urban trees seem to concern applied, small-scale research at the local level, and comparative studies at the international level have been rare (e.g. Claridge 1997; Watson and Himelick 1997; Randrup and Nilsson 1998; Konijnendijk 1999). Multiple-country research overviews have mostly been anecdotal or limited in scope, covering for example only parts of the urban forest resource (street trees, urban woodlands) or of structural human interference (planning, selection, establishment, or management) (e.g. Randrup and Nilsson 1998, Forrest et al. 1999).

Better coordination has sometimes been achieved at the national level. Examples of this are the overviews of arboricultural research compiled in the United Kingdom (e.g. Bradshaw et al. 1988) and the annual arboricultural reviews in Germany (e.g. Dujesiefken and Kockerbeck 2000). National coordination of urban forestry and/or arboriculture activities in countries such as the United Kingdom, Ireland and Germany is enhanced by regular national conferences and the occasional establishment of special institutions, such as the Arboricultural Advisory and Information Service in the United Kingdom and the 'Arbeitskreis Baumpflege' in Germany. These examples, however, should be seen as exceptions.

The limited overview and coordination of research on urban forests and urban trees in Europe, particularly at the international level, was a major incentive for establishing COST Action E12 'Urban Forests and Trees' in 1997 (Randrup and Nilsson 1998). COST stands for 'European Co-operation in the field of Science and Technology'. The COST-programme aims at the stimulation and coordination of research via the establishment of networks of researchers, which are called COST Actions. In this paper, recent efforts within COST Action E12 to provide a state of the art overview of research on urban forests and urban trees in Europe will be introduced. Main results are presented, illustrating the clear need for urban forestry collaboration at the European level.

2. Describing current urban forestry research in Europe

COST Action E12 'Urban Forests and Trees' will run from September 1997 until summer 2002. Currently, about 80 urban forestry researchers (called 'national experts') from 23 European countries are involved. The disciplinary background of the national experts is varied, with emphasis on forestry and horticulture,

[1] Vice-Chairman of COST Action E12 'Urban Forests and Trees'.
[2] Resp. Coordinator, Chairman and former Coordinator of COST Action E12 'Urban Forests and Trees'.

but also including landscape ecology, pathology, landscape architecture and planning sciences. This illustrates the multidisciplinary character of urban forestry. The overall goal of ‘Urban Forests and Trees’ is to improve the knowledge-base needed for the planning, design, establishment and management of urban forests and trees. The Action is organised in three working groups. These deal with the benefits, form and functions of urban forests and trees (WG 1), selection of urban trees and establishment of trees and forests (WG 2), and management (WG 3), respectively. Great care is taken to integrate the activities of the three working groups, and to ensure that their activities relate to the three commonest locations for urban trees that have been identified to date: woodlands, parks and open spaces, and streets (COST Action E12 1997).

A primary objective of the Action is to provide an overview of urban forestry research in Europe. Although this work is still ongoing, a first research overview for 20 European countries was published by the European Commission (Forrest et al. 1999; see also Konijnendijk et al. in press). The remainder of this paper, unless stated differently, derives its information from this report.

The national experts involved in the Action were asked to prepare a ‘state-of-the-art’ report on recent and ongoing research on urban forests and urban trees in their countries. For this purpose, a standard report format was developed. Experts were asked to provide a general introduction of urban forestry in their country, as well as a list of research capacities and of recent and ongoing research and development projects. The latter, including information on project contents, duration, partners, donors and publications, was used for comparing urban forestry research across Europe.

The method for gathering information was left to the national experts, but as a minimum, they were asked to provide a good indicative overview of research efforts in their country. In some cases, the experts embarked on national surveys, while in other cases a review of existing literature and research databases was the main method applied. ‘Research’ was broadly defined, but focus was on academic research. The reports were compiled and compared by a team of editors. The entire process took place between January 1998 and June 1999.

3. Urban forestry research in Europe: differences and similarities

The compilation process resulted in a total of 20 national ‘state-of-the-art’ reports, including all EU countries with the exception of Portugal and Luxembourg, as well as Iceland, Norway Croatia, Hungary, Slovenia, the Slovak Republic and Lithuania. In all, over 400 recent and ongoing research projects on urban forests and urban trees were listed.

Comparative analysis of the reports has shown that universities and colleges are the main research actors, being responsible for about half of all projects, followed by state research institutions and private institutions. The number of international projects, involving research countries from more than one country, seems limited. The main discipline of the research organisations involved in research on urban forests and urban trees are forestry and horticulture, followed by planning sciences, landscape ecology, landscape architecture, and a wide range of other disciplines. Only very few institutions (even at the level of departments or units) in Europe primarily focus on urban forestry or arboriculture.

The overview also indicates that the main sites for urban trees, i.e. streets, parks and open spaces, and woodlands, have been given about the same amount of research attention. In a large number of projects, focus was on at least two of these main sites.

Perhaps most interesting is a comparison of the research topics across Europe. When taking a look in greater detail, the largest group of projects related to the benefits, form and functions of urban forests and trees (the topic of COST E12 Working Group 1) deals with strategic urban forestry and green structure planning. Research includes policy analysis, as well as the development of new planning and design criteria for urban green areas. Moreover, efforts are undertaken to elaborate new planning technologies, for example GIS-based. Another main study topic across Europe is the recreational value and use of urban forests and trees. Within the context of growing policy attention for the values of urban trees to society, studies aim to identify public values and preferences related to the recreative use. The amenity values of urban forests and trees are increasingly stressed. Only very few studies have so far looked at psychological and health aspects of urban forests and trees, or the economic benefits of urban trees. Attention for the health values of urban trees – trees are for example believed to reduce stress – has recently increased, however. An example of this was the conference ‘Trees and Healthy Living’, organised by the English National Urban Forestry Unit in November 1999 (NUFU 1999).

Within the theme 'establishment and selection' (the topic of COST E12 Working Group 2), research also shows large similarities across Europe. A main area of research is the breeding and selection of tree species for urban environments. Europe's researchers try to select and test species and cultivars which are resistant to harsh urban growing conditions, caused by drought, saline conditions, soil and air contamination, soil compaction, diseases, and so forth. Another main topic is the establishment of urban trees and urban forests. Studies focus on improving conditions for tree establishment, for example by developing treatments of plant material, mulches, and by studying tree root development. This topic has a direct link with studies on media and soils, which have as their main research question how soil conditions for urban trees can be improved. Many European countries also show research activities on the damaging effects of pollutants on urban trees, which special attention for the detrimental effects of de-icing agents. A last main study topic is that of pests and diseases of urban trees and how to deal with them during the establishment phase.

This brings us to urban forest and tree management (the topic of COST E12 Working Group 3). The issue of how to deal with pests and diseases, such as Dutch Elm Disease, is also of main concern with regards to the management of urban trees once they are established. In addition, related to management are studies aimed at developing planning and management support systems. Within COST Action E12, an ongoing survey aims to identify the various systems used across Europe. The overall protection of trees is another main topic under the management theme. How can trees, for example, be better protected against trampling, vandalism, urban development or other types of damages? In countries such as Germany, France and Slovenia, considerable attention has been given to the development of methods for assessing tree health and safety to wound reactions and pruning methods. Liability is a major concern for urban green managers, so effective assessment methods can assist in reducing the risk of accidents. Studies in a number of countries have focused on the development of pruning, as well as of the related wound reactions and dressing. Recently, efforts have been undertaken to develop European standards or guidelines for pruning methods.

4. Conclusion

In spite of obvious differences between countries and regions, the main topics of research on urban forests and urban trees seem to be rather similar across Europe. This may be explained from the fact that the main problems facing urban forestry are often comparable, including pests and diseases, soil compaction, pollution, intensive use, cutbacks in management budgets, and a range of other - often typically urban - problems. Cities have in common that they mostly offer rather harsh and unnatural growing conditions for trees. The basic challenge for urban forestry is, therefore, to maintain (in an effective and efficient way) a sustainable urban forest resource that meets multiple societal demands, ranging from recreation to ameliorating the urban environment. While attempting this, urban green managers in Europe's cities have often used similar tree species. A number of species, such as *Tilia*, *Platanus*, *Ulmus*, seem to have been popular for urban use across Europe, for example due to their tolerance to urban pressures.

In spite of the major similarities when broad research topics are considered, not every European country shows the same level of activity in research on urban forests and urban trees. This may partly be explained from differences in the current policy attention for urban green resources. In general, countries with the highest urbanisation rates seem to also have given the highest attention to the planning and management of urban forests and trees. Differences can also be noted in the role of various research institutions. In some countries, universities and colleges play a larger role than in others, where, for example, state research organisations carried out a larger part of the relevant research.

The focus of research may also differ between countries, for example due to the dominance of specific problems. The issue of de-icing salt and its damage to urban trees is particularly pressing in the Nordic countries, as well as in other countries with harsh winters or mountainous areas. In western-European countries, the focus of research seems to be shifting towards more attention for the social and health values of urban forests and trees. This includes the establishment of new urban woodlands to expand urban outdoor recreation areas. In the Mediterranean countries, drought and wildfires in the urban fringe are among the main worries for urban forestry. Major political and economic changes in Eastern Europe have affected urban forestry research as well, thematically, but also in terms of changes in research capacities.

Differences in research may also be due to traditions. In Italy, for example, historical gardens traditionally are a very important element of urban green structures, and quite some studies specifically deal with these gardens. Also, the idea of what constitutes 'urban forestry' differs from country to country, probably due to the fact that it is a relatively new discipline. In many European countries, the term 'urban forestry' is often related to the planning and management of urban woodlands only. Gradually, however, a broader definition of what constitutes an urban forest has gained ground.

The focus of research may differ in terms of urban sites as well as study topics. Nordic countries express a rather strong research focus on woodlands, which is not strange given the important role forests play as main nearby recreation environments in countries such as Finland, Sweden and Norway. In Italy, it seems, most research attention is given to trees in streets and parks. In urbanised regions and countries with a low forest cover, such as Ireland, the United Kingdom, the Netherlands, Belgium, Denmark and parts of Germany, the creation of new urban woodlands has been a major policy issue and needs to be supported by appropriate research.

Overall, the overview has shown how important it is to gather comparative information and to enhance collaboration among countries, especially in the light of common challenges to urban forestry. At the time, many interesting findings with a wider applicability remain at the local or at best national level. Publication of results is mostly done in the national language, in national magazines or journals that have a limited international scope. There is reason to believe, therefore, that a vast amount of data on urban forests and trees and how to best take care of them already exists. It is the task of initiatives such as COST Action E12 to improve access to this fragmented database, and to enhance comparative study of the data.

Summary

This paper presents the main findings of a recent comparative study on the state of the art of research on urban forests and trees in Europe, carried out within the framework of COST Action E12 Urban Forests and Trees. In spite of differences between regions and countries, this overview has identified a number of common main issues directing research. Issues are mostly connected with the overall question how to grow trees in rather hostile and artificial urban environments. The international scope of these problems, and the current lack of coordination of research and development efforts, calls for a better collaboration between European researchers and practitioners. By applying an urban forestry approach, multidisciplinary research integrating attention for a range of urban sites for trees can be stimulated.

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Session 1 – Urban ecology and biodiversity

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The dendrofloristic richness of SE-Europe, a phenomenal treasure for urban plantings

Introduction

Trees are the most conspicuous vegetative elements in towns and cities. Their perceptive value and unique functions in the urban environment make tree preservation a prime goal for sustainable development and maintaining livable conditions in large urban agglomerations. However, urban trees are severely threatened by unfavourable growing conditions. While the improvement of site conditions for healthy tree life is a primary goal of urban forestry, these efforts need to be complemented by the selection of tree species which are well adapted to the urban environment. Trees have to be selected for the specific environmental conditions of the city, i.e. drought resistance, as well as aesthetic and even social dimensions relating to considerations such as crown architecture and amenity value. Those species which were most frequently planted in our cities - i.e. lime and maple, but also horse chestnut and plane - show particularly severe symptoms of stress and decline (Pauleit 1988, Umweltschutzreferat 1993). Cultivars of these species are now commonly specified for urban tree planting – selection often being based on desirable features of the tree crown alone. However, such a basis for selection cannot overcome the basic genetic limitations to enable trees to cope with urban environmental conditions and adverse site factors such as soil compaction and limited water supply.

Even the largest European nurseries have adapted to this market. Their stocks are largely identical and, thus, are not adapted anymore to regionally specific requirements. On the other hand, those nurseries like Hillier, Hesse, Späth and Minier, which played a major role in the introduction and distribution of new species, have either given up for various reasons or largely reduced their assortment. Thus, broadening the range of tree species for urban areas will be highly relevant for developing healthy urban forests. Selection of new tree species needs to be based on sound empirical knowledge both of site requirements in cities and towns as the target areas, and the natural adaptation of tree species to cope with adverse environmental conditions. The paper outlines criteria for tree selection and develops an approach for regional concepts of urban forestry. The potential of the European dendroflora for urban forestry is assessed. The biodiversity treasure of South Eastern Europe and beyond (Asia, Caucasus) may be particularly promising for this purpose.

Material and methods:

Two complementary approaches were used:

to define criteria for identification of suitable tree species for urban forestry. This step was based on a review of literature (Strobel 1997) on site requirements for healthy tree life in the urban environment. Tree inventories have been widely used to collect the required information in different cities and towns (e.g. Pauleit 1988, Land Use Consultants 1993, Nowak 1994), and stress factors for tree life have been described (e.g. Meyer 1982).

A classification of Europe into broad geographical zones to serve as target areas for regional lists of suitable tree species. Frost hardiness was considered as the major constraint for tree life which trees species need to fulfil by all means. The frost hardiness map from Heinze and Schreiber (1984) delineates Europe into 11 frost hardiness zones. The map was conceived in analogy to the much earlier classification of the US into frost hardiness zones by the US Department of Agriculture (USDA 1972).

The frost hardiness zones were overlayed by the map of the biogeographic provinces by Takhtajan (1986). The map broadly divides Europe into zones of similar floristic composition, origin and diversity. This places the information on frost resistance into the context of the history of floristic development after the ice-ages. To make this more easy to understand the line of the maximum glaciation (from Ellenberg 1996) is also marked.

This overlay provides a link to potential sources of high biodiversity, and thus of broad genetic resources for urban horticulture

Results

1. Criteria for the selection of urban trees

Stress factors for tree life are the general urban environment (urban climates, limited space for growth both above and below ground), and more specifically the hard surfacing which limits water availability, and soil compaction, resulting in lack of oxygen supply and exchange (e.g. Meyer 1982). De-icing salts also have to be listed as their use is probably unavoidable in certain areas under various weather conditions in winter. Infrastructure construction and maintenance works have also to be listed as major factors of tree damage which, however, cannot be overcome by the approaches proposed here.

A selection profile for street trees that fits with the site conditions and requirements was developed. The following criteria were considered:

1. Longevity through:

    • stress resistance (to heat and drought, winter conditions, lime content of soils and pH factor, compaction, pests and diseases, emissions, de-icing salt and shade tolerance);

    • physical stability and road safety (adequate ‘head room’, mechanical strength and resistance to wind and snow breakage, lack of allergenic agents).

2. Ease of cultivation and mass-propagation.

3. Design qualities (aesthetic value, bark, leaves, flowers and fruits).

Frost hardiness, the ability to grow in nutrient poor, compacted soils (low oxygen supply), and to cope with low water supply in a highly sealed urban environment were considered as being the major ecological criteria for tree plantings in Central European cities and towns. Suitable species were identified using the available literature (in Strobel 1997) and the 15 most promising candidates were recommended for an extensive test planting. Species from NE America, continental Asia and SE Europe (frost hardiness, drought and heat resistance) fitted particularly well the criteria for urban tree selection. Among these were species such as *Acer cappadocicum*, *Acer heldreichii*, *Acer monspessulanum*, *Catalpa speciosa*, *Fraxinus pennsylvanica*, *Maackia amurensis*, *Quercus frainetto*, and *Tetradium daniellii*. Maximum frost hardiness zones were also documented from several sources. Mature trees of these species are documented in arboreta and parks all over Central Europe, covering a range from moderate oceanic to continental climates (DDG 1982).

Tree surveys in the city of Munich confirmed this assessment for some species. Species like the Cappadocian maple (*Acer cappadocicum*) proved to be very healthy in Munich, even under very difficult environmental conditions where adjacent Norway maples (*A. platanoides*) where heavily declining. Interestingly, the Cappadocian maple and several other species could only be found as specimens which were at least 70 years old. Obviously many species have been neglected or forgotten since the times of major dendrological interest. Field trips to several cities, arboreta and parks of SE Central and SE Europe (Prague, Bratislava, Budapest, Zagreb, Ljubljana, Sofia) gave us further insight into the potential of this region for identifying prospective tree species for urban plantings. However, this rather anecdotal information had to be rigorously confirmed by a more scientific approach (e.g. Lukasiewicz 1978 for Poznan). As a first step towards achieving this goal we worked on a methodological concept to assess the biodiversity potential of Europe for urban forestry.

2. Biodiversity phenomena in Europe

Europe has the most diversified physical background compared with other continents of the world in terms of length of coastline, topography and land-sea interfaces with the Baltic Sea, Black Sea and the extremely differentiated Mediterranean Basin. Climatically, this situation is further diversified by the warming influence of the Gulf stream in winter. However, the status of the Dendroflora in Europe is much less influenced by the current physical setting as by the catastrophic event of the ice-ages in geological history. The once very rich tertiary flora was swept out or pushed away to the Mediterranean peninsulas, the Balkans, Pontus and Caucasus.

Figure 1: Southern border of maximum glaciation and distribution of endemics

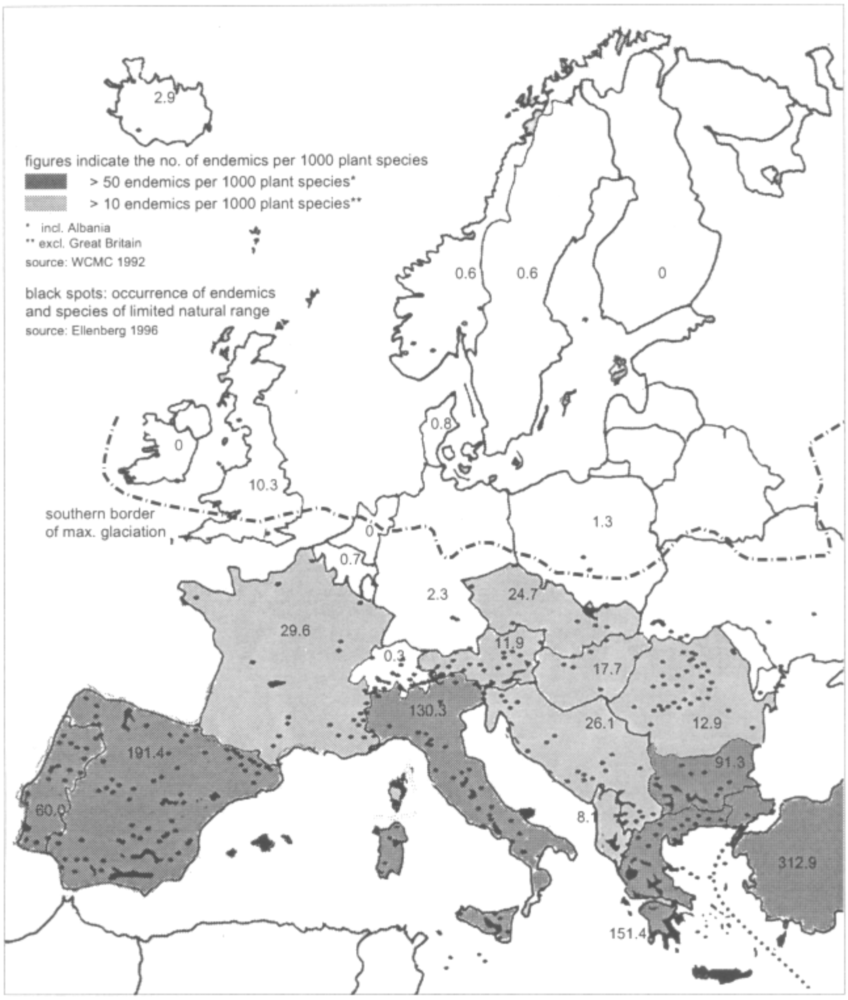
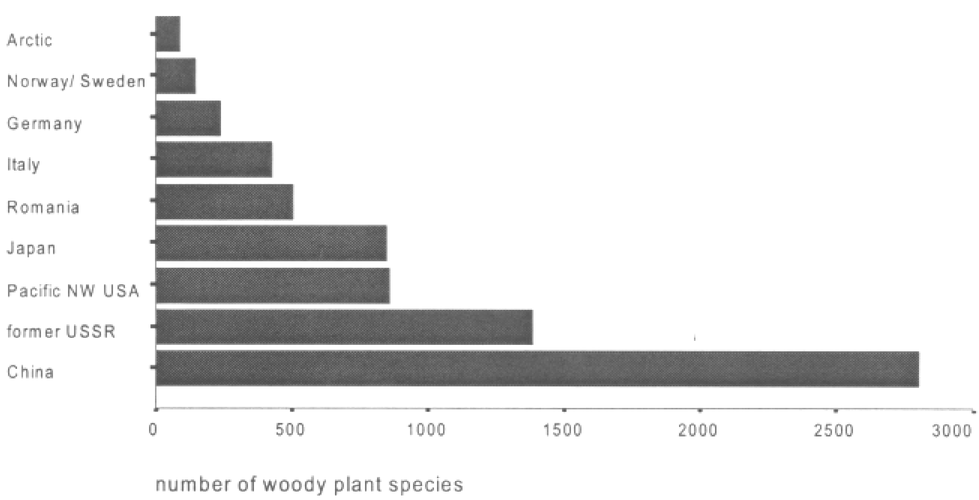


Figure 1 shows the relation between the maximum extent of the glaciations and the occurrence of endemic plant species. The number of woody plant species is much reduced when compared to other regions of comparable climatic conditions such as the North-east of the United States, or East Asia (China, Korea, Japan). The species numbers in Figure 2 for different countries of the Northern hemisphere cannot be considered as a proof for a different biological diversity as the base unit area largely differs in size.

Figure 2: Number of woody plant species in countries of the Northern hemisphere



However, the general differences between countries from Central and Northern Europe such as Germany and Norway/ Sweden on the one hand side and Romania, Japan and the Pacific Northwest of the United States still becomes evident. Areas with specific characteristics and opportunities could be distinguished within Europe by producing an overlay of the biogeographical provinces by Takthajan (1986) and the map of frost hardiness zones by Heinze and Schreiber 18984) (Figure 3).

Figure 3: Integrated Eco-regions of Europe

Eco-regions of Europe (slightly changed after Takhtajan 1986)

1 Arctic
2 Western Europe
3 Central Europe
4 Balkan
5 Pontus
6 Caucasian
7 Eastern Europe
8 Northern Europe
11 Iberian incl. Balearic
13 Liguro-Tyrrhenian
14 Adriatic
15 East Mediterranean
17 Central Anatolian
18 Armeno-Iranian
19 Hyrcanian

Integrated Eco-regions of Europe

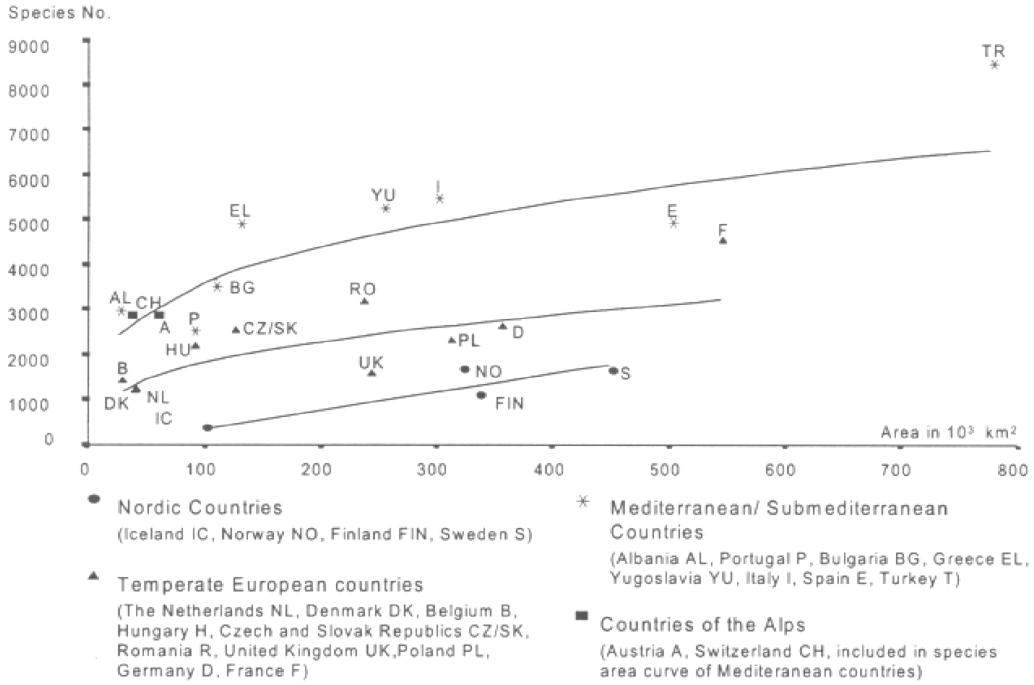
I Nordic
Ia Nordic Island
Ib Nordic Continent
II Atlantic
III Central
IIIa Central
IIIb East Central
IV South-Eastern
IVa Balcan-Caucasus
IVb Anatolian/ Ar.-Ir.
V Mediterranean

The Northern, the Central and Eastern European provinces, the very extensive west-east stretch of the Mediterranean Province and the predominantly Gulf Stream affected Western European Province somewhat west of the 10th longitude. The Balkan, Pontus, Caucasian and Hyrcanian Provinces are intersected between the Central, Eastern and the Mediterranean Provinces. The Northern P. ± north of 60° latitude is naturally poor in plant life. However, regarding winter temperatures, it does not need to be as poor in trees as it is at present; the length of the vegetation period is more limiting than the average minimum temperatures at its southern limits. The Western P. is naturally very poor and dominated by oak and pine woodlands and large tracks of heath and mire areas. Winter temperatures might almost be called submediterranean, while summer heat and drought are lacking. Despite of the poverty of the natural dendroflora the conditions for growing trees are almost unlimited. This is the reason why Britain has been the gateway for many introductions to Europe from all parts of the world and why it is an Eldorado for garden enthusiasts and dendrologists.

In Central and even more so in Eastern Europe frost hardiness is of increasing importance for the survival of trees. The natural dendroflora is still small because of the effect of the ice-ages but the chances for successful introduction of non-indigenous trees are also considerable. The reason for this is the much higher reliability of climatic phenomena: there is a sunny, dry autumn as a prerequisite of frost hardening; the occurrence of even daily freezing and thawing throughout the winter is diminished; compared with the west, late spring and early autumn frost are much less likely. Therefore, the beginning and the end of the vegetation period are much more predictable. Under these conditions even frost hardiness zone 5 can be endured by species which would have problems in zone 6 further west. Much experience is available from North America, including a long list of potentially useful trees for both regions.

A simple species-area curve, which has been calculated from national statistics compiled by the World Conservation Monitoring Centre in Cambridge (WCMC 1992) clearly indicates the differences between countries of the south, the middle latitudes of Europe and the northern countries (Fig. 4). The number of endemics north of 50° latitude is practically nil, in Mediterranean countries it ranges between 10 and 20 percent and for Turkey the percentage is even higher than 30 percent. This is important and explains further results to some extent.

Figure 4: Species-area curves of European regions
(source: WCMC 1992)



Europe, however, has genetic storehouses of its own with the Balkans, the Pontus, the Caucasian and the Hyrcanian Provinces of western Eurasia. Many species survived or remained here, which had a much wider distribution before the ice ages. Also, a high number of endemic species are to be found here. This very rich dendroflora is barely used for improving the choice for successful urban plantings. One endemic of a very limited natural range on the Balkans has became a world champion, the Horse Chestnut, but a large number still have their success story ahead: *Corylus colurna*, *Quercus frainetto*, *Q. macranthera*, *Q. libani*, *Q. pontica*, *Q. hartwissiana*, *Q. castaneifolia*, *Parrotia persica*, *A. heldreichii*, *A. trautvetter*i, *A. velutina*, perhaps even *Gleditsia caspica*.

Further examples are listed in Table 1. The table was compiled for the purpose of an engagement with a German charity which aimed to replant trees in Sarajevo, the capital of Bosnia-Hercegovina. Trees were almost completely cut down during war times. Using the potential of the natural dendroflora from the surroundings would be a means to confer a new identity to the city and establish specialist nurseries as a local industry.

Table 1: Tree species in the surroundings of Sarajevo, Bosnia-Hercegovina

Tree species*1)	**Tree species*1)**
Acer campestre	*Picea omorika*
Acer heldreichii	*Pinus peuce*
Acer hyrcanum	*Pinus leucodermis*
Acer obtusatum	*Prunus avium*
Acer monspesulanum	*Prunus fruticosa*
Acer tataricum	*Prunus mahaleb*
	Platanus orientalis
Aesculus hippocastanum	*Pyrus communis*
	Pyrus amygdaliformis
Celtis australis	*Pyrus pyraster*
Corylus colurna	
Castanea sativa	*Quercus cerris*
Carpinus betulus	*Quercus frainetto*
Carpinus orientalis	*Quercus pubescens*
Cercis siliquastrum	*Quercus petraea*
	Quercus robur
Fraxinus angustifolius	*Quercus trojana*
Fraxinus ornus	
	Sorbus aria
Juglans regia	*Sorbus domestica*
	Sorbus torminalis
Mespilus germanica	
Malus communis	*Tilia cordata*
	Tilia platyphyllos
Ostrya carpinifolia	*Tilia tomentosa*

*1) all species, except *Pyrus amygdaliformis* and *Quercus trojana*, were recorded as mature trees in Central European arboreta at least within frost hardiness zone 6 (source DDG 1982).

Perspectives

We need a cross European information network of the actual dendroflora of major European cities back-packed by frost hardiness experience of Botanical Gardens and other relevant plant collections. Systematic surveys in different cities and towns based on a comparable methodology could result in regionally based lists of trees which have proved to be adapted to the urban situation over long periods. Field trips to cities and towns in south-eastern Central Europe (Ljubljana, Zagreb, Budapest and Sopron, Sofia) gave a first overview of tree species that seem to be especially interesting for wider use in streets. Thus, species such as Common hackberry (*Celtis occidentalis*), Pagoda tree (*Sophora japonica*), Turkish hazel (*Corylus colurna*) Honey locust (*Gleditsia triacanthos*), Manna Ash (*Fraxinus ornus*) and Golden-rain tree (*Koelreuteria paniculata*) are frequently planted in these cities and seem to be very well adapted to the urban situation over long periods.

We also need much better information on potential plant sources and the genetic differences of provenances. Rigorous testing of the material will greatly enhance the options for cities where the natural dendroflora today is very impoverished as the result of ice-ages. Because of the comparability of European and North American frost hardiness maps, the rich experience of the latter is transferable. This approach was adopted by Heinze and Scheiber (1984) for Europe.

Combining frost hardiness zones with biogeographic provinces provides a framework for urban forestry in Europe. The map provides valuable information of biodiversity sources and its potential use for urban plantings. The preliminary interpretation of this map and general literature shows that we can have a large amount of trees available to improve the urban environment as a human habitat.

Finally, launching an initiative “Let’s grow Balkan trees!” is suggested as a step which may help to promote the interest in new tree species in European cities and towns as well as advance the nursery industry in the donor countries (Pauleit and Duhme 1999). Good quality trees for replanting Sarajevo had to be imported from large nurseries in Germany, the Netherlands and Belgium. A co-operation between these large nurseries and companies on the Balcans which specialise on indigenous trees would be for the advantage of both sides. In a similar way, the timber industry which has so much benefited from the genetic resources all over the world could act as a supporter for the preservation of these resources in the wild.

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New shapes and new species in street tree population

Introduction

In the past centuries, the tree-lined boulevards were designed to improve the architectural decoration of the urban streets. In the urban architecture that developed during these centuries, the street tree population perfectly integrated the buildings as a part of the urban furnishing. Public open-spaces and private gardens started playing the leading role in the urban furnishing, because some people thought that it that would have changed the look of the town as well as the way of life. Public open-spaces and private gardens were supposed to improve the urban hygienic conditions which were really terrible at that time, especially in those countries where coal was used as a fuel for the manufacturing industries. The rapid expansion of industries increased the use of coal which is a very polluting element. This situation brought to the "invention" of "public-parks", tree-lined boulevards, wide green areas, public areas to play sports, etc.

Today the technological evolution keeps on developing as fast as the deterioration of the quality of life in all of the most populated areas of the globe. The deterioration of the quality of life partially comes from the pollution of the atmosphere, the soil, the water tables as well as from the acoustic pollution. As a consequence, during the second half of this century the landscape architects become more and more aware of the importance of the environment. The lay-outs of public open-spaces and private gardens were therefore planned to fulfil the functional needs rather than the architectural needs. The environment conditions and the improved quality of life in towns became a primary purpose.

As soon as vehicles became the most important means of transport, the street tree population acquired new additional functions. As an example, street trees became an effective biologic filter against chemical pollution as well as en effective acoustic barrier. However, the street tree population can get damaged while performing this outstanding function. The pollution of air, water and soil can occlude the stomata and cause generic damages to the tree metabolism.

This investigation aims at finding new species and varieties in street tree population which can spontaneously adapt to the urban life conditions and can keep acceptable biologic and physiologic conditions. These street trees should not therefore request any kind of interventions which will undoubtedly rise the maintenance costs.

Materials and methods

The first investigation aimed at identifying the causes of the tree deterioration in the urban environment. Some 2,380 trees were monitored. Every tree was fully described on a Tree Card, showing the characteristics, genre, species, visible defects and maintenance interventions. This investigation was carried out in the *Pianura Padana*, a large plain area in the north of Italy. The exam of the collected information provided the data for the list showing the causes of deterioration. The most common causes are given in detail here under:

3%	de-ice salt treatments on streets
78%	mechanical damages due to street maintenance machinery and to vehicles
36%	damages due to polluting chemical products
8%	high temperature during the summer time
14%	inappropriate water supply
46%	too frequent pruning, which are often incorrect
22%	presence of pests
7%	fungi at the crown level
74%	wood decay fungi

Then, this investigation examined the data about the 5-year maintenance (1994-1999) to highlight on how many trees the public administration carried out the ordinary maintenance. The damages of the tree were not taken into consideration.

The results are given here under:

99%	pruned trees
1%	not pruned tree.

Results

When choosing the ornamental plants for urban areas and gardens, the landscape architects should consider the "artificiality" of the lay-out.

In high-urbanised environment, plants may suffer several external conditions such as the pollution, the small-sized areas, etc. Not-native plants may be used provided that they can survive under such specific conditions (see Table 1).

Table 1: Species resistant to urban pollution

Acer campestre	*Ligustrum*
Ailanthus altissima	*Malus sylvestris*
Alnus cordata	*Mespilus germanica*
Alnus glutinosa	*Morus alba*
Alnus incana	*Morus nigra*
Carpinus betulus	*Prunus cerasifera*
Catalpa bignonioides	*Pyrus calleryana*
Crataegus "Carrierei"	*Pyrus calleryana "Bradford"*
Crataegus x lavallei	*Pyrus calleryana "Chanticleer"*
Davidia involucrata	*Quercus ilex*
Fagus	*Robinia pseudoacacia e cultivars*
Fraxinus	*Sorbus aria*
Gingko biloba	*Tilia x euchlora*
Ilex aquifolium	*Tilia x Europaea*
Laburnum anagyroides	*Tilia plathyphyllos*

In addition to the specific environment characteristics, the species of trees, shrubs and herbs should also own the characteristics which are required by lay-out, maintenance and adaptability even to habitats whose conditions are not usually suitable for the vegetal species.

As to the lay-out and maintenance of open-spaces, the selection of appropriate species and the correct use of agronomic techniques ensure the successful accomplishment of green areas, even without transplanting not-native plants.

All the selected vegetal materials (trees, shrubs, herbs) shall be composed of first-choice healthy plants, that is to say free of diseases, parasites, deformations as well as any other serious damages.

Trees to be transplanted in parks, gardens, beds, boulevards shall have been grown to this purpose. The trunk and main branches shall not have any kind of deformations, pollards, injuries, cut faces, rind galls, hail, barking, binding, sun burns, insect aggressions, fungi and virus diseases. The tree crown shall have a regular, balanced ramification; the root system shall have shot out properly, that is to say rich of capillary roots and without large cuts.

Trees shall be supplied either in their buckets or ball-and-burlapped. Bare-root trees should be provided that the trees are very young, have small dimensions and belong to deciduous species.

As to shrubs and bushes, both the deciduous-leaf and ever-green samples shall not draw up.

Besides, they shall perform at least 3 ramifications at the collar and their height shall be proportional to the crown and trunk diameters. Instructions for the breeding and for the root system of shrubs and bushes are the same instructions given for trees.

As shown by the results of this research, not only is tree pruning a quite high cost for the Public Administration , but it also is one of the main causes of the decay of the street tree population. To prevent tree pruning, the urban project shall consider the proper distance of transplantation among the tree, the streets and the buildings.

The axis of tree transplantation shall lie at least 6 metres from the buildings and at least 1,5 metres from the street pavement.

To ensure the healthy growth, the street trees shall be transplanted at the distance here under:

- large trees (*Quercus*, *Tilia*, *Fraxinus ex.*, ecc.) = from 10 to 15 metres of interaxis
- medium trees (*Alnus*, *Acer*, *Carpinus*, ecc.) = from 7 to 10 metres of interaxis
- small trees (*Prunus*, *Malus*, ecc.) = from 5 to 7 metres of interaxis
- cone-shaped = from 4 to 6 metres of interaxis

Large trees shall lie not less than 25 m. from the cross-roads to ensure the safest driving visibility as well as the easiest driving control next to street passages.

If the space is small, either the cone-shaped varieties (see Table 2) or the small-sized varieties and species can be chosen (see Table 3). Both the cone-shaped and the small-sizedvarieties are generally available in a well-assorted nursery, that is *Acer*, *Carpinus*, *Robinia*, *Quercus*, *Fraxinus*, *Crataegus*, etc.

Table 2: Cone-shaped species and varieties – trees: large (over 18 m) – medium 10 to 18 m) – small (up to 10 m)

Acer campestre " Elsrijk"	*F.s."Dawyck Gold"*
Acer davidii "Madeline Spitta"	*F.s."Dawyck Purple"*
Acer d. "Serpentine"	*Fraxinus excelsior "Westhof's Glori" (giovane)*
Acer glabrum	*Populus alba "Pyramidalis"*
Acer palmatum "Seiryu"	*P.x canadensis "Eugenei"*
Acer platanoides "Columnare"	*P. nigra "Italica"*
A.p."Crimson Sentry"	*P. Simonii "Fastigiata"*
A.p."Erectum"	*P. tremula "Eretta"*
A. p."Meyering"	*Prunus dulcis "Erecta".*
Acer pseudoplatanus "Erectum"	*Prunus serrulata* var. *hupehensis*
Acer rubrum "Columnare"	*Pyrus calleriana "Chanticleer"*
Acer saccharinum "Pyramidale"	*Pyrus communis "Beech hill"*
Acer saccharum "Newton Sentry"	*Quercus robur fastigiata*
A.s. "Temple's Upright"	*Q.r.f."Purpurea"*
Alnus glutinosa "Pyramidalis"	*Robinia pseudoacacia "Monophylla Fastigiata"*
Carpinus betulus "Columnaris"	*Robinia pseudoacacia "Pyramidalis"*
Carpinus b. "Fastigiata"	*Tilia americana fastigiata*
Crataegus monogyna "Stricta"	*Tilia cordata " Sweedish Upright"*
Fagus sylvatica "Dawyck"	*Tilia platyphyllos fastigiata*

Table 3: Medium and small –size species for street trees

Alnus incana	*Morus alba*
Crataegus laciniata "Paulii"	*Prunus cerasifera* "nigra"
Crataegus oxyacantha	*Quercus ilex*
Robinia pseudoacacia "Umbraculifera"	*Tilia cordata* "Erecta"
Prunus cerasifera	
Prunus cerasifera "Pissardii"	
Sorbus aucuparia	
Crataegus "Carrierei"	
Crataegus x lavallei	
Malus spp. *ornamentali*	

During the last years of the past century, the Italian nurseries pushed the production of this kind of plants even though the public and private companies do not usually chose such varieties.

Additional conditions are required to ensure the optimal growth of these plants. They shall be transplanted in an uninterrupted bed with no paved surface. The bed shall be at least 2,5 metre-large for large trees and 1,5 metre-large for small trees.

In case the bed is interrupted, its surface shall not be paved or it shall be covered with a grid. The grid dimensions could be at least 1x1 m. for small trees and m. 2,5x2,5 m. for large trees.

Should the soil be without grids, the earth has to be worked frequently to prevent the tamping. Besides, the earth shall be constantly covered with bark mulch and then protected by appropriate nets to prevent wear, vandalism, animal aggression.

The irrigation and draining installations are important as far as the lay-out of green areas is concerned and they are often fundamental for the survival of street trees.

Draining conduits shall be installed in depth and made of plastics (PVC). They shall be flexible, wrinkled and with slits providing a fast water leakage and preventing the conduits' occlusion.

The draining conduits shall be located near the roots of every tree (the installation depth may change according to the tree species and the kind of earth) and have to be connected to the water sewage installation. This technique can be used in case of emergency irrigation as well as in case of irrigation with fertilisers.

Should the trees lie in a position where cars can easily hit them, the trunks shall be protected properly.

Conclusions

The technological evolution and the urbanisation of large areas develop at the same speed of the deterioration of the quality of life.

The increasing urbanisation of the large areas is undoubtedly reducing the environment potentialities. It is also obvious that this process can be stopped only by means of completely new interventions on the environment which could restore or even improve the natural conditions on the territory.

As a consequence, in the public open-spaces and gardens the lay-out of urban areas shall emphasise the functional needs rather than the landscape. Improved environment conditions and improved quality of

During the second half of this century, the countries of the Middle-Europe chose to balance these 2 functions. Here the new open-space structures were supposed to respond to the main environment requirements (such as protection, shield, acoustic barrier, etc.) and to offer also a beautiful landscape.

In the countries of the Mediterranean area, the situation seems to be different. Here, the people still feel strictly bound up with their past history, that is to the formal garden, to the small and accurate garden structures.

In conclusion, in the Italian regions where this research was carried out it was found that lots of the tree species used in the urban areas are not appropriate, either because of the high maintenance costs or because of these species can be easily attacked by pests and diseases which may then bring to the dangerous fall of the tree, either partial or total.

In Italy, the current trends care for a structurally-valid lay-out of open-spaces. This means that the open-spaces shall play not only the role of natural barrier, but it shall also improve the environment conditions. In addition, the open-areas that are located in the towns, especially in the tourist towns, are also supposed to emphasise the landscape with a furnishing function and to improve aesthetically the urban context.

In view of what stated above, the bibliographic research was carried out to highlight the new species of plants whose peculiarities allow their use in the urban areas and give the opportunity of placing them next to the already known species which are at present used in the public open-spaces.

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The role of trees in urbanistic development of Belgrade

Introduction

Overall and very complex functionality of large woody plants in urban landscape depends on numerous factors. The basic benefits which human beings receive from trees are reflected in their so-called ecological, or sanitary-hygienic performance. But, whenever they are present in a very small number, or when they occupy relatively small and limited space (a commonplace in typical urban setting), this role of urban trees may be only spoken of in principal and just in a symbolic sense. On the other hand, these distinct elements of natural origin in artificially created townscape have much more significant and complex role, a type of performance that is not always so obvious or easily measured [2]. It is customary to refer to this functionality of urban trees as to their esthetic, psychological, cultural-historic and urbanistic-architectonic role. These functions gain on their significance as the number of tree individuals decreases, or their distance from the center of the city increases. Thus, when application of plants is concerned (especially trees, exceptionally valuable site elements in visual and every other sense), it would be natural for proper city planning approach to be based on specific form, aesthetic and psychological singularity of every plant species. It should rely on all the subtle ornamental plants' functions which defy biological or strictly biological definition [5]. And still, most city planners predominantly seek justification (rationalization, explanation) for more or less ample usage of plants in urban environment predominantly in the domain of their ecological significance. It may be justly assumed that the basic city planners' hesitation to pay adequate attention to these important urbanistic functions of trees (but also other categories of plants in urban environment), in fact lies in particular professional indecision of architects to subject their creative city planning activity to something as uncertain and uncontrollable as alive tree in urban landscape. However, when one considers the genuine beauty of trees, wondrous natural creations of specific morphology, characterized by dynamic temporal components, unusual form, mass, contrasts and variability in urban landscape [3], then restrain of some contemporary city planners to rely more readily on these important elements of townscape enhancement is sometimes difficult to accept.

To tell the truth, city planners are right in one thing: when planning or designing actual townscape, it is much easier to control and manage inert material than plants, however skillfully and carefully chosen and incorporated in that townscape. Buildings, streets, squares, bridges, skyscrapers or shopping center are entirely open to technical changes, adjustments and reconstruction, while it is very hard, if not impossible, to do the same with several decades old trees without causing dramatic consequences. Mature tree is governed in both urban and natural landscape by its own, natural laws, the ones that city planners often do not understand entirely. That is why it is much harder for them to grasp and especially to enhance its urbanistic function, which is possible only if action is taken against other, artificial elements of that site, which must be subordinated to the nature of the tree itself. This hesitation towards ample usage of trees becomes even greater in the view of the marvelous but also for contemporary man sobering fact that, despite all miracles of modern technology, technique for expedient creation of mature tree has not been discovered yet. Whatever we do, these silent creatures grow and develop as fast as their biological nature allows. That is why it is quite comprehensible to biologists why trees in urban landscape often provoke professional despair in some architects and city planners. At the same time, however, exactly this tree characteristic is the key source of the respect that they provoke in human beings today, as they did many centuries ago.

Trees and the beginning of modern civil engineering in Belgrade

The most important element of close bond that urban dwellers feel towards trees is mainly based on particular appreciation, sometimes even true esteem for these silent witnesses of endurance and natural companions of man, his ever-present source of food, firewood, building material and beauty. In this respect there is no essential distinction between urban and rural inhabitants, educated and ignorant, or those of different cultural heritage. Belgrade dwellers do not differ much from other urban inhabitants of the modern world in their regard for trees; on the contrary, it could be said that they hold even greater appreciation. This conclusion may be drawn easily from the character and the scope of urbanistic usage of trees in Belgrade city planning ever since it become one of the modern European capitals.

Actual urbanistic development and fast spreading of Belgrade occurred during the first decades of the 19th century, simultaneously with the beginning of Osmanly withdrawal from these parts of Balkan peninsula. There were several factors dictating systematic implementation of plants in Belgrade urban tissue, as one of the keystones in the activity of city planners and administrators of former very small Serbian capital. Most important, besides actual geographical character of Belgrade area and its surroundings, were the habitual life frame involving immediate contact with trees in residential courtyards and gardens, as well as deep spiritual esteem for plant world held by both domestic and Muslim residents. Being well aware of the reality that many newcomers to Belgrade originate largely from the region very rich in forests (the reason why central part of Serbia is called Sumadija - Forest Land), and due to the fact that new city territory was originally very rich in trees, first Belgrade and Serbian city planners paid special attention to urban greenscape, perhaps even greater than was the case in some larger European cities of that time. That is why new modern streets, with first street tree lines, were already established in the first decades of the 19th century, far before final retreat of Turks and long before the foundation of new independent state (in 1878). Initial Belgrade street tree line consisted of *Populus nigra* var. *pyramidalis* tree individuals. It was located in today's Narodnog Fronta St., in the very hart of the city. First Belgrade public parks were planned and established during several following decades(Karadjordjev Park, Kalemegdan, Academic park, etc.).

It should always be kept in mind that these were just the beginnings of Serbian state in modern sense, the times when numerous fundamental issues concerning organization of the city were unsolved still, or have not even been raised yet due to several centuries long stagnation. But, if it was not possible to solve immediately all the Belgrade city planning problems of that time, everything possible was done to provide trees and all the gardens, parks and street tree lines in and around the city with true urbanistic meaning. In that spirit, expressing general tendency to change fundamentally the imposed former way of life and to direct it towards the new age, trying to keep the paste with modern European capitals, the ruler of still semi-dependent principality raised very beautiful park around his newly built summer palace in Topcider, estate near the city. Even today there are old tree specimens of at the time very popular species of European urban trees, where one individual of plane-tree (*Platanus x acerifolia*) still represents rare example of splendid (magnificent) beauty and grand dimensions. This park today, as Versailles near Paris, represents significant part of national cultural heritage. Its urbanistic, visual, cultural and educational values may be spoken of with far more delight then of summer palace itself. Immediately after construction, Topcider palace and its park were connected with the Palace in the center of the city by new wide street. Even today this street represents one of the most vital Belgrade line of communication. Soon after, this street was furnished with rather modest street tree lines, but they grew into high quality, luxurious double linden (*Tilia* sp.) and horse-chestnut (*Aesculus hippocastanum*) street tree lines just a few decades latter, following the first reconstruction and widening of the street. Preserved engravings and photographs taken in those years confirm that this was a street landscape that greatly resembled Parisian urban boulevards of that time, primarily thanks to its street trees. All the prominent citizens of Belgrade could be seen in that somewhat noble although not rich ambient in the afternoon or evening hours. Belgrade dwellers, young and old, strolled under the linden trees speaking of social events and retelling tails. Several smaller parks, partially preserved to the present day, were established along the side of the street facing Sava river bank. All in all, this street (still named after its spiritual founder Knez Milos) was regarded as most beautiful " promenade of the old Belgrade" throughout the 19th and the first half of the 20th century. It is interesting that even today Knez Milos St. represents main traffic artery of Belgrade. The best evidence of the great care that was paid to this communication in the past is the fact that plans and projects of its street tree lines and parks in immediate surroundings were designed and their realization often personally supervised by famous European gardeners, engaged by municipal authorities for their in Europe certified fame [1].

Thus, new "green Belgrade residential quarters" were established in quite favorable circumstances, with at the time not yet seen regular, orthogonal street net. Very carefully, thoughtfully designed and professionally established street tree lines were obligatory, in many details resembling other capitals of middle and west Europe. Typical example was newly established city quarter Zapadni Vracar, once a periphery but today the very center of the city, located in the vicinity of Svetosavski Plateau. Partially preserved original street tree lines may be found there even today, comprised of *Aesculus hippocastanum* along certain streets' sections and individuals of *Aesculus carnea* on the corners of these streets.

Relying primarily on medical motives for using trees in urban environment as well, city planners of that time found scientific and professional justification for Belgrade public green zones' existence mostly, but not exclusively, in ecological motives. Official administrative explanation for necessary existence of gree nery in the very hart of the city was expressed predominantly through sanitary-hygienic, or as we would rather say today, ecological needs. Since trees serve as the source of “shade and coolness for pedestrians and dwellers, and the murmur of leaves contributes to the rest of tired strivers after a hard day’s work”, positive effort of municipal authorities was undertaken to capacitate Belgrade with as ample public greenery as possible. This effort was of ecological and urbanistic nature, as it was of financial. Nevertheless, and despite general appreciation, almost nothing would be done truly had not it been for certain high government officials who found time for both political and ecological issues, holding most of the merit for systematic Belgrade greenscaping during the first decades of the 20th century. The most prominent among them was Atanasije Nikolic, long standing member of the government. He founded the first proper nursery production in Belgrade surroundings in accordance with his education and his convictions, where he supervised production of different plant species, including trees for street tree lines and parks. There was, as it is today, a continuous and pronounced need for properly trained, high quality nursery stock.

Besides being personally and often very self-disciplinary engaged in town greenscaping, heads of the city and of the state were quite strict with Belgrade residents as well. Due to the great number of street trees, city’s population was commanded very sternly, in a form of a law, that “each and everyone in front of his shop or home is obligated to water the tree and maintain the fence around it”. Lack of obedience was very efficiently financially punished, in a sum that covered the cost of purchasing and establishing a new specimen at its previous location [3]. Historical scripts and urbanistic documents evidence that citizens in general understood and approved of such measures. So amazing is this ecological-urbanistic attitude towards city greenscape and remarkable Belgrade spirit of that time. Imaginary comparison of old Belgrade to the attitude prevailing in contemporary cities at the end of the second millennium is the best evidence of this unusual spirit; since any regulation shaped in such a way could hardly withstand “justified protest” in many a modern cities, despite the ecologically very well informed contemporary residents of the world. *O tempora, o mores*.

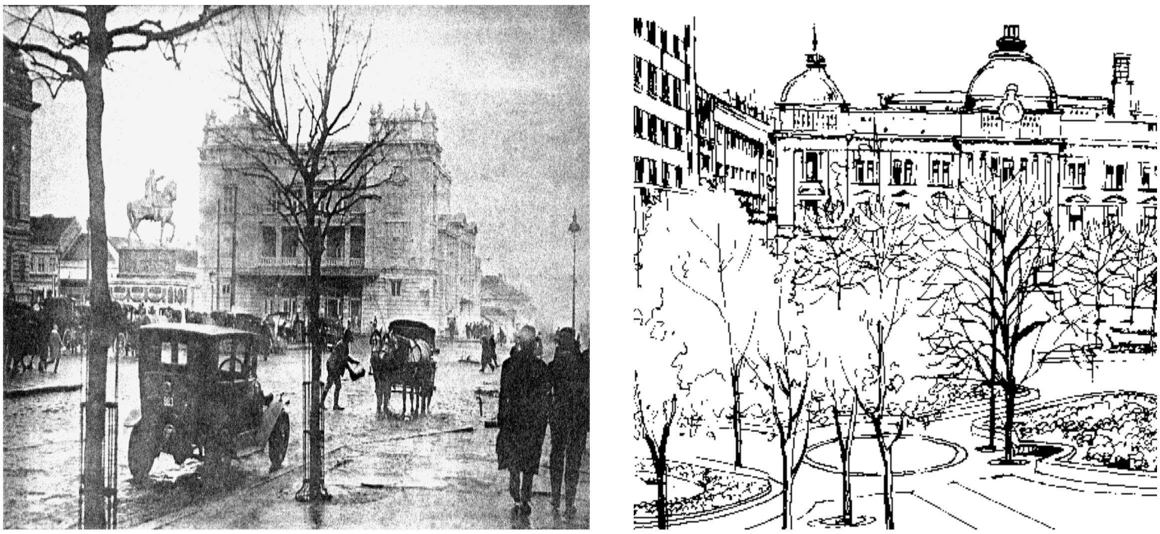

Fig 1: Republic Square - as it was seven decades ago and as it is today

In those early urbanization days, formally the first and truly conscientious Serbian city planner Emilijan Josimovic [3] published his proposal that before foreseeing privatization of state municipal land and their sale to the future private owners, a wreath of plantations and boulevards should be established along former town ramparts. A wreath of parks and street tree lines (“as in Ringstrasse, in Vienna” he cited) raised in proposed way would have had enormous importance for the city as a whole. Quoting in that regard not only ecological but also aesthetic desirability of such greenscaping, and at the same time warning that it would be almost impossible or at least enormously expensive to do the same later, after the privatization, Josimovic defined prevailing trend in greenscaping by this very text. Unfortunately, as a tribute to city’ development, the need for money pushed into the background the awareness of ecological and aesthetic significance of urban greenery.

That is the main reason why just one very small green oasis may be seen in the hart of the city today, on Square of Republic, standing there as a monument to particular state of mind, but also as a warning,. It is the remnant of once commenced but never realized to the end proposal of Josimovic. However, even this miniature green space has exceptional aesthetic, visual and architectonic-urbanistic significance, efficaciously enhancing this most important Belgrade square. Though small, it makes buildings of various and rather dissonant stile more compatible, despite the fact that they were erected in almost 150 years long period of city's development (National Theater, National museum, The House of Reporters, the modern movie theater and the most modern trade and business center, agencies and shops of numerous well known service and trade firms), linking them together and visually harmonizing the square better and more efficiently than any other urbanistic structure could [4].

Urban trees in the 20th century

During the 20th century the tendency of compulsory usage of trees in Belgrade urban tissue still relied on cited, now urbanistically understood traditional values, as well as on the most Belgrade inhabitants' feeling of closeness and attachment to urban greenscape. Even though this whole profession was ever more left to enthusiasts, permanent positive attitude towards the very existence of different street tree species could still be felt among Belgrade dwellers, even when the age and size of this "ecological treasure" represented particular obstacle to common street activities. This still more emotional than rational relationship of common Belgrade inhabitants towards their greenery is very easy to perceive. Calling their street tree lines and green spaces in general by the name of "green treasure", residents of Belgrade demonstrated throughout the 20th century readiness to improve their life frame with trees, often at the price of considerable sacrifices. Even during gravest wartime trials, when many mature trees of suburban parks and woods were cut down, urban street trees survived. By their very existence shade trees of Belgrade succeeded to preserve visual nobleness of many city streets, and not rarely to uphold an illusion of gracefulness in many decades of poverty and renunciation. The best examples of this effect of Belgrade street trees were present in the very center of the city just a year or two ago. True balance and fineness which possessed some of the central city streets was there more for their street trees than for their architecture, as Kralja Aleksandra St., Kneza Milosa St., Srpskih Vladara St., Makedonska St., Dzorza Vasingtona St., Francuska St., etc.

Superficial apprehension of street trees as more of the obstacle than of the benefit for modern city environment started to oppose ever more persistently indisputable tie that Belgrade dwellers hold for their townscape trees. That brought about fierce disputes between city planners and landscape architects about the actual functionality of street trees, especially in recent years. As in many other parts of the world, these discussions often resulted in disagreements concerning tree survival and tree maintenance techniques in ever harder conditions of urban environment. In these discussions, however, it was obvious that Belgrade inhabitants had no understanding for options that would mean elimination of street trees, even during otherwise very difficult years, so that even the advocates of completely opposite opinions had to kneel to this strong stand. One of the negative consequences is, however, obvious on many Belgrade streets; street tree lines exist even in streets that lack space, often at the price of drastic lopping. Belgrade experience shows that citizens, however unwillingly, accept the reasons for such drastic interventions, but do not except any explanation regarding complete removal of street trees without tempestuous protests. It should be said that systematically carried out and nowadays almost customary drastic pruning arises keen opposition as well. These strong reactions are regularly accompanied by principal protest of most of the landscape architects, so it may be concluded that there is a general consensus on trees as specific urbanistic value of Belgrade. Citizens hold a special and from ancient times inherited appreciation for trees and are not prepared to change it easily, even when completely deteriorated street tree individuals are concerned, whether they are decayed and prone to falling, or lopped, or just simply monstrous.

It may be said that street trees are in the very essence of contemporary image of many Belgrade streets. Even when they are not mutually connected in a solid street tree line, street trees are still Belgrade specificity. Smaller groups of old trees, situated in small pavement broadening that became a part of street environment gradually, after street reconstruction or other traffic interventions, tearing down buildings or incorporation of former private gardens into street corridors, have considerable visual value too. Generally, it may be said that felling of an old tree is seldom performed practice. These individuals are sometimes of high biological and aesthetic value, and their intended removal would certainly face the opposition of the whole city. There are more than several valuable ambient parts of street landscape in the center of the city area, among which, besides already mentioned, are also so-called Reporters Square in front of the Radio Belgrade Building (Makedonska St.), with five maple-trees (*Platanus x acerifolia*) of great beauty and

Flower Square in front of the Yugoslav Drama Theater (Srpskih Vladara St.), with the oldest tree specimen in Belgrade of exquisite appearance (*Quercus pedunculata*), more than 250 years old.

Fig. 2: The oldest living been in Belgrade - *Quercus pedunculata*, more than 250 years old

All the modern architectural and urbanistic reconstruction solutions for old Belgrade ambient still relay on plentifulness of greenery as one of the most important visual characteristics of these zones in more or less near past. Unofficial but quite distinct city planners' perception states that in the future as well, typical Belgrade urbanistic space can not function successfully without the presence of ornamental plants, most of all trees. This is the main reason why both temporary and permanent urbanistic solutions of central Belgrade area use trees as major elements and tools of visual shaping. Examples of so arranged central squares and city promenades are numerous, especially in last decades. There is Nikola Pasic Sq., with several tens of maple trees which have already reached impressive dimensions, and the Square of Republic, with individuals of *Betula pendula* which in just a few years became the "trade mark" of this urbanistically very valuable area. There is also thoroughly reconstructed Knez Mihajlo St., one of the few central Belgrade streets that did not hold street tree lines in the past. Today, however, this street is ornamented with several agreeably shaped large jardinieres with exceptional specimens of *Quercus rubra* of extraordinary vitality and esthetics.

Finally, from this long-lasting and up to the day preserved appreciation for trees originates systematic, inescapable local urbanistic rule concerning all new or reconstructed, suburban or urban residential blocks of Belgrade. In the second half the 20th century not one residential zone was erected without quite an ample area covered with ornamental plants. Negative side of this persistence is reflected in from time to time too large a number of newly established trees. Examples of such practice are most frequent in residential blocks of New Belgrade, where too densely planted trees are prone to numerous types of damages and diseases. Dense street tree lines are characteristic not only for New Belgrade area, but for some streets in central Belgrade as well. Such is the case with superfluous linden trees in certain sections of Knez Milos St., as well as in other streets where insisting on disproportionate usage of too large trees (*Platanus* sp., for example) just makes the matters worse in relatively narrow streets.

Instead of conclusion

What will happen with Belgrade street tree lines in the future? This question can not be answered easily. However, all possible should be done to keep trees within the urban tissue, and thus preserve the essential visual characteristic of Belgrade for the future as well. This should not be too hard to do, considering presented city planning, historical, cultural and emotional appreciation that Belgrade dwellers have for street trees and ornamental plants in general. Even though the trees' existence in street environment is becoming ever harder, it is of great importance that shade trees and whole greenscape still hold the same important place in Belgrade of 21st century as they did in all the previous centuries. This discernment is not based only on appearances or contemporary ecological findings. It is in complete harmony with essential principles of human existence. It also reflects the most important psychological and ecological survival needs of future inhabitants of a large city such as Belgrade. Expressed as concisely as possible, the basic suggestion is: all the existing large urban trees should be regarded not only as specific long-lasting monuments to inhabitants' relation towards nature, but also as cultural and historical monuments regarding the whole nation. That is why special recommendation concerns their very careful and thoughtful preservation, professional maintenance, regular renewal and (most of all) systematic research of various complex effects of trees on urban environment, including their urbanistic, visual and every other value.

Summary

Paper discusses the role of urban trees and their functional incorporation into Belgrade urban tissue during its almost two centuries long urbanistic development. The arising of organized tree establishment in central city area is analyzed, with a special emphasis on urban street trees. Particular ecological and historical significance of their existence in urban environment has been underlined, and individual specimens that should be preserved singled out. All the existing old Belgrade trees are regarded as memorial monuments, specific natural mausoleums of national history and culture which, accordingly, deserve special attention and very attentive and intensive care.

key words: Belgrade, city planning, street trees

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Defining key pests, key plants, and their relationship to vegetational diversity in residential landscapes

Introduction

The focus of our work at the University of Maryland at College Park is to develop, implement, and evaluate integrated pest management (IPM) and plant health care (PHC) programs for managed ecosystems involving woody and herbaceous plants in parks, public gardens, and commercial and private landscapes. Integrated pest management is an ecologically based and environmentally sensitive approach to maintaining pest populations at tolerable levels. This approach is accomplished by combining and integrating a variety of tactics such as the use of resistant plant materials, sustainable landscape design, ameliorative cultural practices, and biological and chemical controls into comprehensive management plans. One of the pillars of all IPM and PHC programs is a fundamental knowledge of the pest complex found in the landscape (Raupp et al. 1999). Unfortunately, to date there have been relatively few studies of the diversity of arthropods found in urban landscapes. Notable exceptions include the work of Owen (1978), Taylor et al. (1978), Owen (1983), Holmes and Davidson (1984), Raupp and Noland (1984), Balder et al. (1999), Lozzia (1999), Rigamonti and Lozzia (1999).

Not only is it important to understand what arthropod pests are found in the landscape, but it is also important to understand the relative importance of each pest from a management standpoint. Recently, it has become clear that a relatively small number of pests called key pests are responsible for the majority of biotic problems found in the landscape (Raupp and Noland 1984, Nielsen et al. 1985, Raupp et al. 1985, 1992, 1999, Harris et al. 1999).

With the recognition that a relatively small number of arthropods were responsible for the majority of problems came the understanding that some plants were exceptional in both their value to the landscape and propensity to harbor damaging levels of pest. This lead to the emergence of the concept of key plants in landscapes (Nielsen 1983, Raupp et al. 1985). In this paper we report on a few of our attempts to enumerate the key arthropod pests, and key plants found in residential landscapes in suburban Maryland, USA. Furthermore, we attempt to find useful relationships between the types of plant materials found in landscapes and their propensity for problems. Ultimately, we would like to provide information to arborists and landscapers that will help them detect and manage landscape pests in efficiently and effectively. We hope that this information will be useful to landscape designers in understanding the types of plant materials and landscape designs that are very pest prone in the mid-Atlantic region of the United States.

Materials and Methods

Data were gathered from 275 residential landscapes in central Maryland that were studied in 1980, 1981, and 1982. Beginning in April, undergraduate and graduate students visited home landscapes and recorded the identity and number of each woody plant species found. Beginning in May and continuing through September at biweekly intervals all plants in each landscape were examined for the presence of insect and mite pests. Records were kept on the identity and severity of each pest. Samples that could not be identified in the field by students were returned to the University of Maryland where specialists assisted with the diagnosis.

The size of these home landscapes ranged from one quarter to ten acres and the average size was between one quarter to one half acre. A detailed discussion of the specific composition of landscape plants found in these landscapes has been presented in greater detail elsewhere (Hellman et al. 1982, Holmes and Davidson 1984, Raupp and Noland 1984, Raupp et al. 1985).

Our first objective was to identify the key pests found in these landscapes. Enumerating the taxa of insects and mites encountered and determining how frequently they caused problems allowed us to rank pests according to their relative importance. The most frequently encountered pests were considered the key pests. Our next analysis identified the most pest prone woody plants. Each genus of plant was ranked by its relative abundance in the landscape and by its likelihood of harboring arthropod pests. Using these rankings it was possible to investigate the relationship between the relative abundance of a taxon in the landscape and the likelihood that it incurred a pest problem. We used a Spearman Rank Correlation analysis to investigate this relationship (Zar 1996).

To investigate the relationship between the number of arthropod species found in a landscape and the number of plants, plant species, species diversity (H') and relative diversity or evenness (J') linear regression analyses were used. Plant species diversity was estimated using a Shannon Wiener Diversity Index (Zar 1996). Plant species diversity was calculated as follows:

$$H' = (n \log_n n - \varphi f_i \log_n f_i) / n$$

where n = total number of plants; f_i = number of plants of each species; and $\log_n$ = natural log. Plant species evenness or relative diversity was calculated as follows:

$$J' = H' / H'max$$

where H'max = $\log_n$ K and K = the total number of plant species and was the maximum possible diversity. To determine which components of diversity best predicted the number of arthropod pests in the landscape, a regression analysis was performed on the number of pests and the number of plants, number of plant species, plant diversity (H') and plant evenness (J') (Proc REG, SAS Institute 1990).

Results

The total number of plants examined during the course of our study exceeded 14,000 and with a minimum of 10 observations each season the total number of records exceeded 140,000. We found that a relatively small group of arthropod pests accounted for the majority of the problems. For example in the program conducted at 100 home landscapes in 1982, lace bugs, mites, and scales accounted for more than 50 % of the problems.

Table 1: Ten most common insect and mite pests encountered in 100 Maryland landscapes in 1982

Pest	% of total arthropod pests (913)
Lace bugs	21
Mites	19
Scales	13
Borers	7
Leaf miners	7
Japanese beetle	4
Aphids	4
Bagworms	4
Galls	3
Weevils	1
Total	**83**

We used data from our two largest programs 1981 and 1982 to examine relationships between estimates of plant abundance and diversity and the number of arthropod pest encountered. The two best predictors of arthropod pest diversity were the number of plants and number of plant species found in the landscape (Figures 1 and 2). Although there was a significant relationship between plant diversity, H', and the number of pests observed, this relationship was weak and explained less that three percent of the variation in the number of pests found. There was no relationship between plant evenness, J', and the number of pests observed.

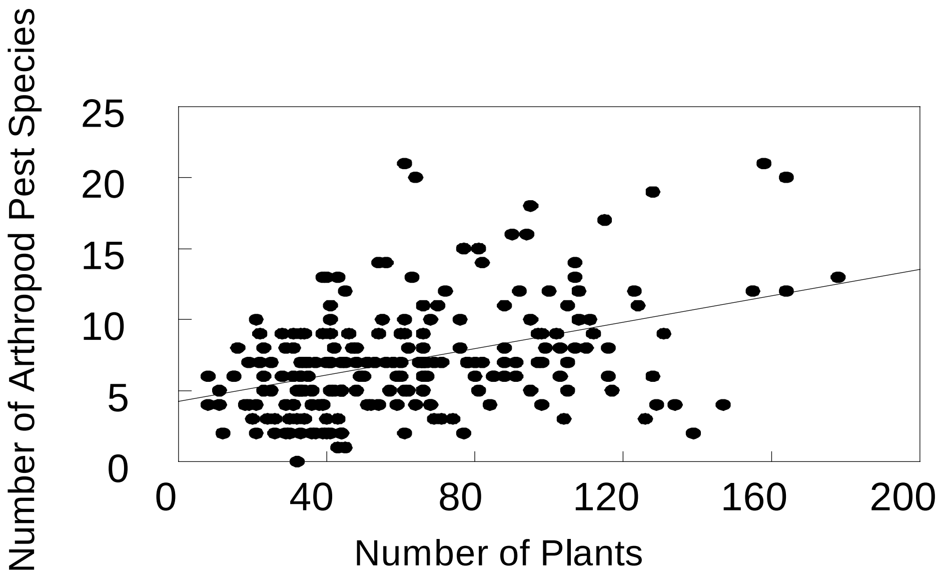

Figure 1: Relationship between the number of plants in a landscape and the number of arthropod pest species associated with them. The linear regression was significant at the P = 0.001 and the regression equation was y = 0.047 x + 4.14 where y = number of pest species and x = total number of plants.

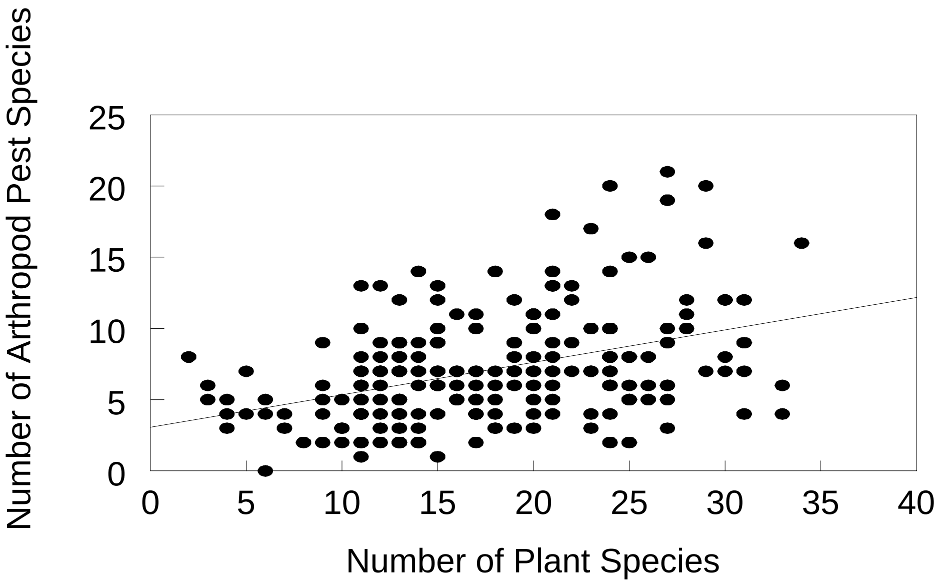

Figure 2: Relationship between the number of plant species in a landscape and the number of arthropod pest species associated with them. The linear regression was significant at the P = 0.001 and the regression equation was y = 0.227 x + 3.08 where y = number of pest species and x = number of plant species.

We pooled data from all four studies to investigate the relative abundance of different plant genera in the landscape. We found that *Rhododendron* was by far the most common woody plant used in Maryland landscapes (Figure 3). However, no relationships existed between the commonness of a plant taxon in the landscape and its frequency of being attacked by pests (Spearman Rank Correlation, $r_s = -0.026$, $p > 0.05$). Common genera of plants were just as likely to incur arthropod problems as rare ones (Table 2).

Table 2: Five most pest prone trees and shrubs found in 100 Maryland landscapes in 1982. Percentages greater than 100% indicate multiple problems on every plant examined.

Plant	% of plants with problems
Tree	
Peach	110
Crabapple	78
Apple (fruit)	67
Flowering cherry	31
Dogwood	26
Shrub	
Firethorne	67
Lilac	60
Boxwood	43
Rose	37
Euonymous	36

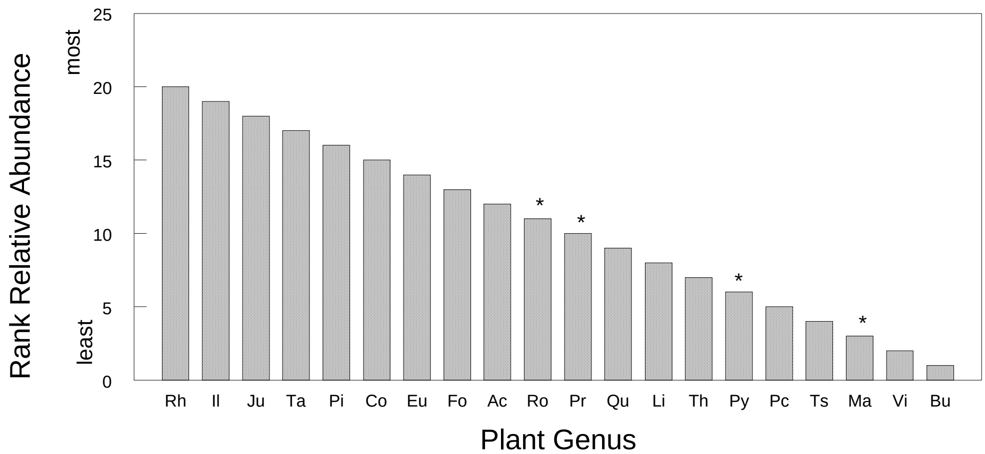

Figure 3: Relative abundance of twenty most common genera of woody plants found in residential landscapes in Maryland. Rh = Rhododendron, Il = Ilex, Ju = Juniperus, Ta = Taxus, Pi = Pinus, Co = Cornus, Eu = Euonymus, Ac = Acer, Ro = Rosa, Pr = Prunus, Qu = Quercus, Li = Ligustrum, Th = Thuja, Py = Pyracantha, Pc = Picea, Fo = Forsythia, Ts = Tsuga, Ma = Malus, Vi = Viburnum, Bu = Buxus. Asterisk (*) identifies genera in the Rosaceae

However, regardless of their relative abundance in the landscape, plants in the family Rosaceae were significantly more likely to have arthropod pests than plants in other families. The four most pest prone genera found in all four studies were *Malus, Pyracantha, Prunus, and Rosa* (Figure 4).

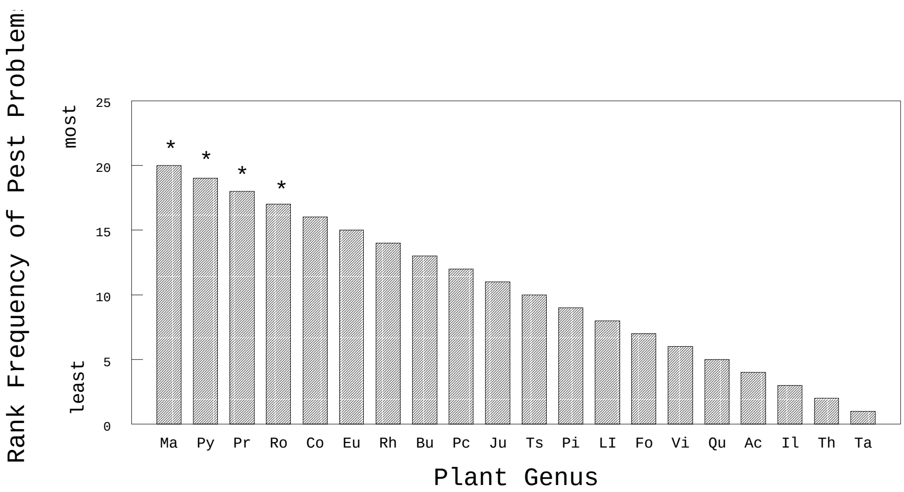

Figure 4: Rank of the frequency with which common genera of woody plants incur pest problems in residential landscapes in Maryland. Ma = Malus, Py = Pyracantha, Pr = Prunus, Ro = Rosa, Co = Cornus, Eu = Euonymus, Rh = Rhododendron, Bu = Buxus, Pc = Picea, Ju = Juniperus, Ts = Tsuga, Pi = Pinus, Li = Ligustrum, Fo = Forsythia, Vi = Viburnum, Qu = Quercus, Ac = Acer, Il = Ilex, Th = Thuja, Ta = Taxus. Asterisk (*) identifies genera in the Rosaceae.

Discussion

The fact that a relatively small number of arthropod taxa account for the majority of problems is good news for arborists and landscape managers. By learning to identify these key pests and understanding their biology, landscape managers can focus their training, monitoring, and intervention activities (Holmes and Davidson 1984, Raupp and Noland 1984, Harris et al 1999). The analysis of the relationships between the number of arthropod pests and the number plants and plant species in a landscape revealed several interesting findings. The slopes of regression equations for total number of plants and number of plant species on number of pests both differ significantly from one. The rate at which the number of pests accrues in a landscape is less that rate at which numbers of plants are added (Figure 1). This trend confirms the observation that many plants in every landscape lacked any insect or mite pests for the duration of the study. The rate at which the number of pests increased in a landscape was also significantly less than the rate at which plant species are added (Figure 2). This pattern likely reflects an important relationship between arthropod pests and their host plants. Several earlier studies established the fact that some plants, key plants, were likely to be attacked by pests while others were less so (Raupp and Noland 1984, Holmes and Davidson 1984, Raupp et al. 1985, Ball 1987). The relative absence of arthropod pests on many common woody plants likely causes the relationship between number of plant species and number of pest species to be less than one to one. The mechanism underlying this pattern remains unkown. However, it is generally believed that herbivorous arthropods are relatively specialized in their dietary breath eating relatively few taxa of plants (Bernays and Chapman 1994). There is strong evidence for this trend in landscapes where many of the key pests such as lace bugs, armored scale insects, aphids, defoliating caterpillars and sawflies, and borers tend to have relatively restricted host ranges (Holmes and Davidson 1984, Raupp and Noland 1984, Ball 1987, Johnson and Lyon 1988). Increasing the taxonomic diversity of a landscape increases the number of pests that will be found in a site but the rate at which pests accumulate is far less than the rate at which plants or plant species are added (Shrewsbury et al. in prep.). There is increasing evidence that key pests are less likely to reach outbreak levels in diverse rather than simple landscapes (Hanks and Denno 1993, Balder et al. 1999, Shrewsbury in prep).

Landscape designers and managers should be aware that the commonness of a plant in a landscape does not necessarily correlate with the likelihood that it will be attacked by pests. Our analysis reveals that there is no relationship between the generic abundance of a plant taxon and propensity for harboring pests. Whether this relationship also holds at the level of plant species or cultivars is unknown. The occurrence of pests on landscape plants seems much more strongly tied to the taxonomic composition of the plants found in the landscape. In our studies, plants in the rose family were much more likely to incur problems than any other family of common landscape plant (Figure 4). The mechanism underlying this phenomenon is unknown.

However, it is possible that through their long history of cultivation by man for the production of edible fruit, that at least some taxa of rosaceous plants such as *Malus*, *Prunus*, and *Rosa* some of the naturally occurring resistance factors may have been bred out and lost. This could predispose some genera of the Rosaceae to arthropod attack thereby elevating them to the level of key plants.

Summary

The findings of previous researchers and those presented here can be incorporated into IPM and PHC programs and landscape design in the following way. First, through careful record keeping mangers can define a relatively short list of arthropod pests that cause the majority of problems in the landscape. These are the key pests and form the basis for training, monitoring and intervention activities. In a similar way a relatively small number of plants, key plants, harbor a disproportionately large number of pests. In the mid – Atlantic region of the United States plants in the family Rosaceae are among the most pest prone. At the time of landscape design and installation these plants should be avoided or resistant cultivars should be used. For existing landscapes key plants should be identified for they will be the focus of monitoring and intervention activities. We have shown that landscapes containing many plants and plant species will tend to have more pest species than those with fewer plants or species of plants. We caution that while we demonstrated relationships between numbers of pests and plants and species we did not attempt to quantify the levels of damage pests were causing. In most cases pest species were not at levels that warranted intervention. On the contrary, there is mounting evidence that the severity of pest damage will be reduced as plant diversity in landscapes is increased **(**Hanks and Denno 1993, Balder et al. 1999, Shrewsbury in prep.). Hopefully, this information will be useful in designing landscapes that are more sustainable and making monitoring and intervention action more efficient and effective.

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Investigation on the population of beneficial organisms on urban trees*

Introduction

Integrated systems in plant protection are good practice in modern cultivation of agriculture and horticulture, biological methods are a successful part of them. Beneficial organisms are very common in natural ecosystems, but in urban areas there is only a small knowledge of their occurrence, spectrum and importance (BALDER et al. 1996). The key factors are not easy to understand. In gardens and parks, but on street trees too, are no economic obligations, so integrated systems in plant protection with the help of beneficial organisms should be developed and proved. So in a program urban stands with *Tilia* spec. were investigated to understand the complex urban ecosystems.

Materials and methods

For two years leaves of lime-trees were collected from different street stands (avenues, main streets, side streets with a different vegetation, parks et al.) in Berlin and Braunschweig during the whole vegetation period in short intervals. In the laboratory the areas of leaves were determined, the symptoms analysed, pests and beneficial organisms counted and differentiated with the help of specialists. In addition branches were beaten and the organisms caught in a cotton sack for determination. In July and September the crowns of the lime-trees were investigated in a different height.

Results

1. Spectrum of beneficial organisms

The spectrum of beneficial organisms was very similar in the tested fields on lime-trees in 1998 and 1999, although the population of aphids and mites was higher in the first year than in the following one. The spectrum of the organisms was very wide. There were only some specialists, for example *Stethorus punctillum* Weise feeding exclusively on mites, mostly the found beneficial organisms were polyphag (Tab. 1).

Table 1: Spectrum of beneficial organisms on lime-trees in urban areas and their food

Spectrum of beneficial organisms	Main food
spiders (Araneae)	flies, midges, aphids and other small insects
predaceous mites (Trombididen)	mites, thrips, young caterpillars, aphids
predatory mites (Phytoseiidae)	mites, thrips, pollen, spores
earwigs (Dermaptera)	mites, aphids and other small insects
predatory thrips (*Aelothrips* sp.)	aphids, mites, white flies, scales
predatory bugs (Heteroptera)	mites, thrips, young caterpillars, aphids, flies, beetle larvae
lacewing predators (Chrysopidae)	larvae: mites, thrips, young caterpillars, aphids adults: predator, nectar, pollen, honey-dew
ladybirds (Coccinellidae)	aphids, scales, mites, pollen
Stethorus punctillum Weise	mites
parasitoids	nectar, honey-dew, saps, body juice of hosts

The identification showed that different ladybirds were present on lime-tree stands in urban areas (Tab. 2). Frequently *Adalia bipunctata* and *Propylaea quatuordecimpunctata* were observed. Furthermore *Scymnus* sp. was found, but not differentiated. Only *S. punctillum* and *Tea vigintiduopuctata* are living monophag, the other ladybirds are polyphag.

* supported from the German Ministry of Food, Agriculture and Forestry, Bonn

Table 2: Ladybirds collected on lime-tree stands in urban areas

Name	Biotope
Adalia bipunctata Mulsant	trees and bushes
Propylaea quatuordecimpunctata Mulsant	bushes, corn and other light vegetation
Calvia quatuordecimguttata Mulsant	bushes, edges of forest stands
Synharmonia conglobata Gglb	broad-leaved trees (fruit-trees, *Populus* spec.)
Stethorus punctillum Weise	broad-leaved and fruit-trees
Adalia decempunctata Mulsant	broad-leaved trees, meadows
Thea vigintiduopunctata Mulsant	bushes and trees (often on *Quercus* spec.), meadows,
Tytthaspis sedecimpunctata Crotch	dry grass areas, hot wastelands

The collected predatory bugs belong to the families Anthocoridae and Miridae (Tab. 3). The collected bugs are living zoophag or phytophag. The first species are not specialized in their biotopes and their food. Mostly the species are very common, for example *Anthocoris nemoralis*. Only some species such as *Anthocoris sibiricus* are rare. Their population was different in the years. Some species were found only in one year, others distinguished in the population density. Very often *Deraeocoris lutescens* (Schill.) was found, *Deraeocoris flavilinea (*Costa) was present frequently in 1998, but not in the following year.

Table 3: Predatory bugs collected on lime-tree stands in urban areas (Berlin)

Family	Species	1998	1999
Anthocoridae	*Anthocoris nemoralis* F.	+	-
	Anthocoris sibiricus H.S.	+	-
	Anthocoris nemorum (L.)	-	+
	Anthocoris confusus Reut.	-	+
	Orius vicinus (Rib.)	+	
Miridae Lebensweise:	*Deraeocoris lutescens* (Schill.)	+	+
	Deraeocoris flavilinea (Costa)	+	+
	Campyloneura virgula (H.S.)	+	+
	Heterotoma planicornis (Pallas)	+	-
	Phytocoris tiliae F.	+	+
	Phytocoris populi (L.)	-	+
	Blepharidopterus angulatus Fall.	-	+
	Pilophorus perplexus Dgl.Sc.	-	+
	Malacocoris chlorizans Panz.	-	+
	Phylus melanocephalus (L.)	-	+
	Megacoelum infusum H.S.	+	-
Miridae Lebensweise:	*Lygocoris viridis* Fall.	+	+
	Lygus rugulipennis Popp.	-	+
	Orthotylus nassatus F.	+	+
	Orthotylus tenellus Fall.	-	+
	Orthotylus viridinervis Kb.	-	+
	Pinalitus cervinus H.S.	+	+
	Reuteria marqueti Put.	+	+
	Kleidocerys resedae Panz.	-	+
	Psallus lepidus Fb.	-	+
	Psallus perrisi Muls.	-	+
	Stenoderma virens (L.)	-	+
	Cyrtopeltis geniculata Fieb.	+	-

For special interest is the population of predatory mites. All collected mites belong to Phytoseiidae. The spectrum of predatory mites on lime-trees is wide, very often *Euseius finlandicus* was found. This mite is widespread and common on fruit-trees, berry bushes and grapes. Furthermore two predatory mites were found in Germany for the first time: *Seiulus aceri* (Collyer) and *Anthoseius foenilis* (Oudemans). The proof of *S. aceri* is the first observation in urban areas world-wide. *S. aceri* was frequent especially on *Tilia cordata*. The mite prefers warm climate-regions (such as South-England, Crimea) and lives normally on *Acer*, *Prunus*, *Juglans* and *Ribes* sp. (KARG, 1994).

Table 4: Predatory mites collected on lime-tree stands in urban areas (differentiated by KARG, 1999)

Name	Biotope	1998	1999
Amblyseius alpinus (Schweizer)	leaf straw, herbs, broad-leaved trees	-	+
Amblyseius andersoni (Chant)	berry bushes, broad-leaved trees	-	+
Amblyseius barkeri (Hughes)	herbs, broad-leaved trees	+	-
Anthoseius foenilis (Oudemans)*		-	+
Euseius finlandicus (Oudemans)	fruit-trees, berry bushes, vineyards	+	+
*Kampimodromus aberrans (*Oudemans) (Oudemans)	lime-trees, grapes, *Coryllus, Salix*	+	-
Metaseiulus longipilus (Nesbitt)	fruit-trees, broad-leaved trees, grapes	+	+
Paraseiulus soleiger (Ribaga)	orchards, vineyards	+	+
Paraseiulus triporus (Chant et Shaul)		-	+
Seiulus aceri (Collyer)*	broad-leaved trees	+	+
Seiulus tiliarum (Oudemans)	fruit-trees, berry bushes, vineyards	+	+
Typhlodromus pyri (Scheuten)	broad-leaved trees, grapes, herbs	-	+

*first proof for Germany!

2. Spreading of beneficial organisms on urban stands

Tree stands in urban areas are very different. Trees in parks and gardens are surrounded by a various vegetation, in side streets there may be some small gardens and planted tree-grids, main streets are normally formed as avenues without any other vegetation. Therefore the conditions for beneficial organisms are different, too, for example the microclimate, the food, the hiding-places. But the comparison of lime-tree stands in the centre of Berlin, in new districts, suburbs and garden cities showed, that the population of predatory mites is more or less similar (Fig. 1). Only the beneficial organisms were found in a higher density in side streets and parks, but the trees in the park areas are older, so a comparison is difficult (Fig. 2).

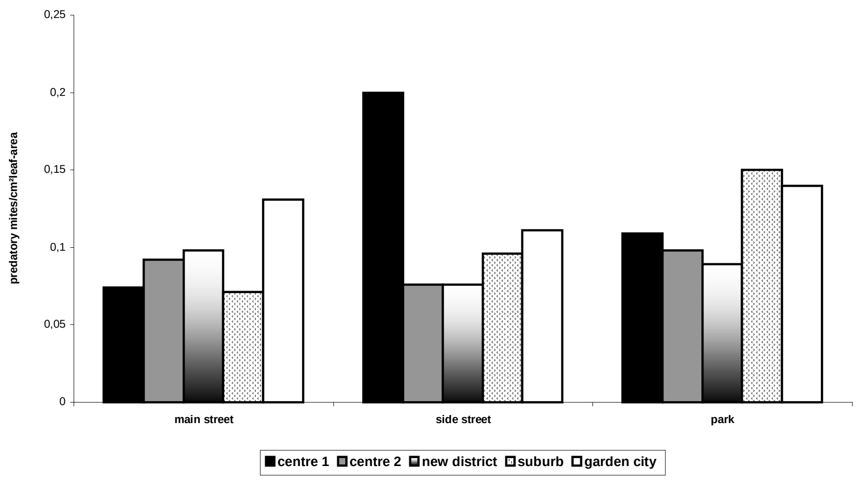

Figure 1: Population of predatory mites on different lime-tree stands in Berlin, 1997

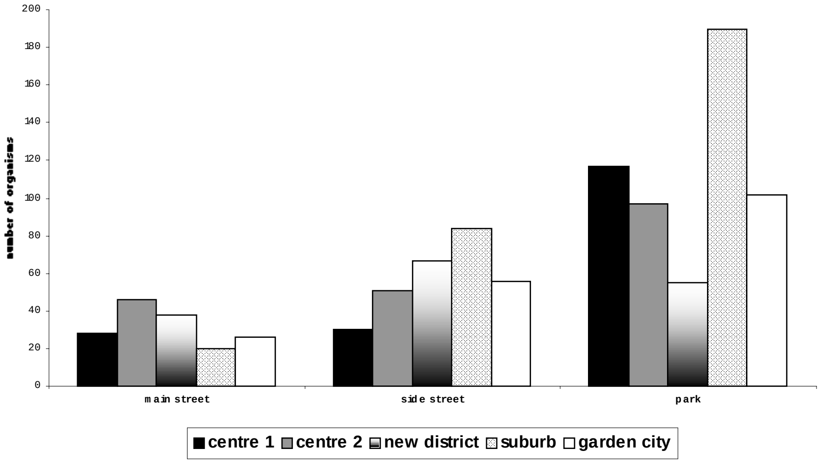

Figure 2: Population of beneficial organisms on different lime-tree stands in Berlin, 1997

A study of the situation in different parts of the crown showed, that especially predatory mites were widespread both in the upper and the lower crown (Fig. 3). They were present in every year independent from the climate and the population of the spider mites. Furthermore a first regional study about the populations at comparable lime-tree stands in Braunschweig and Berlin came to the result, that most of the described species of beneficial organisms were present (Fig. 4).

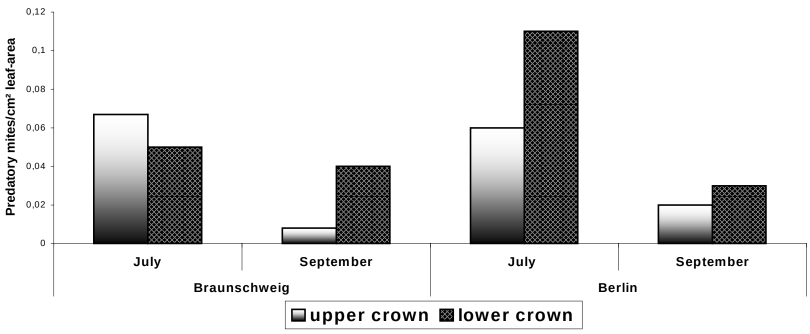

Figure 3: Predatory mites on different parts of the crown on lime-trees at various periods of assessment, 1999

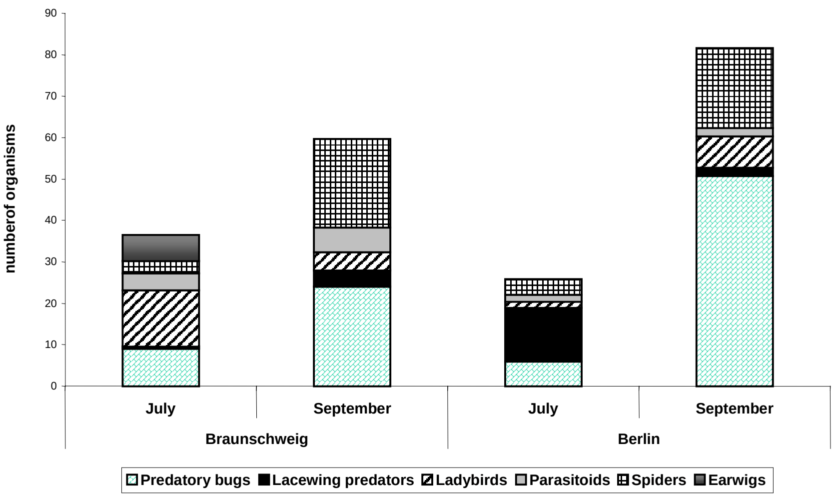

Figure 4: Quantity of beneficial organisms in different towns at various periods of assessment on lime-trees, 1999

Discussion

Methods of biological plant protection are a part of a modern cultivation system in agriculture and horticulture. In landscape as well as in tree care there is only a small knowledge of the natural existence of predators in urban areas and the possibilities of a support. The present study emphasizes first results that beneficial organisms are normally very widespread in cities (BALDER et al., 1996; 1999; LONGARDT et al., 1991). At the lime-trees the population of *Eotetranychus tiliarum* and predators was investigated over some years intensively.

Furthermore it is not a big surprise that the spectrum of the predators has a wide variety and that first proofs of organisms in the investigated areas could be done. Especially predatory mites are present in the whole crown of big trees and in various vegetation without the presence of their prey. Therefore they can influence the development of pests every year in spring, because they will be at first on the trees. It depends on abiotic and biotic factors in every location whether they can control the pest within a vegetation period or not. The main abiotic influencing factors seem to be temperature, humidity, ventilation, time of sunshine and the landscape of the stands. Biotic factors are the quantitative relation between prey and predator, the age and the variety of tree. The field studies showed, that not the quantity of predators was decisive for the control of spider mites but the efficiency of predatory mites. The complex mechanism is unknown yet (BALDER et al., 1999; SCHNEIDER et al. 2000).

More investigations are necessary to understand all influencing factors on the efficiency of predators in urban ecosystems with a special view to further the predators. This means to optimize plant production in the nursery, an ecological landscaping and a knowledge of these connections in tree care. So the creative research has to go on for a practical use of natural enemies in urban areas. This should be very important because the use of pesticides for a direct control of pests in cities will be more difficult in future.

Summary

The population of beneficial organisms in urban areas was studied in Berlin and Braunschweig. A comparison of different lime-tree stands showed that predators are very widespread in both cities. The spectrum has a wide variety and is similar on avenues without other vegetation as well as in parks and side streets. Mostly the population density of predators in parks is the highest, only predatory mites are nearly at the same level on every investigated location. Furthermore they lived in the upper and lower part of the crown without any correlation to spider mites. The predator mites *Anthoseius foenilis* (Oudemans) and *Seiulus aceri* (Collyer) were collected in Germany for the first time. The results indicate that beneficial organisms play an important role in the control of pests in urban areas and that their activities should be improved. Studies are necessary to optimise planning, planting and care of tree stands in cities for a stabilisation of urban ecosystems.

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The non–poroid wood–inhabiting and wood–destroying macromycetes occurring on native woody plants in urban environment of Slovakia

Introduction

The woody plants are significant components of urban environment. They create relaxation zones, reduce temperature, function as dust filters and noise barriers. To fill the required functions the woody plants need protection and care. They are exposed for negative influence of many stress factors (industrial emissions, mechanical disturbance), what brings down the woody plants resistance from pests and diseases. The mechanical injures work often as a mycosis entrance. The attacked woody plants are sources of infection for healthy trees and can be dangerous for people too (falling branches). There are many fungi species attacking woody plants. It is possible to divide them into the groups according to definite criteries. We deal with wood–inhabiting and wood–destroying non–poroid macrofungi in this work. The objective was to state the occurrence and distribution of these fungi on native woody plants in seats of Slovakia and host relationship of these species.

Material and methods

The results come from author's research during period 1982 – 1989. The macrofungi were collected from living trees (trunks, trunk cavities, branches) as well as from stumps and dead trees. Most records were got during the summer and autumn months but extensive research covered the whole year. One record (*Lentinus degener*) is taken from Kotlaba's treatment (Kotlaba and Pouzar, 1967). The names in the list of fungi species and in the table are arranged alphabetically. The nomenclature according Marhold and Hindák (1998) is used. The components of records in the list are following:

Brief description of a find place.

Distribution – seat names with finds number for each of them are given. There are names of district where the seat is located in the gaps.

Hosts – hosts with finds number (in the gaps) for each of them are given. They are determined at the species or lower level. In some cases there were possible to determine only the genus of hosts.

The obtained data were analysed and ranged into the table according to relations: fungi species – host woody plant species number and occurrence seat number (Table 1). The seats where the fungi occurred are marked on the map of Slovakia (Fig. 1). The found fungi species number defines the size and form of the sign on the map.

Results

There were recorded 218 finds of 40 fungi taxa occurring on 39 native woody host plant taxa in 52 towns and villages of Slovakia. In generally, the most common species was *Schizophyllum commune* (50 finds).This species was most distributed (in 25 seats) too. The other very often found species were *Stereum hirsutum* (33 finds in 19 seats) and *Chondrostereum purpureum* (27 finds in 18 seats). 17 species were found only one time. The highest host species number was attacked by *Radulomyces confluens* (10 host species), *Stereum hirsutum* (9 host species) and *Chondrostereum purpureum* (8 host species).The highest fungi species numbers were identified on *Tilia cordata* (14 species) and *Salix alba* (10 species). The richest fungi species spectrum was found in the towns of Nitra (9 species), Košice (8 species) and Michalovce (8).

Table 1: Fungi taxa survey

Taxon	**Host species number**	**Occurrence seat number**	**Total finds number**
Heterobasidiomycetes			
Auriculariales			
Hirneola auricula–judae (Bull.) Berk.	2	4	4
Tremellales			
Tremella mesenterica Retz.	4	6	6
Homobasidiomycetes			
Aphyllophorales			
Byssomerulius corium (Pers.) Parmasto	1	1	1
Coniophora puteana (Schumach.) P. Karst.	3	2	3
Dichostereum granulosum (Pers.) Boidin et Lanq.	1	1	1
Gloiothele lactescens Hjortstam	1	1	1
Hyphoderma mutatum (Peck) Donk	1	2	2
Hyphoderma puberum (Fr.) Wallr.	1	1	1
Hyphoderma setigerum (Fr.) Donk	2	2	2
Hyphodontia alutaria (Burt) J. Erikss.	1	1	1
Hyphodontia sambuci (Pers.) J. Erikss.	5	6	7
Hyphodontia sp.	1	1	1
Hyphochnicium bombycinum (Sommerf.) P. Karst.	2	2	3
Chondrostereum purpureum (Pers.) Pouzar	8	18	27
Mycoacia sp.	1	1	1
Peniophora quercina (Pers.) Cooke	1	1	1
Peniophora sp.	1	1	1
Phanerochaete laevis (Pers.) J. Erikss. et Ryvarden	1	1	2
Phlebia radiata Fr.	1	1	1
Radulomyces confluens (Fr.) M. P. Christ.	10	10	16
Schizophyllum commune Fr.	7	25	50
Steccherinum ochraceum (Pers.) Gray	2	2	2
Stereum hirsutum (Willd.) Gray	9	19	33
Stereum sanquinolentum (Alb. et Schwein.) Fr.	2	2	2
Hymenochaetales			
Hymenochaete rubiginosa (J. Dicks.) Lév.	1	1	1
Agaricales			
Armillaria mellea (Vahl.) P. Kumm s. str..	2	2	2
Coprinus disseminatus (Pers.) Gray	1	1	1
Coprinus micaceus (Bull.) Fr.	2	2	2
Flammulina velutipes (Curtis) Singer	6	8	11
Lentinus degener Kalchbr.	1	1	1
Lentinus tigrinus (Bull.) Fr.	2	3	3
Pholiota adiposa (Batsch) P. Kumm.	2	2	2
Pholiota aurivella (Batsch) P. Kumm	1	1	3
Pholiota populnea (Pers.) Kuyper et Tjall. – Beuk.	3	7	8
Pholiota sp.	1	1	1
Pholiota squarrosa (Weigel) P. Kumm.	1	1	1
Pleurotus dryinus (Pers.) P. Kumm.	2	2	3
Pleurotus ostreatus (Jacq.) P. Kumm.	7	4	8
Pleurotus sp.	1	1	1
Xerula radicata Relhan Dörfelt	1	1	1

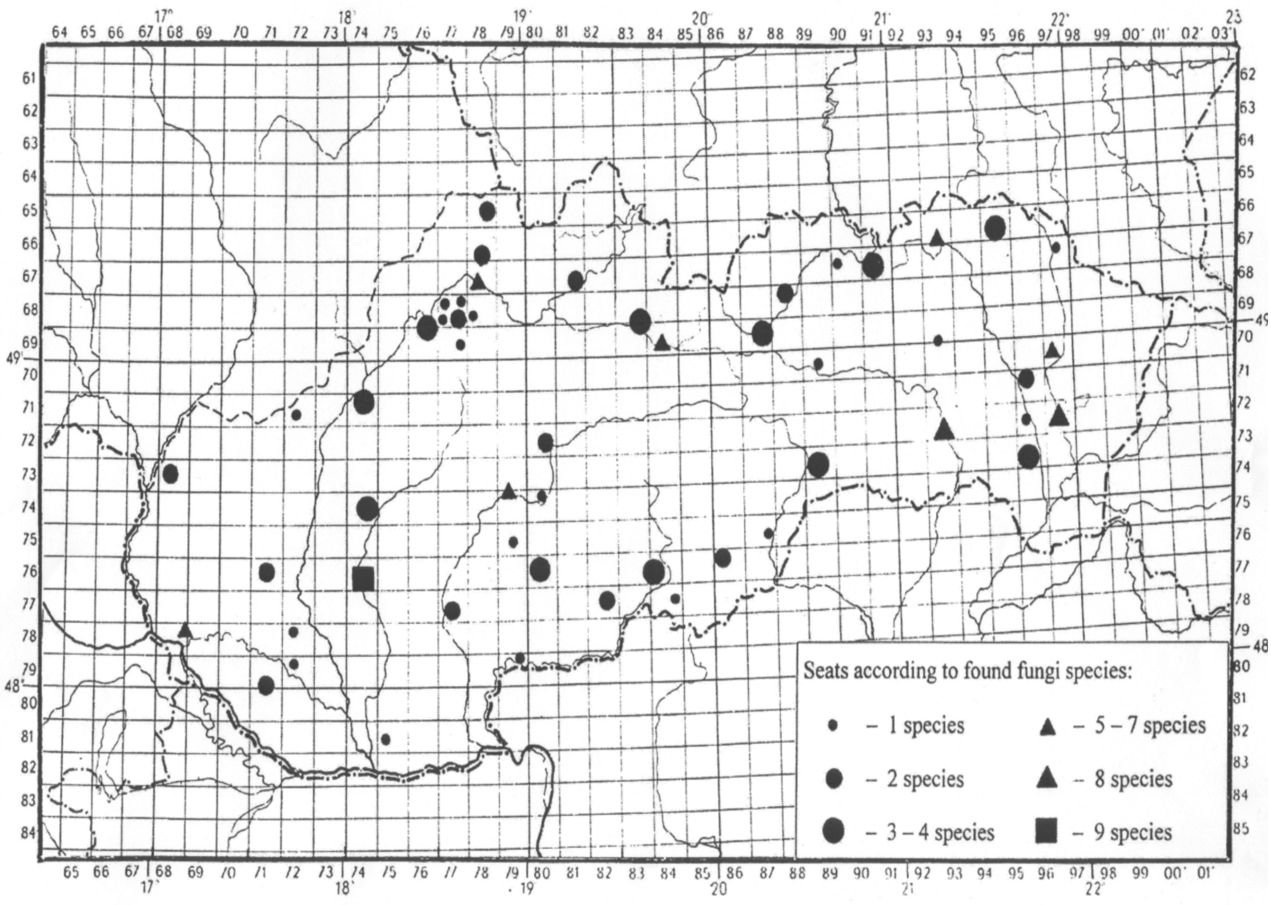

Fig. 1. Towns and villages where non – poroid fungi were recorded.

<u>List of the fungi taxa</u>

<u>Heterobasidiomycetes</u>

<u>Auriculariales</u>

***Hirneola auricula– judae* (Bull.) Berk.**

It was collected on a stump (1 record) and on the trunks of living trees (3 records)

Distribution: single finds in Humenné, Košice, Žiar nad Hronom, Žilina.

Hosts: single finds on *Acer pseudoplatanus*, *Platanus x acerifolia*, unknown (2).

<u>Tremellales</u>

***Tremella mesenterica* Retz.**

Usually as a saprophyte on stumps, dead branch or wounded trunk but sometimes on living trunks (2 finds). Distribution: single finds in Dolná Strehová (Vel'ký Krtíš), Kysucké Nové Mesto, (Čadca), Levice, Michalovce, Rajecké Teplice (Žilina), Trebišov. Hosts: single finds on *Alnus glutinosa*, *Fraxinus excelsior*, *Platanus x acerifolia*, *Tilia cordata*, unknown (2 finds).

<u>Homobasidiomycetes</u>

<u>Aphyllophorales</u>

***Byssomerulius corium* (Pers.) Parmasto**

The fruitbody was found on a dead branch. Distribution: Žilina: 1. Hosts: *Acer platanoides* (1).

***Coniophora puteana* (Schumach.) P. Karst.**

It was found as a saprophyte of stump and injured trunks. Distribution: Nitra: 1, Trenčín: 2.

Hosts: single finds on *Alnus glutinosa*, *Tilia cordata*, *Alnus sp*.

***Dichostereum granulosum* (Pers.) Boidin et Lanq.**

The only one record from a trunk cavity of a living tree. Distribution: Plaveč (Stará L'ubovna): 1.

Hosts: *Tilia cordata* (1).

***Gloiothele lactescens* Hjortstam**

Found on a stump. Distribution: Michalovce: 1. Hosts: uknown (1).

***Hyphoderma mutatum* (Peck) Donk**

A typical saprophyte found only on dead branches. Distribution: single finds in Humenné, Michalovce. Hosts: *Tilia cordata* (2).

***Hyphoderma puberum* (Fr.) Wallr.**

A single collection from a small trunk cavity. Distribution: Kysucké Nové Mesto (Čadca): 1.

Hosts: *Crataegus laevigata* cv. Paul Scarlet (1).

***Hyphoderma setigerum* (Fr.) Donk**

The collection derive from a wounded trunk of a living tree and from a dead branch of living tree. Distribution: single finds in Bratislava, Humenné. Hosts: single finds on *Carpinus betulus*, *Tilia cordata*.

***Hyphodontia alutaria* (Burt) J. Erikss.**

It was found on a wounded living trunk. Distribution: Stara L'ubovna: 1. Hosts: *Tilia cordata* (1).

***Hyphodontia sambuci* (Pers.) J. Erikss.**

A typical saprophyte of rotten tree trunks and branches. Distribution: Košice: 2, single finds in Kežmarok (Poprad), Liptovský Mikuláš, Poprad, Rožnava, Žilina. Hosts: *Sambucus nigra* (2), *Tilia x euchlora* (2), single finds on *Acer pseudoplatanus*, *Salix alba* cv. Tristis, *Tilia cordata*

***Hyphodontia* sp.**

The record derives from a conifer stump. Distribution: Michalovce: 1. Hosts: unknown (1).

***Hypochnicium bombycinum* (Sommerf.) P. Karst.**

Found on both bark and wood of living tree trunks. Distribution: Fil'akovo (Lučenec): 1. Košice: 2. Hosts: *Acer pseudoplatanus* (2), *A. campestre* (1).

***Chondrostereum purpureum* (Pers.) Pouzar**

10 records derive from living trunks and branches of trees. It was found also as a saprophyte of dead trunks and stumps. Distribution: Banská Bystrica: 1, Bardejov: 1, Bratislava: 1, Humenné: 1, Košice: 4, Kúty (Senica): 1, Liptovský Hrádok (Liptovský Mikuláš): 2, Liptovský Mikuláš: 1, Michalovce: 1, Nitra: 3, Prešov: 2, Svidník: 3, Tren Trenčín: 1, Trnava: 1, Vranov nad Topl'ou: 1, Žiar nad Hronom: 1, Žilina: 2. Hosts: *Salix alba* cv. Tristis (7), single finds on *Acer platanoides*, *A. pseudoplatanus*, *Betula pendula*, *Carpinus betulus*, *Fagus sylvatica*, *Populus x canadensis*, *Sorbus aucuparia. Prunus sp*. (3), *Acer sp*.(2), *Betula sp*.(2), single finds on *Alnus* sp., *Fagus* sp., *Populus* sp., *Salix sp*., unknown (2)

***Mycoacia* sp.**

Found on a dead branch. Distribution: Košice: 1. Hosts: *Salix alba* cv. Tristis (1).

***Peniophora quercina* (Pers.) Cooke**

On a fallen branch. Distribution: Čany: 1. Hosts: unknown (1).

Peniophora sp.

On dead branches in living trees. Distribution: Považská Bystrica: 2. Hosts: *Prunus sp*. (2).

***Phanerochaete laevis* (Pers.) J. Erikss. et Ryvarden**

A single collection from the base of a dead trunk. Distribution: Plaveč (Stará L'ubovna): 1.

Hosts: *Tilia cordata* (1).

***Phlebia radiata* Fr.**

On bark of a living tree trunk. Distribution: Poprad: 1. Hosts: *Sorbus aucuparia* (1).

***Radulomyces confluens* (Fr.) M.P.Christ.**

The sporocarps occur predominantly on thin dead branches of living trees. Its were collected also on a living trunk cavity, on living damaged trunks as well as in the ramification place of a living tree trunk. Distribution: Bratislava: 1, Dolný Kubín: 1, Humenné: 1, Lučenec: 1, Nitra: 1, Poprad: 1, Považská Bystrica: 7, Rožnava: 1, Čany: 1, Spišská Nová Ves: 1,

Hosts: single finds on *Acer campestre*, *A. platanoides*, *A. pseudoplatanus*, *Crataegus laevigata* cv. Paul Scarlet, *Fagus sylvatica*, *Fraxinus excelsior*. *Salix alba* cv. Tristis, *Sorbus aria*, *Tilia platyphyllos*, *Quercus robur*, *Prunus* sp. (6).

***Schizophyllum commune* Fr.**

This species is fairly common. The sporocarps develop on both tree trunks and branches. The fungus is economically very harmful, because limetrees are ones of the favourite in our conditions. Distribution: Bardejov: 4, Bratislava: 14, Čadca: 1, Dunajská Streda: 1, Galanta: 2, Hurbanovo (Komárno): 2, Košice: 3, Krupina (Zvolen): 1, Levice: 1, Liptovský Hrádok (Liptovský Mikuláš): 1, Lučenec:1, Medzilaborce (Humenné): 1, Michalovce: 1, Nitra: 4, Plaveč (Stará L'ubovna): 3, Rimavská Sobota: 1, Rožnava: 1, Svidník:1, Šahy (Levice): 3, Šafárikovo (Rimavská Sobota): 1, Trebišov: 1, Trnava: 1, Vranov nad Topl'ou: 3.

Hosts: *Tilia cordata* (36), *Tilia platyphyllos* (4), single finds on *Fagus silvatica*, *Sorbus aucuparia. Fraxinus sp*.(1), *Prunus sp*.(1), *Tilia sp*.(2), unknown (4).

***Steccherinum ochraceum* (Pers.) Gray**

A less abundant fungus, found twice on dead branches, standing or fallen. Distribution: single finds in Bardejov, Dolná Strehová (Vel'ký Krtíš). Hosts: *Salix fragilis* (1), unknown (1).

***Stereum hirsutum* (Willd.) Gray**

A polyphagous harmfull parasite of mechanically damaged trees. As a saprophyte of different tree parts is also abundant. Distribution: Bardejov:1, Bratislava: 1, Dolný Kubín: 1, Jasenové (Žilina): 1, Košice: 2, Krupina (Zvolen): 2, Liptovský Hrádok (Liptovský Mikuláš): 1, Lučenec: 5, Nitra: 1, Parchovany (Trebišov): 1, Poluvsie (Žilina): 1, Poprad: 1, Považská Bystrica: 1, Rimavská Sobota: 1, Svidník: 1, Čany: 3, Trebišov: 1, Zvolen: 6, Žiar nad Hronom: 2.

Hosts: *Carpinus betulus* (6), *Alnus glutinosa* (2), single finds on *Acer pseudoplatanus*, *Fraxinus excelsior*, *Pyrus communis Sorbus aria*, *Sorbus aucuparia*, *Ulmus carpinifolia*, *Ulmus glabra*. *Prunus* sp. (12), single finds on *Alnus* sp., *Malus* sp., *Quercus* sp., unknown (3).

***Stereum sanquinolentum* (Alb. et Schwein.) Fr.**

A rare species in the urban environment, found twice on stumps. Distribution: single finds in Liptovský Hrádok (Liptovský Mikuláš), Liptovský Mikuláš. Hosts: *Picea abies* (1), *Pinus sp*.(1).

Hymenochaetales

***Hymenochaete rubiginosa* (J.Dicks.) Lév.**

The fruitbodies were found only once during our study on a timber. Distribution: Moravské Lieskové (Trenčín): 1. Hosts: unknown (1).

Agaricales

***Armillaria mellea* (Vahl.) P. Kumm s. str.**

It was found as a parasite of a living trunk and as a saprophyte of a stump. Distribution: single finds in Michalovce, Trenčín. Hosts: *Salix alba* cv. Tristis (1), *Fraxinus sp*.(1).

***Coprinus disseminatus* (Pers.) Gray**

It was found as a saprophyte of a stump. Distribution: Liptovský Hrádok (Liptovský Mikuláš): 1.

Hosts: *Quercus sp*.(1).

***Coprinus micaceus* (Bull.) Fr.**

It was found as a saprophyte of rotten trunk and stump. Distribution: single finds in Liptovský Hrádok (Liptovský Mikuláš), Žilina. Hosts: *Tilia x euchlora* (1), *Fagus sp* (1).

***Flammulina velutipes* (Curtis) Singer**

5 collections derive from stumps. The other ones derive from hardly wounded trunks of living trees and from the rot branches in living trees. Distribution: Bratislava:1, Jasenové (Žilina): 1, Nitra: 2, Porúbka (Žilina): 1, Rajec nad Rajχiankou (Žilina): 1, Zbynov (Žilina): 1, Žiar nad Hronom: 1, Žilina: 3. Hosts: *Tilia x euchlora* (3), *Salix alba* (2), single finds on *Tilia cordata*, *T. plathyphyllos. Salix* sp.(3), *Acer sp*.(1).

***Lentinus degener* Kalchbr.**

This record derives from field notes of František Kotlaba (Praque) covering the period 1953 – 1989 (Kotlaba and Pouzar, 1967). Distribution: Michalovce: 1. Hosts: *Populus alba* (1).

***Lentinus tigrinus* (Bull.) Fr.**

Two finds derives from a stump and a rot living trunk. The exact habitat of the third find is unknown. Distribution: single finds in Bratislava, Lučenec, Tomášikovo (Galanta).

Hosts: *Salix alba* cv. Tristis (1), unknown (2).

***Pholiota adiposa* (Batsch) P. Kumm.**

On wounded tree trunks. Distribution: Bardejov: 1, Žilina: 1. Hosts: single finds on *Acer platanoides*, *Tilia cordata*

***Pholiota aurivella* (Batsch) P. Kumm.**

On wounded tree trunks. Distribution: Nitra: 3. Hosts: *Salix alba* cv. Tristis (3).

***Pholiota populnea* (Pers.) Kuyper et Tjall. – Beuk.**

The collections derives from both dead and living trees as well as from stumps and wooden product. Distribution: Banská Bystrica: 1, Bratislava: 1, Dunajská Streda:1, Komárno: 1, Košice: 2, Nitra: 1, Žiar nad Hronom: 1. Hosts: *Populus alba* (5), *Ulmus laevis* (1), *Populus sp*.(2).

***Pholiota squarrosa* (Weigel) P. Kumm.**

A parasite found at the base of a living trunk. Distribution: Banská Štiavnica (Žiar nad Hronom): 1. Hosts: *Tilia cordata* (1).

***Pholiota* sp.**

The record derives from a trunk cavity. Distribution: Považská Bystrica: 1.

Hosts: *Salix alba* cv. Tristis.

***Pleurotus dryinus* (Pers.) P. Kumm.**

A parasite found in a trunk cavity. Distribution: Čadca: 2, Kežmarok (Poprad): 1.

Hosts: *Tilia cordata* (2), *Sorbus aucuparia* (1).

***Pleurotus ostreatus* (Jacq.) P. Kumm.**

Six records derive from stumps. The sporocarps were also collected from mechanically damaged tree trunks (2 finds). Distribution: Bratislava: 1, Kúty (Senica): 1, Nitra: 4, Žiar nad Hronom: 2.

Hosts: single finds on *Alnus glutinosa, Fagus sylvatica, Fraxinus excelsior. Populus alba*, *P. x canadensis*, *Salix alba* cv. Tristis, *Tilia cordata*, unknown (1).

***Pleurotus* sp.**

A parasite found on a living tree trunk. Distribution: Krupina (Zvolen): 1.
Hosts: *Tilia cordata* (1).

***Xerula radicata* (Relhan) Dörfelt**

On a stump. Distribution: Liptovský Hrádok (Liptovský Mikuláš): 1. Hosts: *Quercus sp* (1).

Host species number, occurrence seat number as well as total finds number are briefly presented in table 1. *Schizophyllum commune, Stereum hirsutum*, *Armillaria mellea* s. str. and *Pholiota* sp. div. belong to the most harmful pathogens.

Discussion

The non–poroid fungi taxa grow largely as saprophytes in urban environment as well as in forest environment. As we have presented in the results, we range the species *Schizophyllum commune*, *Stereum hirsu-*

tum, *Armillaria mellea* s. str. and *Pholiota* sp. div. to the most harmful pathogens (from the woody plant protect point of view).

The *Schizophyllum commune* infection progress through the frost rents. Woody plants suffer from rot caused by these species along roads maintaining by salt sprinkle in winter (salt attack) and the woody plants which suffer by rainfall absence.

Stereum hirsutum penetrates into living woody plants through various mechanical injures (scratches, untreated lop surfaces and so on).

We range *Armillaria mellea* s. str. to much harmful rot originators too, opposing its poor abundance. It is possible the urban environment inhibits the fructification (fruitbody development).

On native woody plants in urban areas of Slovakia there were researched only polypores (*Polyporales s.l.*) (Gáper, 1996). There were recorded 476 finds of 63 polypores species here. 23 species of them are considered much harmful pathogens of woody plants opposing the poor abundance of some these species too.

In compare with polypores there is only approximately half finds number of non–poroid fungi taxa and only a few of them are really much harmful.

Conclusions

1. On 39 woody plant taxa in Slovakian urban areas 40 fungal non–poroid taxa were recorded.
2. The most abundant fungal species are following: *Schizophyllum commune* (50 finds), *Stereum hirsutum* (33 finds), *Chondrostereum purpureum* (27 finds) and *Radulomyces confluens* (16 finds).
3. *Schizophyllum commune*, *Stereum hirsutum*, *Armillaria mellea* s. str. and *Pholiota* sp. div. belong to the most harmful pathogens.

Abstract

The data about wood–destroying and wood–inhabiting fungi are presented in this work. There were found 40 taxa of non–poroid macromycetes occurring on 39 autochtonous woody plant taxa in the urban environment. The finds come from 52 seats (towns and villages) of Slovakia from 1982 – 1989. The found fungi species belong to 25 genera and 4 orders. Most often were attacked injured trees. The macromycetes occurred on trunks and branches of living trees and on trunks and dead branches. Most of the woody host plants were attacked by *Cerocorticium confluens* (10 host plant species) and *Stereum hirsutum* (9 host plants species) – they are polyphagous. The most diffused species were *Schizophyllum commune* (in 25 seats), *Stereum hirsutum* (in 19 seats) and *Chondrostereum purpureum* (in 18 seats). The seats with the highest fungi species number were the towns of Nitra (9), Košice (8) and Michalovce (8). In 19 seats there was found only 1 taxon.

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Session 2 – Biotic disease factors of plants in urban stands

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Pests of ornamental plants in urban streets, parks and gardens in the UK

Introduction

Ornamental trees, shrubs and other plants in urban areas are attacked by a vast assemblage of pests, ranging from insects and mites, through slugs and snails to various vertebrates (Alford, 1997) including, on occasions, man himself. This paper, however, is restricted mainly to consideration of invertebrates, with particular reference to phytophagous insects.

In recent years, the urban environment in the UK has been greatly enhanced by the planting of ornamental shrubs and trees and by the annual cultivation of herbaceous plants in parks and on urban roadsides, including embankments and roundabouts. Landscaping of new housing estates is also a welcome feature. That having been said, there are still many bleak, desert-like areas and also, within some local authorities, a mistaken view that street trees are a major cause of house deterioration. As a result, many established trees, that have for many years been a welcome feature of urban streets, have been removed: some legitimately, following root damage caused by careless providers of underground services (e.g. cable television, electricity, water), but others for no good reason. Man can also inflict chemical damage to trees and can also be guilty of cultural malpractice (Strouts and Winter, 1994).

On the plus side, however, householders in urban areas are becoming more and more aware of the pleasure to be gained from growing ornamental plants, whether as trees or shrubs or as herbaceous plants grown in window boxes (or other containers) or in gardens. There are some 16 million back gardens in Britain, with 80% of the population having access to one. In London alone, the total area of parks and gardens is said to exceed the land area of the Isle of Wight. The environmental significance of such areas, nationally, therefore, is very significant and the range of plant life considerable.

This richness of plants offers a plentiful food source for phytophagous species. However, most plant-feeding insects on cultivated plants in urban areas cause little or no damage; thus, they may be regarded as enhancing the quality of the environment by adding to species diversity.

Main pest groups – a brief general survey

Within the Hemiptera, aphids of course can be major pests in urban areas, notably rose aphid (*Macrosiphon rosae*) and rose-grain aphid (*Metopolophium dirhodum*) on *Rosa* and the newcomer *Macrosiphon albifrons* on *Lupinus*. Aphids, e.g. green spruce aphid, *Elatobium abietinum* (family Aphididae) and various species of *Cinara* (family Lachnidae) can also be major problems on ornamental conifers. Members of the family Aphididae are also significant pests of a wide range of herbaceous plants grown in and around the house and garden; infestations of violet aphid (*Myzus ornatus*), for example, are often extremely a severe and persistent problem on pot plants. Leafhoppers, again for example on *Rosa*, can also be of importance. Scale insects, too, can be devastating: brown soft scale (*Coccus hesperidum*) on house-plants such as *Ficus*, is a common example. Not only can pests such as aphids and scale insects cause direct damage but the honeydew they excrete can be a nuisance, as can the sooty moulds that often then take a hold. The trunks of street trees in southern England are often now covered extensively with the scales of *Pulvinaria regalis*, an American species unknown in Europe before the 1960s. Fortunately, this pest appears to cause little or no direct damage; infestations are, however, unsightly. Bay sucker (*Trioza alacris*), a species first introduced into Britain in the 1920s, is now a common pest on potted plants of *Laurus nobilis* which adorn the pavements outside the entrances of city restaurants and office blocks; many such plants are heavily infested by this pest and have severely galled foliage.

Vine weevil (*Otiorhynchus sulcatus*) is probably the most important coleopterous pest in urban areas of the UK. This species causes damage to a wide range of ornamental plants, ranging from those grown in parks and gardens, to glasshouse and house-plants (including ornamentals in window boxes). Various kinds of chrysomelid beetle cause damage to plants in urban areas. Lily beetle (*Lilioceris lilii*), for example, can be a problem in gardens in some parts of southern England. However, the devastating chrysomelid *Agalastica alni*, often so abundant and damaging in mainland Europe (for example on both wild and ornamental *Alnus* and *Betula* in Germany and the Netherlands), seems no longer to occur in the UK.

As far as Diptera are concerned, then leatherjackets (Tipulidae) can sometimes cause damage to plants in flower borders and ocasionally lawns but, with few exceptions, other phytophagous flies and midges tend to be relatively unimportant on urban ornamentals, although virtually every *Ilex* hedge is likely to be infested by holly leaf miner (*Phytomyza ilicis*).

The number of lepidopterous insects associated with plants growing in urban areas is enormous. They range from monophagous species (e.g. *Bucculatrix thoracella* — a species which has become increasingly common on *Tilia* trees in and around London (Emmet, 1984)), through those with a strictly limited range of hosts (e.g. lilac leaf miner, *Caloptilia syringella* — on *Ligustrum*, *Syringa* and other Oleaceae), to highly polyphagous ones (e.g. vapourer moth, *Orgyia antiqua* — often abundant in the City of London and in many other urban, as well as rural, areas), and from those whose larvae usually occur singly (e.g. angle-shades moth, *Phlogophora meticulosa*; peppered moth, *Biston betularia*) to those that feed in large assemblages (e.g. buff-tip moth, *Phalera bucephala*, and lackey moth, *Malacosoma neustria*).

Phytophagous Hymenoptera are often abundant in urban areas and some species of sawfly can be extremely destructive. Examples include: *Arge* spp. on *Rosa*; *Nematus* spp. on *Salix*; Solomon's seal sawfly (*Phymatocera aterrima*) on *Polygonatum* (in Britain, first reported in London in 1846); and columbine sawfly (*Pristiphora alnivora*) on *Aquilegia* (in Britain, first reported in 1946).

Within the minor insect orders, members of the Thysanoptera are probably the most frequent cause of damage to plants in urban areas. This includes, on occasions, privet thrips (*Dendrothrips ornatus*) on garden hedges of *Ligustrum vulgare*; the cause of damage (in this case severe silvering of the foliage) can often baffle the householder.

Infestations of phytophagous mites in towns and cities have often been suppressed by noxious sulphur fumes in the atmosphere. However, the cleaner air of modern-day living is no doubt responsible for their resurgence and, today, it is by no means unusual to find a wide range of leaf-russeting and gall-forming eriophyid species on ornamental trees and shrubs in city centres. Broom gall mite (*Eriophyes genistae*) is a common example of a species often found on ornamental *Cytisus* and *Genista* in urban parks and gardens, and there are many others.

Most gardeners curse the devastation caused by slugs and snails, and ornamental plants in flower borders often fall victim to attack; damage can be mistaken for that caused by caterpillars, or even birds, but most gardeners quickly come to recognize the characteristic tell-tale signs of slug or snail attack. Domestic pets (notably cats and dogs) can also cause damage to ornamental plants; urinating male dogs, for example, are especially liable to scorch the foliage of small conifers.

New pests

Foreign invaders have often found a place in urban environments, and several recent additions to the UK list have first appeared (or at the least have first been reported) on ornamental herbaceous plants, trees or shrubs in our towns or cities (Table 1).

Table 1: Examples of recent additions to the UK insect fauna.

Species	**Host plant(s)**	**First record**
Contarinia quinquenotata	*Hemerocallis*	1989
Dasineura gleditchiae	*Gleditsia*	1980s
Macrosiphum albifrons	*Lupinus*	1981
Otiorhynchus crataegi	*Ligustrum, Syringa*	1985
Phyllonorycter leucographella	*Pyracantha**	1989
Phyllonorycter platani	*Platanus*	1990

* Also associated with other Rosaceae.

No doubt pest species will continue to arrive and establish themselves in urban areas within the UK. Can it realistically be expected that the horse-chestnut leaf miner (*Cameraria ohridella*), for example, a very damaging leaf-mining pest of *Aesculus hippocastanum* (Pschorn-Walcher, 1994), first found in Macedonia in

1985 and now well established in Austria and other parts of mainland Europe, including Germany (Butin and Führer, 1994), will fail to reach the UK?

Environmental impact of alien and native pests

Invading species such as *Cameraria ohridella*, and those cited in Table 1, are all associated with specific host plants (or with a very closely related group of host plants). Further, Agassiz (1996) states that 46 per cent of invading Lepidoptera species in the UK are associated in the larval stage with non-native plants. Certainly, international trade in exotic ornamental plants has increased the chances of new pests arriving in Europe, in spite of quarantine measures. The recent appearance in the UK of the pittosporum sucker *Trioza videoradiata* is a recent example of a pest of New Zealand origin; the mealybug *Trionymus diminutus*, that attacks *Cordyline* and *Phormium tenax*, has also relatively recently reached England on plants imported from New Zealand (e.g. Bartlett, 1981). Species such as these, however, are unlikely to pose environmental risks as they are not expected to turn their attention to our native plants; nor are they likely to attack crops. There are, however, examples in the UK of highly polyphagous invaders, including carnation tortrix moth (*Cacoeciomorpha pronubana*) from South Africa and the notorious western flower thrips (*Frankliniella occidentalis*) from America, as well as several other species, such as dipterous leaf miners, that classify as important crop pests (Alford, 1999). Even seemingly innocuous new comers (such as *Blastobasis decolorella* — a mainly detritus-feeding species from Madeira, in Britain first recorded in suburban London) have, unexpectedly, become pests (in the case of *B. decolorella*, the larvae causing damage to maturing apples and other fruits).

Conversely, native phytophagous insects have on occasions moved from their normal wild hosts to cause damage to ornamentals: the large blue flea beetle (*Altica lythri*) is an example, in the UK being associated mainly with willowherbs (Onagraceae) but recently having turned its attention also to ornamental *Fuchsia*, including cultivated plants growing in hanging baskets.

Alien terrestrial flatworms of Australasian origin (notably the New Zealand flatworm, *Arthurdendyus triangulatus* — formerly known as *Artioposthia triangulata*) are now established in various parts of the UK; the so-called Australian flatworm *Australoplana sanguinea alba*, for example, occurs mainly in suburban gardens in England. Although not plant pests, the flatworms often shelter in plant containers, or deposit their egg capsules therein. Thus, these organisms can be moved readily from site to site following the innocent exchange of plants between gardeners or the transfer of plants from one site to another. The flatworms are obligate predators of earthworms and are implicated in declines of their prey, which could have important environmental consequences; there are also implications for horticultural trade at an international level (see Alford *et al*., 1998).

In some areas and some years larvae of the brown-tail moth (*Euproctis chrysorrhoea*) can represent an environmental health hazard. Not only can the larvae defoliate rural and urban rosaceous hedges (e.g. hawthorn, *Crataegus monogyna*) but their urticating hairs can spread to clothes and bed-linen hung out to dry on garden washing lines. Many people have significant adverse skin reactions to the hairs of this insect, a well-known example of urticaria. The collection and destruction of the overwintering webs of brown-tail moth is often a task undertaken by local authorities.

Impact on vegetation

Of course, some phytophagous species can kill their host plants. However, the impact of others is usually far more benign and often non-existent. Colonial phytophagous insects (whether large or small, and whether truly gregarious or just numerous) can be extremely harmful. Some gardeners in southern England, for example, have found it impossible to cope with the constant destruction of lupins caused by the aphid *Macrosiphon albifrons* and have given up growing such plants. Less persistent problems, such as a one-off infestation of ornamental *Cotoneaster* by hawthorn webber (*Scythropia crataegella*), can cause severe but localized damage but plant recovery is usually good. Similarly, bushes or stands of *Pyracantha* damaged by heavy infestations of the newcomer *Phyllonorycter leucographella* can look extremely sickly in winter; however, host plants usually recover sufficiently during the following spring or early summer for the ‘problem’ then to be ignored or overlooked.

Several phytophagous pests induce host plants to produce galls, some of which are extremely colourful and eye-catching. In urban areas, for example, galls formed on *Gleditsia triacanthos* following infestations of the midge *Dasineura gleditchiae* are often regarded as ‘pretty’, although they later develop into unattractive blackened structures! Galls induced by eriophyid mites (such as those often clustered on the leaves of ornamental *Acer*) can also be attractive, although they can also cause unsightly or unwelcome distortion of leaves and shoots. Young oak trees are sometimes planted in city parks and other amenity areas, and these too can sometimes bear highly colourful galls, in this case initiated by cynipid wasps (e.g. *Cynips quercus-folii*).

Phytophagous insects themselves may also be highly attractive and colourful. Fully grown larvae of sycamore moth (*Acronicta aceris*), for example (minor pests of several kinds of urban trees, especially *Aesculus hippocastanum*), are often found wandering over city pavements prior to pupation. However, the brightly coloured larvae of mullein moth (*Cucullia verbasci*), although in themselves attractive, are usually an unwelcome sight as they are most often found in association with ornamental *Verbascum* plants, the flower heads of which they can totally destroy.

Pest control in urban horticulture

Most phytophagous insects in urban areas do not classify as pests, and those that do will often fail in any particular situation to cause economically important damage. Nevertheless, many gardeners spray regularly to combat aphids on their prize rose bushes, and they will also use slug pellets more or less as a routine to keep seedling losses and damage to vulnerable plants (such as *Hosta*) to a minimum. Persistent vine weevil infestations may also require householders to resort to chemical treatments. Certainly, some pest outbreaks are likely to justify the application of chemicals. However, the use of pesticides in home gardens and amenity areas (as elsewhere) needs always to be kept to a minimum.

Apart from in glasshouses, few opportunities exist in urban horticulture for the adoption of artificial biological control measures. However, natural biological control (owing to the presence of a wide range of natural enemies — notably, parasitoids and predators) will often keep potential pest populations in parks and gardens in check. Maintenance of a healthy environment will encourage species diversity in urban areas and this will reduce the risk of pest problems arising, whether on our ornamental native plants or on the ever increasing number of exotic ornamental plants introduced from abroad.

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Pests and diseases of trees in continental urban areas in Croatia – current status and future trends

Introduction

Urban horticulture in Croatia has its roots in the Austro-Hungarian monarchy. Some of the oldest urban parks and gardens in the cities of Zagreb, Osijek and Varaždin date as early as late 18th century. Organized care for urban greenery in the capital of Zagreb started in 1892. Ever since, there has been a growing demand for better and more intensive municipal activity in the field of establishment, maintenance and recovery of urban horticultural objects.

Plant health research has been sporadic and based on emergency cases. However, there have been some valuable contributions in this field (BALARIN et al. 1979, KOMLENOVIĆ 1990, MACELJSKI 1986, MACELJSKI and BALARIN 1972, MILATOVIĆ et al. 1979). All these findings, along with some neighboring countrie's experiences, served as a basis for our ongoing multiyear research. Presented results refer only to the continental urban centers of northern and northeastern Croatia, these being climatically and horticulturally coherent.

Pests and diseases by their host trees

The importance of specific tree pests and diseases in urban areas is a simple reflection of popularity and horticultural value of their respective hosts. Their real ecological impact and true physiological damage on the amenity trees is often neglected, while at the same time their nuisance character prevails in the public opinion. Off course, sometimes both effects unite, and this is mostly the situation when relevant authorities react with some corrective measures. In the text that follows we tried to sum up the most important pests and diseases, both "publicly" and scientifically acknowledged, and present them by their host trees, discussing only their most important ecological features relevant to the problems of integrated plant protection in urban horticulture.

PLANES (*Platanus* × *acerifolia* WILLD., *P. orientalis* L.)

Plane trees, though numerous and popular with urban horticulturists, have remained almost "pest-free" for a long time in Croatia. Problems arose with the spread of plane leaf miner *Phyllonorycter platani* (Stgr.) after the World War II, and especially with the introduction of sycamore lace bug *Corythuca ciliata* (Say) in the early seventies (MACELJSKI and BALARIN 1972). Leaf miner populations are firmly established in large parks and tree lined avenues producing four to five generations yearly. Their damage is not considered important though sometimes a large portion of leaves is attacked and by the end of August crowns are tinged brown with leaves scorched by numerous old mines. No direct measures are taken except for fall leaf sweeping and composting which reduces the next year's spring swarming of the moths. A positive effect of this measure is visible in the first half of the year and only in urban centers and paved streets where leaves can be collected entirely. With the onset of the second and third generations, attack is spreading from the wider area of non-swept plane trees in large parks, private gardens and periurban tree lined roads. Different approaches and active chemical measures are taken in forest and horticulture nurseries where young plane trees are sprayed with contact and systemic insecticides at least twice a year (during the first swarming in mid-April and the second in mid-June). The sycamore lace bug presents somewhat of a different problem. Along with its obvious damaging effect and resulting premature leaf falloff it is regarded as far more important due to its nuisance effect in urban environments. Public concern for this pest emerges from a rising number of allergic reactions and "general appall" toward myriads of tiny bugs entering homes and flats in the vicinity of large parks and tree lined streets. Accordingly, various chemical methods have been tested since the mid-seventies (MACELJSKI and BALARIN 1974, 1975). The biological characteristic of adult bugs overwintering beneath the bark scales of host trees has been utilized to apply a specific chemical method. In early fall (beginning of September) during the descendence of mature tingids to their over- wintering sites, lower parts of larger branches and tree trunks are sprayed with various contact insecticides (BALARIN and MACELJSKI 1980). If this doesn't suffice, another treatment in the spring can be conducted targeting emerging and the survived portions of the overwintered population. From the early development of this method until now only low toxic chemicals have been used (from carbaril and malathione to various pyrethroids), and these applied at minimum concentrations. Foliar spraying was regarded impossible from the beginning due to concerns of aerial drift if aerosols were used or "out of reach heights" if high-pressure pumps were involved. None of these problems occurs in nurseries and efficient control measures keep the sycamore lace bug populations at a minimum in these production sites. Apart from being an annoyance, its numerous sucking nymphs and adults cause visible yellowing of the leaves and premature fall off which is also considered "unsightly" and in some years stirs up public concern. It is the main reason why municipalities urge tree-caring companies to conduct the bole spraying and keep the tingid populations as low as possible. From the physiological standpoint and in accordance with our observations there is still no measurable detrimental effect on plane trees attacked by this pest. Biological warfare against the sycamore lace bug has also been addressed in some research. Intensive efforts have been made to discover the rate and suppressive potential of specific natural enemies (MACELJSKI and BALARIN 1977, MACELJSKI 1985).

The main disease on plane trees is *Apiognomonia veneta* (Sacc. et Speg) Höhn. From year to year it can cause a serious wilting of young shoots and leaves. If the heavy infections occur each year, severe damage that leads to the dieback of branches is inevitable. Often, the first wilting symptoms are easily visible during the spring in parks and gardens. Numerous dead shoots give us a poor crown picture. Later on a non-infected shoots develop new generation of leaves, and crowns recover. Primary infections of leaves by conidia of the state *Discula platani* (Peck.) Sacc. and ascospores of the state *Apiognomonia veneta* in the spring or summer lead to typical symptoms of leaf necrosis. As it is well known, the fungus can subsequently enter the petiole and shoots, causing tissue necrosis. Control measures are limited to prevention only. Leaves are collected in autumn and infected branches are pruned when possible. No fungicide applications have been done. As the fungus overwinters in the state of *D. platani* in the bark of shoots and branches, disease occurrence and development could not be totally eliminated. The consequence and the permanent problem is not only in aesthetic view of poor crowns but also in presence of dead branches that pose wind breakage risks in urban areas.

HORSE CHESTNUT (*Aesculus hippocastanum* L.)

Until recently almost no pest related problems were connected with this widely planted tree species. Remarkable discovery and sudden spread of new European gracillariid, horse chestnut leaf miner (*Cameraria ohridella* Deschka et Dimić), turned the scientific and public focus on an emerging problem with regard to tree protection measures and even survival of the beloved and historically valued tree specimens. First notes on the occurrence of a new pest in Croatia were given by MACELJSKI and BERTIĆ (1995). In 1989 the first sporadic mines of some unidentified insect were noticed in the Zagreb parks. Infestation grew rapidly in 1994 and reached an epidemic character in 1996. By the mid-nineties the whole country had been infested with the new gracillariid. Today, it is regarded as the single most dangerous pest and urban plant health threat in the country (HARAPIN 1999). Easily observed and striking damages resulted in public demand for taking action. Research on the biology and phenology started immediately and some trial suppression measures have been undertaken. In urban and periurban areas the moth can complete three or four generations annually. This is related to the local climate, which is very variable in Croatia. First flight period begins as early as mid-April, and is followed by two or three swarmings in June, August and late September. The overwintering pupae population is quite often decimated for some abiotic and anthropogenic reasons (leaf sweeping, street salting and accumulation of toxic substances) but polivoltine capability overcomes this and by the emergence of second and third generations of moths (late summer) tree crowns are already completely brown and start shedding leaves. In most severe instances one can observe a second flowering and leafing in October. This again is the reason why fall leaf sweeping and composting gives limited results. A positive effect of this ecologically preferable method is that it is short termed and lasts only until the second generation of moths disperse and spread the infestation. Infestation loci are similar as in the case of *Phyllonorycter platani* and flying moths can be dispersed easily even by light breezes. This suppressive measure, in spite of its relative weakness, has been practiced in the capital of Zagreb for several years. Combined with other, more aggressive chemical measures, it should become a part of an integrated protection approach. Chemical suppression measures have been targeted against the first, springtime swarming moths, eggs and their larvae, and have been carried out only in a small portion of municipal horse chestnut tree strips or parks in Zagreb. So far, IGR compounds, like teflubenzuron and diflubenzuron have been tested and sometimes a small portion of pyrethroids has been added to the spraying mixture. Satisfying results have not been achieved yet and it seems crucial that the application is done before larvae enter leaf epidermis. Other part of the problem is acquiring an even deposition of an active ingredient throughout the dense horse chestnut crowns, these being often out of reach for ordinary spraying kits and atomizers. Intensive contacts with Hungarian researchers and application specialists will hopefully result with more efficient suppressive solutions. Monitoring of the natural enemy complex started in 1997. So far, quantitative and qualitative analyses show no difference from neighboring countries. Parasitoid fauna has not been established enough to efficiently reduce its host population. Parasitism rates are still reaching only 5% at the best.

Leaf disease *Guignardia aesculi* (Peck) Stew., like *Apiognomonia veneta*, is also wide spread in urban areas in Croatia. Periodically it causes certain damage to horse chestnut trees. In August and September, as the consequence of intensive fungus attack, infected leaves fall off. Sometimes the whole trees are defoliated. Control measures are based mainly on collecting of fallen leaves and rarely on fungicide applications. As in urban areas, the fungus is present in nurseries as well, where fungicide treatments are used as a control measure undertaken on a regular yearly basis.

MAPLES (*Acer platanoides* L., *A. pseudoplatanus* L., *A. negundo* L., *A. sacharinum* L., *A. campestre* L.)

Maples are widely planted urban trees and cope very well with harsh urban environment. Occasionally, some problems arise which have a minor impact on plant physiological conditions. Among insect pests, leaf aphids (*Chaetophorella aceris* L and *Chaetophoria aceris* Walker) are sometimes causing problems more with the honeydew production and its side effects on objects in the vicinity (dripping on parked cars) than its negative effect on tree health. Unsightly effect is even more pronounced later in the summer when leaves are covered with sooty layers of proliferating moulds. In some instances leopard moth attacks (*Zeuzera pyrina* L.) have been recorded (BALARIN et al 1979). From our recent observations such cases occur when young plants are infested during their growth in horticulture nurseries. Therefore, it is of great importance that nursery plants are kept in topmost condition prior to replanting. Ash-leafed maple (*A. negundo*) is a preferable host tree for fall webworm (*Hyphantria cunea* Drury) against which, in some instances, suppressive measures are being taken. This is typically the case in periurban areas of the eastern parts of Croatia.

On different maple tree species there are several pathogenic fungi which frequently occur, but none of them causing problems like *Apiognomonia veneta* on plane trees. *Uncinula bicornis* (Walr.) Lév. and *Rhytisma acerinum* (Pers.) Fr. are present on leaves. *U. bicornis* is more frequent on *A. negundo* and *R. acerinum* on leaves of *A. pseudoplatanus* and *A. campestre.* Damage to the trees is mainly considered as physiological and aesthetic. In the crowns of *A. pseudoplatanus* twig and smaller branches dieback occurs. *Diplodina acerina* (Pass.) Sutton is also frequently found on twigs and branches (up to 3 cm in diameter) causing bark necrosis. Our opinion is that fungus plays a role of a week parasite, which rapidly develops on stressed trees. Different abiotic factors play role as predisposing factors. These are: drought, poor site conditions in urban areas, air pollutions in certain level, and others. Control measures have not been considered as necessary. Another problem that we have observed in freshly planted maple trees was the presence of discolored wood. Our research revealed that discoloration starts forming after wounding by leopard moth caterpillars, and mechanical injuries with unspecified origin. We also found the longitudinal fissures across the tree trunk that could be also an entrance to air and the beginning of discoloration processes. Fissure appearance themselves have not been explained yet, but we suspect that the reason may originate in certain physiological processes following intensive manuring.

LIMES (*Tilia × europaea* L., *T. platyphyllos* SCOP., *T. cordata* MILL., *T. tomentosa* MOENCH)

Lime trees are common species in Croatian urban environment. Among insects there are really no serious pests but in some circumstances two heteropteran species aggregate on tree trunks during late fall and this causes people to complain and urge municipalities to act accordingly. These are the linden bug (*Pyrrhocoris apterus* L.) and chinch bug (*Oxycarenus lavaterae* Fabr.). Their aggregations can grow to large colonies hanging sideways on lime trunks and being quite noticeable. They are not regarded as true pests and no suppressive measures are undertaken. Usually by the time public complains the colonies disappear and the whole case is forgotten. Among other less important pests which can ordinarily be found on lime foliage are some aphids and gall mites.

On leaves of different lime species, *Apiognomonia tiliae* (Rahm) von Höhn could be found, rarely causing some serious problems.

BIRCHES (*Betula pendula* ROTH., *B. pubescens* EHRH.)

Birch crowns can sometimes bear heavy populations of lygeid *Kleidocerys resedae* (Panz.). It is again the nuisance effect, which causes sporadic and localized suppression measures. There are rarely any other significant insect pests occurring on birches in urban environments.

Mildew *Phyllactinia coryllea* (Pers.) Karst. is frequent on birch leaves in urban areas and in forests as well. Significant injuries have not been observed though it sometimes causes premature leaf fall off. Another fungus, *Piptoporus betulinus* (Bull. ex Fr.) Karst. is very frequent and causes significant damage to birch trees. Decay process is present in branches and trunk as well. The consequence and the permanent problem in urban areas is not only in aesthetic view of birch crowns but also in wind breakage risk resulting from decayed branches and trunks. No control measures have been taken, except pruning, which is primarily done to avoid the breakage risks.

ASHES (*Fraxinus excelsior* L., *F. americana* L.)

White ash is commonly attacked by leaf aphids *Prociphilus fraxini* (Geoffr.) and *P. bumeliae* (Schr.). These cause visible swellings in the crowns and are more of an aesthetic significance. There have been no suppressive measures undertaken against these pests. At the beginning of the nineties serious problems were caused in the capital of Zagreb on some tree lined streets where eruption of ash sawfly *Tomostethus nigritus* F. occurred. Due to a lack of knowledge on its biology and inappropriate technical equipment, excessive defoliation took place for several years. The outbreak is now going through its sixth year and in spring of 1999 the spraying was conducted successfully, destroying the generation of ecloded larvae. Prepupal analysis reveals that there is still some portion of eonymphs diapausing in the soil, which means we will have this pest ecloding in future years. Our observations showed that strong population of hymenopteran parasitoids have followed the outbreak but total defoliation through several years urged tree-protecting companies to undertake more drastic measures. Their decision was sound as it was obvious that some of the heaviest defoliated ashes nearly failed leafing in spring of 1999, a month prior to spraying action. Pressure from local citizens was also very strong since they witnessed the horror of larval masses falling from completely defoliated trees in former years.

Leaves of *F. americana* can often be infected by mildew *Phyllactinia coryllea* (Pers.) Karst., but serious damages have not been observed.

OAKS (*Quercus robur* L., *Q. petraea* LIEBL.)

Microsphaera alphitoides Griff. et Maubl. is wide spread in forests and urban areas on leaves of two main oak species. Primary infections occurring in spring by overwintering mycelia are more frequent and important than primary infections caused by ascospores. Damages on oak trees in urban areas are not as intensive as they are on oaks in forests, but are considered as one of the stress factors. A direct injurious impact is manifested in decreasing of assimilation process and, in case of severe attack, the fungus can cause shoots and leaves dieback. Up-to-date no fungicide control measures have been done in urban areas, while in forests, where situation is different, control measures are carried out as necessary.

Black locust (*Robinia pseudoacacia* L.)

Black locust is planted more often in periurban areas and is regarded as a prime honey producing bee pasture. Being of western origin its pests are gradually following and spreading through the country. Black locust miner *Parectopa robiniella* Clemens has been recorded in Croatia at the beginning of the eighties (IGRC and MACELJSKI 1983, MACELJSKI and IGRC 1984). Since then it has became a widely distributed pest. Our observations confirm that another species has entered Croatian territory after being recorded in neighboring countries. It is the *Phyllonorycter robiniella* Clemens, second gracillariid producing mines on locust leaves. This is the first report on its occurrence in Croatia, though it has obviously become a member of our noxious fauna for maybe a decade. At the moment no suppressive measures are being undertaken against these two pests and the viability of the black locust seems to overcome their attack.

PINES (*P. nigra* ARNOLD, *P. heldreichii* VAR. *leucodermis* /ANT./ MARKGRAF)

Pine needles of *P. nigra* can be attacked by several fungi: *Micosphaerella pini* Rostrup ap Munk (=*Scirrhia pini* /Funk et Parker/) *Lophodermium pinastri* (Schrad. ex Hook) Chév., and *Cyclaneusma niveum* (Pers.) DiCosmo, Peredo et Minter. Not too often *M. pini* and *L. pinastri* are capable to cause some serious damage to host trees, which are reflected by premature needles fall off. Another fungus, *Sphaeropsis sapinea* (Fr.) Dyko et Sutton causes serious dieback of shoots, branches and hole crowns of pine trees in the last few years (DIMINIĆ 1999). *P. nigra* and *P. heldreichii* var. *leucodermis* turned out as the most susceptible pine species to the fungus attack in parks and gardens. It was also concluded that one, more often two or even more factors predisposed pine trees to *S. sapinea* outbreak (e.g. drought, poor site conditions, mechanical injuries, air pollution). SO_2 concentration increased above certain level can damage the leaf surface and has influence on leaf physiology. According to KOMLENOVIĆ (1989) it may lead to increased transpiration. Together with precipitation deficit it results with drought stress. Research results on sulfur content in *P. nigra* needles on some localities in the Zagreb revealed that concentrations are above the critical level (KOMLENOVIĆ 1990). Control measures have been targeted against *M. pini* and *L. pinastri* up-to-date when needed, but no measures have been used to control *S. sapinea* yet.

Thujas, false cypresses and junipers (*Thuja* spp., *Chamaecyparis* spp., *Juniperus* spp.)

Thujas, false cypresses and junipers are often planted as ornamental trees and hedges. Occasionally they endure some abiotic and biotic negative impact. Among insect pests the most important are scolytid beetles of the genus *Phloesinus* Chapuis and argyresthiid leaf miner *Argyresthia thuiella* Pack. (OPALIČKI 1991). During early and late summer when beetles and adult moths expose themselves and start with the egg laying or supplemental feeding, in other words become susceptible to the use of contact insecticides, some localized suppressive measures are taken. Such incidents happen more frequently with drastic trimming of older hedges after which proper sanitary measures have not been taken. This especially affects the scolytid population buildup. Harsh winters and dry summers have additionally made host trees more susceptible.

DECAY FUNGI

Numerous different fungi cause decay of mainly broadleaved urban trees. No direct control measures have been used, except for some prevention methods that are focused on decreasing the occurrence of mechanical injuries in urban areas. Pruning wounds are often protected with fungicide and insecticide preparations. Some of the most frequent decay fungi are: *Armillaria mellea* (Vahl. ex Fr.) Kummer, *Piptopourus betulinus* (Bull. ex Fr.) Karst., *Ganoderma applanatum* (Pers.) Pat., *Fomes fomentarius* (L. ex Fr.) Fr., *Phellinus robustus* (Karst) Bourd. et Galz.

OTHER INSECT PESTS OF LESSER IMPORTANCE

On many other horticulture and shade tree species and bushes more members of noxious fauna have been recorded. Their appearance was sporadic and their role of minor importance to the plants health status. Some of these were as follows: *Rhyacionia buoliana* Den et Schiff, *Neodiprion sertifer* Geoffr., *Leucaspis Loewi* Colvee, and *Ips bistridentatus* (Eichh.) on *Pinus nigra*, *Sacchiphantes viridis* Ratz., *Physokermes piceae* Schr., *Ips typographus* (L.) and *Pityophthorus micrographus* (L.) on *Picea abies* (L.) Karst., *Acantholyda hierogliphica* Christ. on *Pinus mugo* Turra, *Elatobium abietinum* (Walker) on *Picea pungens* Engelm., *Eopineus strobus* Hartig on *Pinus strobus* L, *Phyllaphis fagi* L. and *Mikiola fagi* (Hartig) on *Fagus sylvatica* var. *atropurpurea* Reg., *Cimbex femorata* L on *Betula pendula*, *Stereonychus fraxini* Deg. on *Fraxinus excelsior*, *Euproctis chrysorrhoea* L. on *Quercus robur* L., *Agrilus auricollis* Kiesw and *Eotetranychus tiliarum* Herman on *Tilia × europaea* and *Monarthropalpus buxi* (Laboulbène) on *Buxus balearica* Lam.

Conclusion

Current status of plant health research in Croatian urban environments is strongly affected by short-termed appearances of specific biotic agents. Evident need for more consistent and continuously founded research is still evolving. Recent instances of massive insect infestations and fungal infections (*Cameraria ohridella, Sphaeropsis sapinea*) emphasize this necessity and accelerate the development of ever improving methods targeting not only on new pests and diseases but also old problems which have not been addressed appropriately in the past. The plant health status in urban environments in the last decade has been seriously affected. Among the rising impact of non-biotic damaging effects, including urban environment *per se*, some pests and diseases added their part to this complex, causing most weakened species or individuals to collapse. This was the case with some pines, planes and horse chestnuts in heavily stressed urban centers and locations in Croatia.

From our point of view, we need most urgently to develop new application methods, whether by improving the old ones or applying completely new ones. It seems that much is going on in the field of developing efficient technical appliances for LV, ULV or new injector applications in urban environments. Active ingredients are becoming more specific and selective and it is becoming possible to use them efficiently enough and at doses acceptable to humans' urban environment. There has been some major progress in the use of completely non-toxic chemicals in the field of pheromone tactics. Biological measures are not to be neglected since they could sometimes be the only acceptable suppression strategy, therefore these researches should be kept on-going.

Finally, we can conclude with optimistic belief that plant health in urban horticulture, as a specific field of research and amalgam of various operational skills will get stronger hold in our community in the years to come. It is of vital importance that we benefit from the present tide of growing public interest and are ready to cope with the new pests and diseases in the millennium that has just begun.

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On the main sources of Belgrade street trees′ decline

Introduction

Street tree lines represent one of the most important greenscape category in urban settlements. Shade trees improve the air quality in streets' surroundings, moderate micro-climatic conditions and reduce urban noise to certain extent. Their decorative-esthetic effect on visual perception of the surroundings is equally important, while their screening effect when shabby and ugly old facade and walls are concerned is often irreplaceable. Shade trees also exert particularly beneficial psychological effect; by their various shapes, colors and scents they provide urban dwellers with necessary connection to surrounding nature. All in all, streets represent a far more pleasant environment when shade trees are present [4]. This fact is in the very essence of common practice of establishing street tree lines in contemporary urban conditions wherever possible.

All above mentioned functions of street trees are of far greater significance in a large than in a small settlement, in central city zones then on their periphery, due to very strenuous living conditions in densely populated areas. Central Belgrade is a good example in that respect. Unfortunately, harsh urban conditions are becoming ever more difficult for street trees as well. How truly unfavorable these environmental conditions are may be judged by trees' overall appearance and their habitual life span. Street shade trees quite often reach only half of the age that is characteristic for urban trees in less demanding and strenuous environment (such as in adjacent urban parks), and in general live several times shorter than the same species' individuals growing in natural surroundings [2].

Numerous indicators of endangered survival of Belgrade street tree lines may be divided into two large groups. First group is comprised of relatively easy to detect morphological characteristics, such as mechanical injuries, epicormic growths, broken or died back branches, stem cracks (as a consequence of intensive light or frost damages), various trunk and crown deformations, etc. The second group includes all the phenomena that follow infections, diseases or pest attacks, whether they are of primary or secondary nature.

All in all, it may be said that street tree lines in general, and Belgrade street trees in particular, are objectively the most endangered category of Belgrade urban greenscape [1]. There are several groups of causes responsible for such a state. First of all, these plants usually grow and develop in deficient and unfavorable environmental conditions, both above and below ground level. Trees periodically lack light and grow in something like a large flowerpot which limits the space for tree root development, and does not offer good soil conditions. At the same time they are constantly exposed to high concentrations of various pollutants (exhaust gases, motor oil, deicing salts, etc.) Each street tree line individual is in constant danger of mechanical injury from most various sources (motor vehicles, pedestrians, municipal services, newsstands and other metal constructions on pavements, etc.). The other important group of reasons which cause considerable endangerment of Belgrade street trees lies in a poor quality of tree transplants. It should be pointed out, however, that this is not the consequence of improper domestic nursery production, but rather of its absence. Belgrade shade trees of today are in the largest part individuals taken directly from nearby forests or neglected plantations, and just exceptionally properly nursery produced and trained woody plants (even in that case, chiefly imported). Finally, in the third group are all the reasons that originate in inadequate, sometimes completely erroneous aftercare of street tree lines throughout their existence in urban ecosystem, which is largely due to lack of sufficient financial support.

Nevertheless, central Belgrade shade trees even today represent clear material evidence of our ancestors kindhearted attitude towards street trees. Well aware of the beneficial effect of trees on their surroundings, predecessor of today's Belgrade dwellers left permanent positive urbanistic trail behind. Present generations try to keep the pace following their footsteps, but many of these trails they can hardly follow, while others they had to abandon completely under the pressure of misfortunate circumstances. When the filed of domestic landscape architecture is concerned, it may be said that a number of exquisite and precious green spaces from the past are today degraded and to a large extent reduced to bare formal existence. Some of them are almost without any true functionality, otherwise so needed and possible (Academic park, for instance). The others are so poorly cared for and neglected that can no longer be regarded as in any sense efficient urban green spaces (Terazije Park in the very hart of Belgrade, for example). There is also a number of parks that practically ceased to exist due to intensive paving (Park near the main railway station, for instance). Unfortunately, numerous street tree lines in the center of the city today may hardly bear that name, specially when serious consideration is given to their appearance and the aftercare techniques (mostly reduced to erroneous lopping, as is the case with Plane-trees in King Aleksandar St.). Should this trend continue, there is a real danger that Belgrade shade trees will soon be treated as secondary, and thus not truly necessary street structures [3]. Should that happen, pedestrians already squeezed between high buildings and parked cars would loose the last motive to stroll through the streets, while streets themselves would become utterly unattractive and inhumane zones where people would stay just for a short time and only out of pure necessity.

Fig. 1: Lopping is one of the most important reasons of Belgrade street trees' decline

Such gloomy future is certainly not what dwellers of Belgrade are longing for. That is why these urban structures that may be regarded as the most valuable elements of Belgrade city planning heritage, must not become one of the renounced traditions. However, judging by their indisputable decline in the central city area, such fears are not without grounds. Results presented in this paper strongly confirm this statement.

Material and Method

In order to establish the degree and the main causes of street tree decline in researched area of central Belgrade, systematic, long-term study has been undertaken. Periodical estimates of each individual's state were made on five occasions during growing seasons of the years 1972, 1977, 1984, 1991 and 1998. Study included all the streets that hold street tree lines in central city area. At the beginning of the research in 1973 every tree individual was numerated and determined. All trees were then tabulated and worksheets innovated during each phase of survey with all relevant data concerning the state, or better yet the rate of decline of each tree individual. Table 1. synthesizes these findings, showing in sum the present state/decline of the most prevalent street tree species in central Belgrade.

On the basis of obtained data and general appearance of every tree, each individual was evaluated for its vitality and esthetics on the scale from 1 to 5 (1- unsatisfactory, 2 - poor, 3 - intermediate, 4 - good, 5- excellent). Vitality grade is a direct consequence of the type and rate of established phenomena on each individual, thus representing objective measure of the tree's health state, while so-called aesthetics grade, however, includes also unavoidable individual, subjective criterion. Constant decrease of these grades during research years is the best measure of Belgrade street trees decline.

Results and Discussion

Examination of Belgrade street tree lines showed that central Belgrade area holds a total of 9,576 tree individuals, of which exactly 8,798 specimens belong to eight most commonly used shade tree species. Since they encompass more than 90 % of surveyed tree individuals, and being the most abundant ones, only these eight species will be presented in this paper. Systematic survey of current state of trees in street tree lines of the most polluted central urban zone gave numerous, various, and quite indicative results (Table 1, Table ., Table 3, Table 4). Table 5 is of special interest since it shows gradual decrease of the total number of trees in the category of the oldest, and increase of the youngest street tree individuals, which by itself speaks of continuous decline of analyzed street tree lines.

As Table 1 shows, none of the species possesses average vitality grade higher than 3.4. It is very indicative that the vitality of *Acer platanoides*, one of the most abundant Belgrade street tree species, was graded no higher than 2.4 on average. The grade for esthetic properties of all researched tree species, even though somewhat higher, may also be regarded as generally low, since the most representative area of the capitol is concerned.

Table 1: General state of the most common street tree species in central Belgrade

SPECIES	Number of trees	VITALITY	AESTHETICS
Platanus acerifolia	1028	3.1	2.2
Tilia argentea	376	3.2	3.5
Acer platanoides	1486	3.1	3.7
Aesculus hippocastanum	486	2.6	3.1
Tilia parvifolia	1293	2.9	3.6
Fraxinus excelsior	588	3.2	3.4
Tilia grandifolia	1678	3.1	2.9
Acer pseudoplatanus	1863	2.4	2.7
Total	**8798**		

Furthermore, Table 2 shows that a large number of trees, regardless of species, exhibits pronounced decay of the trunk and main branches. Even though it is indisputably the most frequently manifested disease, its primary initiative is not in the fungi itself, but in the presence of large wounds left after cutting back or lopping main branches, erroneous and unfortunate common aftercare practice in Belgrade, carried out to the extreme especially during the last decade [2].

Table 2: Diseases of Belgrade street trees (%)

SPECIES	trunk decay (%)	trunk cancer (%)	leaf diseases (%)
Platanus acerifolia	11	9	8
Populus nigra pyramidalis	48	11	13
Tilia argentea	37	13	6
Acer platanoides	18	7	11
Aesculus hippocastanum	35	29	22
Tilia parvifolia	27	12	14
Fraxinus excelsior	19	5	4
Tilia grandifolia	32	8	17
Acer pseudoplatanus	38	4	10

Almost every third mature tree, from medium age on, suffers from more or less intensive stem decay . Even though the causes of this occurrence may vary, its appearance is regularly connected to large wounds, cracks and cavities left after pruning or other mechanical injuries to stem and branches. It should be mentioned that on some previously decayed trees (around 80) appropriate tree surgery measures were applied when pronounced stem break-out cavities were in question, but no treatment of decayed main branches was evidenced. As it is the case with most surveyed damages of research area trees, the number of specimens with pronounced stem decay grew over the years. Table 2. also shows that considerable number of trees suffer from different kinds of stem cancer, as well as of leaf diseases, which may also be attributed, to a certain extent at least, to inadequate aftercare of newly established transplants. Finally, discoloration, wilting, curling or early dropping of leaves, phenomena commonly regarded as phytopathological manifestations, have not been proven to be true for street trees in the research area, since the actual primary pathogen has been isolated quite rarely. The phenomenon of early discoloration and wilting of leaves during summer or early autumn, induced by the action of various pollutants and dust, or lack of water and nutrients in the street soil, is considerably more widespread, which is just one proof more that urban environment has considerable negative effect on the living world.

Visible physiological manifestations of generally poor state of street trees presented in Table 3. directly show that there is extremely large percent of deformed tree crowns (sometimes even over 80 %) followed by the development of epicormic growth in similar proportion. There is no doubt that both of these phenomena are in direct correlation with persistent drastic cutting of main branches and lopping of the whole tree crown, directly provoking unnaturally dense crowns with twisted thin branches and enormous number of so-called epicormic growths. There is no better indication not only of hard environmental conditions but also inadequate measures that lead to over-reduced and unshaped tree crowns.

Table 3: Physiologically damaged Belgrade street trees

SPECIES	light and frost cracks	deformations	epicormic growth	branch dieback	repeated leafing
Platanus acerifolia	9 %	86 %	88 %	13	4
Populus nigra pyramidalis	16	4	98	22	-
Tilia argentea	14	58	69	17	5
Acer platanoides	37	64	27	16	6
Aesculus hippocastanum	28	37	66	21	9
Tilia parvifolia	33	43	59	14	3
Fraxinus excelsior	9	49	48	8	-
Tilia grandifolia	36	45	68	17	2
Acer pseudoplatanus	26	43	72	11	4

Presence of epicormic growths on trees, specially the older ones, regularly indicate their poor condition . In the research area, however, the total of epicormic growths relatively stagnates. Based on results of this long-term research, it may be concluded that the main reason for the extent of this occurrence lies in systematic lopping of trees every few years. Such practice in fact regularly removes numerous shoots around the wounds of older cuts, keeping the number of trees with pronounced epicormic growths almost unchanged for decades. Nevertheless, as large as it is, this number clearly indicates hard environmental existential conditions: around 40 % of trees have epicormic growths on various stem positions.

Mechanical and every other type of damage brought to the tree by the action of various environmental factors vividly speak of the whole complex of environmental conditions in which Belgrade street trees exist today. Objectively hard site conditions on the one hand as much as lopping as a substitute for non-existent standard transplants for replacement of deteriorated or oversized tree individuals on the other hand, transform the very existence of street tree lines into a pure formality in ever increasing number of central Belgrade streets. Even such existence of shade trees on Belgrade streets is becoming ever more uncertain day by day. The seriousness of the situation is evidenced by the dynamics and distribution of average street trees' age over the years (Table 5). There is a clear tendency in which young are overpowering the old, since the number of young trees generally and steadily increases, while equally persistently decreases the number of mature ones. This would not be alarming, on the contrary, if it were not for the fact that these young tree individuals are too young, untrained, ecologically ineffective and practically dysfunctional, which further lowers the general quality and efficacy of researched street tree lines. The same conclusion may be derived upon the supposition that street trees' functionality period (period in which trees perform satisfactorily in ecological and esthetic sense), with most of the researched tree species should not be less than 60 years [2]. Presented results, however, clearly confirm that the average age of street tree lines, and thus indirectly their functionality as well, is constantly decreasing.

Table 4: Damages of Belgrade street trees due to light or frost cracks, mechanical injuries or lopping (%)

SPECIES	trunk damage	branch damage	lopped crown
Platanus acerifolia	21	17	86
Populus nigra pyramidalis	16	9	74
Tilia argentea	19	14	69
Acer platanoides	8	11	58
Aesculus hippocastanum	37	39	36
Tilia parvifolia	13	9	71
Fraxinus excelsior	7	8	51
Tilia grandifolia	18	16	79
Acer pseudoplatanus	10	13	54

Table 5: Average age structure of Belgrade street tree lines

research year	0-20 years	20-40 years	> 40 years
1973	1088	3684	4291
1984	1765	4287	3011
1998	2578	4611	1609

The number of died back or broken branches also increases over the years. Both occurrences, though of different origin (die back is usually due to the lack of adequate, qualitative nutrients in the root system zone, while broken branches are primarily the consequence of wind action) also suggests hard environmental conditions in which trees grow and develop.

Of all kinds of damages observed during the research period, those of entomological nature were the most scarce. Pests were detected only individually, and the damages, especially when compared to those of non-biotic nature, were insignificant.

All presented results indicate that crucial causes of Belgrade street trees' decline lie in general urbanistic and ecological factors which prevail in researched zone (general pollution level, poorly regulated traffic, unsolved civil engineering situation, overcrowds, etc.) and inadequate professional action of municipal services which are trusted with the care of Belgrade urban trees, regardless if that care concerns tree nursery production, tree establishing techniques or maintenance of already existing trees. In any case, the main causes of street trees' decline in Belgrade center, as everywhere else were similar conditions prevail, directly contribute to the fact that theoretically defined main sources of decline [5] of properly maintained street tree lines - diseases and pests - further degrade street trees and totally reduce their general and by the best current knowledge, today even more than ever precious functionality.

Conclusions

Central Belgrade is the most endangered city zone in urbanistic, ecological and transportation sense. Street tree lines comprised of eight most common street tree species hold a total of 8,798 tree individuals. Presented results of almost three decades long research are the sound ground for following conclusions:

1. General causes for relatively poor state of street tree lines are as various as numerous. Among all the researched damages that were the basis for evaluation of street tree lines' vitality, the most pronounced are the mechanical injuries. Their origins are numerous, but the most important are motor vehicle traffic, often erroneous and not intensive enough maintenance measures, as well as low quality, under-aged tree transplants. All these factors are reflected on both esthetics and vitality of street tree lines. There is also a constant increase of broken, died back or decayed main branches, unprotected large cutting wounds and lopped tree individuals. Lopping is more the cause of further street trees' decline than maintenance measure.

2. The average age of street tree lines of researched area is continuously decreasing, as a consequence of permanent replacement of old and deteriorated street trees with too young tree transplants. Excessive replacement needs are indications by themselves of ever harder environmental conditions, in which once habitual tree existence period of eight to ten decades is not possible to achieve, except in singular cases. Numerous above and below ground street installations are part of the general causes of such state, since they participate in limitation of available space for new street tree lines. Therefore, young transplants soon become deformed, stunted, and more susceptible to general decline. From time to time these installations serve as an alibi for lopping procedures, further lowering the vitality level of existing trees.

3. Numerous negative factors of urban environment systematically decrease the vitality and esthetics of studied street tree lines, thus contributing to the general decrease of their specific functionality and accelerating their ever more pronounced decline.

   It should be pointed out that young trees are particularly endangered, especially in the first several years after transplantation, when a large number quickly fades away and replacements have to be made several times in a row. This phenomenon is especially pronounce in recent years, in which new transplants have been acquired almost solely from nearby forests, often so young that did not even reach the diameter at breast height of 1.0 cm.

4. All presented facts indicate that urgent maintenance measures of central Belgrade street tree' lines have to be undertaken, but also a complete "change of hearth" when their professional care is concerned. Only thus will street tree lines once more represent one of the most valuable street structures, as they did up to just a few decades ago.

Summary

Paper presents a survey of Belgrade street trees conducted in more than twenty years long research period. Obtained data and general research results ascertain that vitality of these important elements of urban tissue is declining constantly, and their general and specific functionality simultaneously declining as well. Exactly 8,798 trees were surveyed in the streets of central city area. Attained results are the reliable indicators of ever more serious disruption not only of vitality and homogeneity of street tree lines, but also of their overall aesthetic and psychological functionality. Constant decrease of all tree species' general vitality level (average grade less than 3,00) shows that Belgrade environment is slowly but certainly becoming ever more unfavorable for both existing plants and capitol inhabitants. Absence of adequate maintenance measures is undoubtedly other important reason of such undesired state of Belgrade street tree lines.

key words: street tree lines, decline, Belgrade, urban environment.

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Viruses - an unrecognized damaging agent in urban gardens

Summary

The urban environment includes a large variety of plants from shade trees to large parks of open space and private homes gardens, having a mixed population of plants. This plant population is composed of a mixture of seasonal and perennial weeds to centuries old trees. The most common plants in urban areas are the ornamentals, in which size and yield are not considered important. Yet research in recent years showed the ornamentals to serve as hosts for numerous viruses. Unlike the gardening practice in open urban space, the ornamentals industry (potted plants and cut flowers) is paying much attention to virus infection that may cause symptoms in flowers reducing the whole plant and flower size. Therefore, the possibility exists to compare between ornamental plants grown in a nursery to those grown for a long period of time in the open unprotected environment of a garden.

Since plants harbor viruses for many generations, many infected plants are hard to recognize because of their attenuated effect of the virus that causes minimal symptoms or symptomless but infected plants. On the other hand, the spread of viruses in urban gardens is relatively efficient, since minimal attention is given to protecting the plants from the arthropods vectors that spread the viruses from one plant to another. Urban gardens are also places where plants from different environments and areas of the world are grown together exposing the harbored viruses to new hosts. In addition to plants grown in public urban areas, urban dwellers grow intheir private areas, various ornamentals and herbs. In many urban areas vegetables and fruit trees are cultivated in private gardens, where very little attention is given to reduce virus spread by their arthropod vectors.

Therefore it may be assumed that viral diseases are common and have a significant effect on urban gardening, yet overlooked, or simply not recognized at all. Here I discuss the general effect of virus infection, symptom appearance, and attempt to reduce the phytopathogenic damage caused to plants.

General Discussion

Many arthropod species feeding on plants serve as vectors to transmit viruses. The arthropods transmit viruses in a; persistent, semi-persistent and non-persistent, manner (Matthews, 1991). While feeding the arthropods may transmit the virus directly to the plant vascular system, which accelerates the systemic spread of the infecting virus.

Viruses propagate and multiply in the leaf parenchyma cells or the leaf phloem tissue of sieve tubes and companion cells. In the infected cells, the viruses interfere with the normal protein and starch metabolism and may affect the movement of assimilates in the leaves (Tecsi et al, 1996). Furthermore, chloroplast structure is also affected and, in many cases, the number of chloroplasts per cell is reduced (Gao and Nassuth, 1993, Salomon and Seifers, in press). Collapse of cell walls and numerous biochemical changes are associated with virus infection (Kofalvi and Nassuth,1995). There is no direct correlation between virus proliferation and the severity of symptoms and pathogenic damage to the plant (Wijdeveld et al, 1992, Lapidot et al, 1997). However in most virus infected plants pathogenic damage is expressed to a low extent, which in turn is manifested in mild or non-visible symptoms (Cooper, 1995). Yet such viral infection may result in growth retardation and yield reduction (Cooper, 1995, Salomon and Seifers, in press). The broad distribution of viruses in plants at non cultivated areas was studied and reviewed (Cooper ,1993, Raybould et al., 1999, Raybould et al., 2000 in press). Ornamental plants are susceptible to virus infection at the same rate as all other cultivated plants. Symptoms of viral infection may appear as colored mosaic in the flowers, distorted flower shape and mutilated flowers. Symptoms on leaves appear as mosaic spots, streaks, or even necrotic lesions. In extreme cases the entire leaf may dry therefore, the economical damage to the ornamentals industry may belarge. Thus a major effort is invested by this industry to avoid viral infection and damage.

In urban open parks and private gardens, it is assumed that a similar virus population exists with similar effects. Therefore, flowers of the same species grown in open unprotected spaces like parks will be much smaller and have shorter stalks compared to those grown in a covered nursery. Parks and urban gardens harbor many species of perennial weeds from various areas of the world that carry numerous viruses, common in their area of origin. This co-cultivation may expose the viruses to new hosts, such a phenomenon was observed in ornamental garlic infected with turnip mosaic virus (TuMV) (Gera et al, 1997). The transfer of a virus from its long established host to a new one may result in a much stronger virulent effect (Salomon, 1999). The heterogeneous plant population of the urban garden has the advantage of avoiding large scale virus epidemic as regularly occurs in cultivated crops. However this heterogeneous plant population exposes the viruses to new hosts, that may be extremely susceptible and develop severe pathological symptoms. A simple way to reduce this phytopathological hazard is to control the propagation material used for gardening. Most nurseries apply control measures to eliminate viruses from their propagation material. Therefore, obtaining planting material from controlled sources may reduce the inoculum source of viruses in urban gardening.

Introducing shrubs and trees from uncontrolled open areas into gardens may bring a large and diverse virus population to those gardens. These viruses will spread by natural vectors to surrounding plants. Thus, such practice is not recommended. Naturally occurring virus infection of perennial plants may be by many different viruses, since unrelated viruses do not cross protect from each other. A mixed virus population may emerge in their tissues (Cooper, 1995,).These viruses may be transmitted by the same or different arthropods (Cooper, 1993, Shiboleth et al, 1997, Raybould et al, 1999).

Some plant viruses have a synergistic effect on the host were the combined damage to the host plant caused by the mixed infection is much greater than the damage caused by each virus alone (Baker, 1987, Cohen et al, 1988 , Vance, 1991, Vance et al, 1995). For example, wheat infected by high plain virus (HPV) and wheat streak mosaic virus (WSMV) together showed yield loss of about 70%, while each of these viruses alone causes as small as 10% yield reduction (Seifers et al,1998).

Many urban dwellers use insecticides in their gardens to protect fruit and trees from insects and fungal disease. The result of such practices may be an enhanced spread of viruses. Virus spread by aphid in the non-persistent manner is enhanced by insecticide application, especially during the time from application to death of the aphid, during this period aphid movement results in enhanced hoping from plant to plant and spreading viruses to a larger extent, than untreated aphid (Seifers and Harvey,1989). Therefore reduced use of insecticide in urban gardens will not affect virus spread. Limited insecticides application has environmental benefits,. the natural population of arthropods will not be distorted and natural enemies of many of the damaging insect species will prevail and control the damaging pest population. Also, insecticides may have an accumulating damage potential to mammals, thus their use in urban areas should be minimized.

Additional factors influencing virus spread to plants, is irrigation and fertilization. Viruses spread mainly by arthropod vectors attracted to strong and vigorous plants. Irrigated and fertilized gardens, especially in arid and semiarid zones, will result in lush green plants. These plants will attract arthropods from the drying wild vegetation around, conveying to the garden plants the viruses harbored in the wild plants. Some of the viruses brought by the vectors to the garden plants may infest new hosts, with severe virulence, others may form mixed infections in plants already infected with other viruses. Thus, controlled use of fertilizers and irrigation should be employed to attract smaller number of arthropods. Furthermore, a common agricultural practice copied in gardening is the use of excess fertilizers that are drained by the irrigation and contaminate the underground water. Therefore, limited fertilization and controlled irrigation in urban gardening may have an additional environmental benefit.

Another practice in gardening that may reduce or altogether avoid virus damage is the use of tolerant or resistant plants. Although in ornamentals, selection for virus resistance was not at the top priority, as was done with crops, it is possible to select asymptomatic plants and avoid the propagation of the most symptomatic susceptible lines.

Moreover, together with all the previous indicated measures that are designed to reduce virus damage in urban gardens, it is worthwhile to eradicate plants showing severe viral disease. Such plants are stunted and often have mutilated leaves, so they do not comply with ornamental purposes. Such plants also serve as inoculum sources to infect other plants, especially by viruses with a very broad host range. Examples are: cucumber mosaic virus (CMV), tobacco mosaic virus (TMV), potato virus Y (PVY), turnip mosaic virus (TuMV) and alfalfa mosaic virus (AlMV). Furthermore, these viruses are from diverse groups and thus do not cross protect against each other, resulting in a mixed infection with a devastating effect to the host plant.

Eradication of severely disease plants may limit the spread of such viruses in the urban garden and help improve the plants appearance. Although the ornamentals industry is investing a large effort to reduce, or even eliminate viruses from their crops, very little is done in the open gardens, both public and private. However the damage exists, this short presentation indicates some simple measures that can reduce the damage, generally overlooked, of viral disease to urban gardens.

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Phytophthora spp. on trees – present situation in Germany

<u>Introduction</u>

In Germany species of the fungus-like microorganisms *Phytophthora* are well known pathogens in horticultural crops. They cause severe losses in ornamental plants, in orchards and in woody nurseries. During the last ten years *Phytophthora* species have been more and more reported to attack big trees in public green space and in open landscapes.

<u>Disease sypmtoms</u>

On trees *Phytophthora* species mainly cause root and collar rots as well as stem cankers. Symptomatology with trees affected by *Phytophthora* species is difficult, because generally the first visible symptoms are unspecific secondary symptoms like chlorosis, wilting, small leaves and sparse foliage (Figure 1a). Depending on environmental factors infected trees can tolerate the loss of many roots without showing visible above-ground symptoms. A more characteristic manifestation of collar rots or stem cankers are the ‚tarry spots‘ or bleeding cankers of some non-coniferous trees. These are dark brown or black spots or black coloured bark areas on the main trunk (Figure 1a, 2a) with or without fluid coming out of the dying bark.. Under the discoloured bark the tissue is red-brown to brown and can be clearly destinguished from the healthy tissue (Figure 2b). Depending on the tree species and the disease development coppice shoots may arise from the main stem. Once attacked by *Phytophthora* species the trees can withstand the disease for many years and eventually they collaps and die within one year. In some cases the spread of the pathogen in the tissue is restricted and no tree dieback occurs.

<u>Hosts in Germany</u>

On trees outside the nurseries up to now *Phytophthora* species have been isolated mainly from alder (*Alnus* spec.), oak (*Quercus* spec.) and horse-chestnut (*Aesculus hippocastanum*). But characteristic disease symptoms have also been reported from beech (*Fagus* spec.), hawthorns (*Crataegus* spec.), Mountain ash (*Sorbus* spec.), maple (*Acer* spp.), fir (*Abies* spec.), and spruce (*Picea* spec.). There are also a lot of other woody ornamentals like *Chamaecyparis* spec., *Rhododendron* spec. and *Taxus* spec. which are also attacked by *Phytophthora* species.

Diseased trees have been reported from public green spaces as well as from river banks, forest areas and other places outside nurseries in different regions of Germany.

<u>*Phytophthora* species</u>

Up to now many different *Phytophthora* species could be isolated from tree tissue samples in Germany. To give some examples: From horse chestnuts *P. cactorum* could be isolated. In diseased alder, isolates similar to *P. citricola* and *P. megasperma* and the new ‚alder-*Phytophthora*‘ could be detected. *Fagus sylvatica* was attacked by *P. citricola* and *P. cambivora*. And *Quercus robur* was contaminated for example with *Phytophthora quercina*, *P. citricola* and *P. gonapodyides*. Thus in Germany trees have been attacked by *Phytophthora* species which are highly specialised like the ‚alder *Phytophthora*‘ and *P. quercina* or by species with a wide range of host plants like *P. citricola* and *P. cactorum*. From tree tissue *Phytophthora* species with low temperature requirements like *P. syringae* and the new ‚alder Phytopthora‘ as well as species which preferably grow at high temperatures like *P. citricola* could be isolated.

Often more than only one *Phytophthora* species could be isolated from the same tissue sample. In addition in soil samples from the surroundings of diseased trees further *Phytophthora* and/or other species could be detected.

Figure 1: Pale green leaves (a, right tree) and bleeding canker (b) on horse-chestnut infected with *Phytophthora* spec.

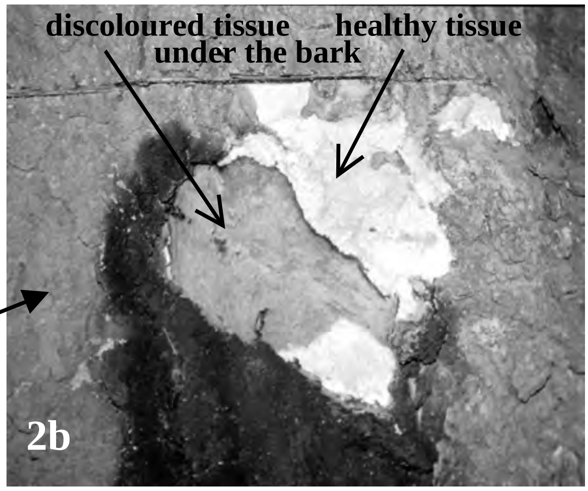
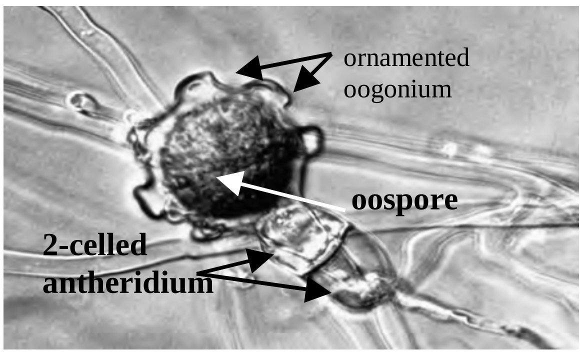


Figure 2: ‚Terry spots‘ on oak (a) and red-brown discolouration under the spots (b)

Figure 3: Ornamented oogonium, 2-celled antheridium and oospore of the new ‚alder Phytophthora‘



Biology and epidemiology of *Phytophthora* spp.

Phytophthora species can produce different structures. Restingspores like oospores and chlamydospores enable the survival in the soil or in plant tissue for many years. It depends on the species whether they can produce both kind of resting spores or not. For distribution and infection the zoospores are the most important structures. They are produced in sporangia. The zoospores are motile due to two flagella and they can swim actively to the root tips. The ability to produce zoospores amplifies the potential of *Phytophthora* spp. to infect host tissue. Reproduction is asexual by zoospores and sexual by oogonia and antheridia (Figure 3).

Infection and disease development

Infection of trees is not yet fully understood. It is very probable that most *Phytophthora* species invade the trees via the root tips. It may also be that they enter the tree tissue at the collar level. Some *Phytophthora* species are able to invade the tissue activley without a wound, but generally wounds are an important infection court. After infection the pathogens probably spread vertically and laterely within the phloem (inner bark) and cambium of woody roots and stems. These tissues are killed and after the tree is girdled the tree dies. In advanced stages penetrating hyphae may be found in xylem tissues. Normally, the pathogen extends vertically from fine roots into the increasingly larger ones and the stem base.

The most important factors for infection and disease development are water and temperature. *Phytophthora* species are well adapted to water. They need water to produce sporangia and the motile zoospores. Thus high water or stagnant soil moisture which we have in many German regions mainly during winter and spring favours *Phytophthora* infection on trees. That, for example, could be observed with alders growing on river banks. But on the other hand characteristic tarry spots could be found on beech trees growing at a slope without a strech of running water in the vicinity and without high ground-water level. The influence of temperature on the development of bleeding canker could be seen on horse chestnuts in public green space and in house gardens in Germany. In 1995/1996 and 1999 there were long periods with abnormally high temperatures during the summer months. And it was during these years that bleeding canker on the horse chestnuts increased.

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Wood degradation patterns and their significance at the host-fungus-interface in the xylem of living trees

Introduction

Many studies attempting to explain the limitations of colonisation at the host-pathogen interface have been restricted to the description of discoloration and decay patterns in wood (SHAIN, 1967, 1971, 1979; SHIGO AND MARX, 1977). On the basis of such observations the CODIT-model was proposed and developed by SHIGO AND MARX (1977). According to the CODIT-model, decay columns in trees are bounded and restricted by boundaries laid down in the wood.

To date, few studies have addressed mechanisms of lesion expansion by decay fungi at the host-pathogen interface (PEARCE, 1996). Recently, light microscopy studies by SCHWARZE AND FINK (1997) showed that reaction zone penetration by *Inonotus hispidus* (Bull.:Fr.) Karst in London plane (*Platanus x hispanica* Muenchh.) was accomplished by forming soft-rot like tunnels through the cell walls. A soft-rot mode of growth within reaction zones apparently enabled hyphae to circumvent impedances within the cell lumina (SCHWARZE AND FINK, 1997). A similar mode of action was also described for *Meripilus giganteus* (Pers.:Pers.) Karst. in false heartwood of beech (SCHWARZE AND FINK, 1998). On the ground of these observations, it was postulated that the ability of *I. hispidus* and other basidiomycetes to cause a soft-rot either in addition or alternatively to their more typical mode of action, i.e. a white rot, may be a common phenomenon, which may play a significant role in lesion expansion for a range of other decay fungi (SCHWARZE AND FINK, 1997, 1998).

Objective of the present study is to compare mechanisms of reaction zone penetration by different decay fungi in naturally infected beech trees (*Fagus sylvatica* L.), with the modes of degradation in artificially inoculated wood blocks of beech, containing the interface of reaction zones and healthy sapwood. For this purpose three basidiomycetes *Inonotus hispidus*, *Ganoderma adspersum* and *Fomitopsis pinicola* and one ascomycete *Ustulina deusta* were selected. With the exception of *F. pinicola* all the decay fungi used to investigate reaction zone penetration are capable of degrading both lignin and cellulose, and have the ability to invade living host sapwood (WILKINS, 1943; PEARCE AND WOODWARD, 1986; PEARCE, 1991; SCHWARZE AND FINK, 1997).

Material and Methods

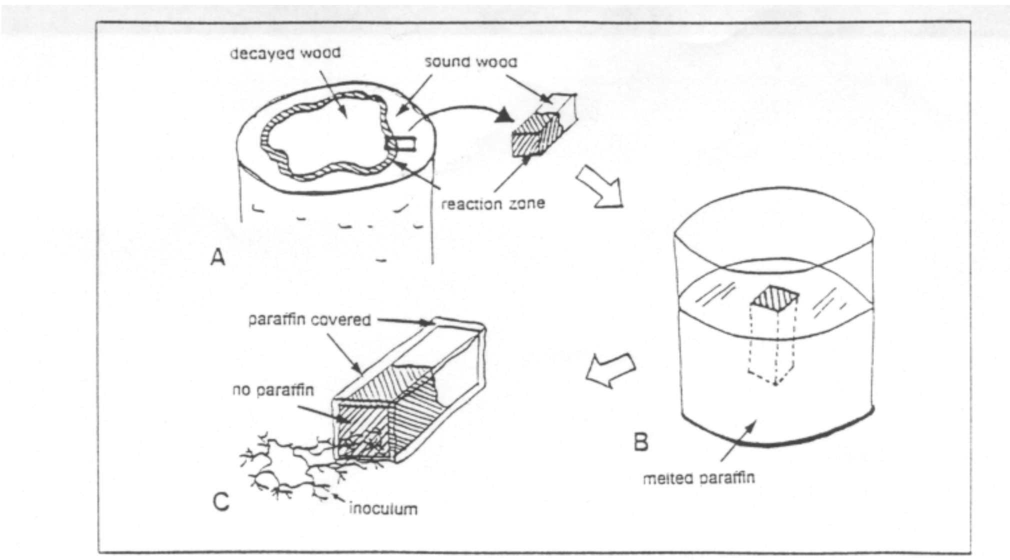

Fig. 1: Schematic diagram showing preparation steps for artificial inoculation of beech wood blocks. (A) Small wood blocks containing reaction zones and healthy wood were taken from a naturally infected beech tree. (B) After sterilisation, wood blocks were inserted into melted paraffin, the side of the reaction zone remained unsealed. (C) For colonisation, test blocks were placed separately onto pure cultures of the different fungal isolates.

The material and methods that were applied for the microscopical investigation of naturally infected beech wood have recently been published elsewhere (SCHWARZE et al., 1995; SCHWARZE AND FINK, 1997; SCHWARZE and BAUM, 2000). The steps which were applied for the inoculation of wood blocks containing reaction zones (SCHWARZE AND BAUM, 2000) are summarised in Figure 1.

Results

The anatomical features of sound wood of beech and the modifications recorded within the reaction zone are presented in figure 2 and 3. The schematic diagram of the reaction zone (Fig. 3) will be used to summarise and illustrate the different mechanisms of fungal penetration by decay fungi.

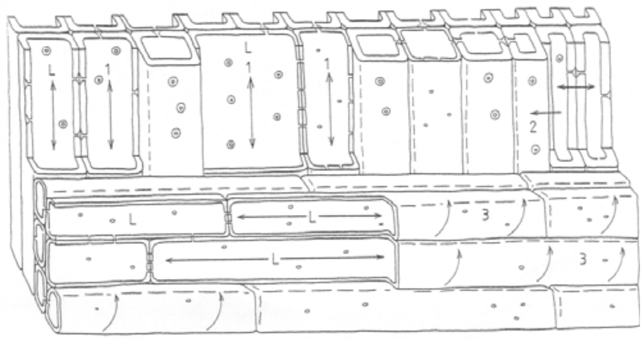

Fig. 2: Schematic diagram showing the diffuse porous wood structure of beech. Longitudinally (fibre-tracheids, vessels and axial parenchyma) and transversely aligned cell lumina (xylem ray parenchyma) correspond with walls 1 and 2, the latewood with wall 3 of the CODIT-model

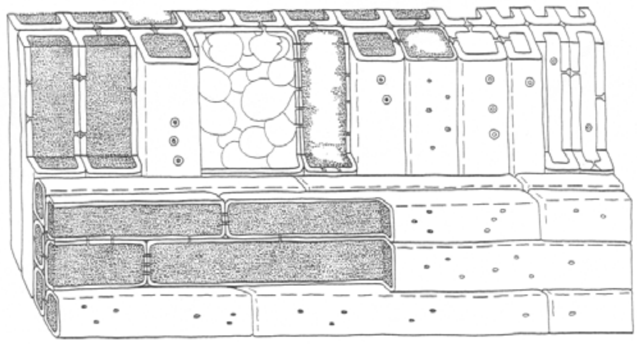

Fig. 3: Schematic diagram illustrating the modified wood structure within a reaction zone of beech. Tyloses formation is apparent within vessels. The S3-layer of axial parenchyma cells is encrusted with a polyphenolic layer, whereas cell lumina fibre-tracheids are occluded with abundant polyphenolic deposits.

Fungal spread and wood degradation patterns within reaction zones

The colonisation of artificially inoculated wood blocks including the interface of reaction zones and healthy sapwood by decay fungi occurred exclusively over the non-sealed reaction zone surfaces exposed to the fungal mycelium. Throughout the incubation periods all the other surfaces of the wood blocks remained completely sealed with paraffin. Although colonisation took place rapidly by all decay fungi, behaviour and modes of degradation within reaction zones and adjacent healthy sapwood varied greatly. Therefore a separate account is given for each decay fungus.

Inonotus hispidus

Dual modes of degradation by I. hispidus were apparent within artificially inoculated wood blocks of beech. At the margin of reaction zones hyphal growth within the occluded lumina of fibre-tracheids was sparse. Hyphal growth was mostly confined to the secondary walls of fibre-tracheids, where the majority of hyphae were < 1 µm in diameter. Cell wall degradation was only evident in secondary walls, in which soft rot was recorded (Fig. 4a). Cavities were of indefinite length and followed the helical alignment of the cellulose microfibrils (Fig. 4a). In transverse sections, discoloration of the secondary wall in immediate proximity to cavities was observed (Fig. 4a).

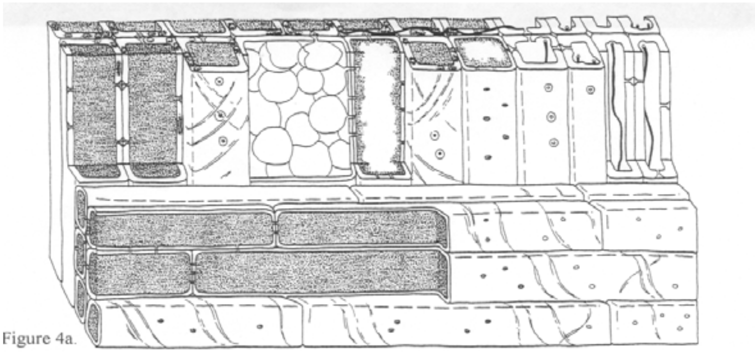

Fig. 4a: *Inonotus hispidus* defeats reaction zones by penetration hyphae and a soft rot mode within secondary walls of xylem ray parenchyma

Within the reaction zone, penetration hyphae had frequently grown transversely through the cell wall of fibre-tracheids. Growth of penetration hyphae was also often distinctly diverted within the secondary walls around occluded lumina of fibre-tracheids. This mode of action was constantly observed within the reaction zones and a switch in this characteristic growth mode was only apparent in the healthy sapwood adjacent to the reaction zone. In regions with healthy sapwood, cell walls showed a typical white-rot attack, with erosion of secondary walls by hyphae lying on the surface of the cell lumen.

Ustulina deusta

Within reaction zones of artificially inoculated and naturally infected beech wood, soft rot and cavity formation in the secondary walls of fibre-tracheids and xylem ray parenchyma was recorded (Fig. 4b).

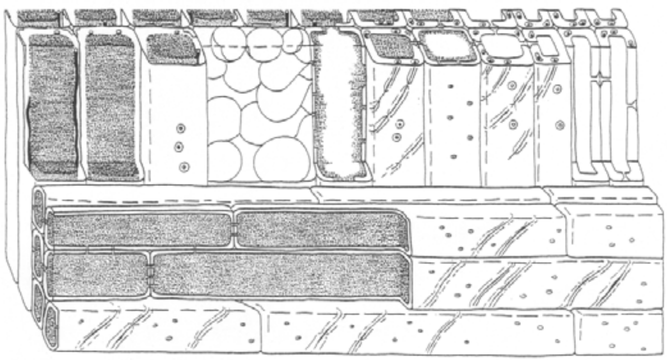

Fig. 4b: *Ustulina deusta* defeats reaction zones by a soft rot mode without significant degradation of polyphenols

The cavities widened with the advance of decay, mostly reaching 2 - 6 µm in diameter and often occupying the entire thickness of the secondary walls (Fig. 4b). Dark hyphae, 0·5 - 1 µm in diameter were often apparent within cavities (Fig. 4b). Tangential sections showed that individual cavities were 10 - 50 µm in length and had tapered ends (Fig. 4b). In xylem ray parenchyma cavities were 1 - 3 µm in diameter, of indefinite length and followed the spiral alignment of the cellulose microfibrils (Fig. 4b). At an advanced stage of decay, a 'skeleton' remained, consisting of the compound middle lamellae of the fibre tracheids, parenchyma and vessel cells together with the largely unaltered polyphenols (Fig. 4b). Sections of the defeated reaction zone viewed under the fluorescence microscope sections merely showed suberisation of tyloses within vessels. At this stage polyphenols formerly infiltrating bordered pits were visible as casts between degraded fibre tracheids and axial parenchyma cells (Fig. 4b). At this stage the compound middle lamellae only showed a localised destruction. In naturally infected wood, hyphal growth within the secondary walls of xylem ray parenchyma was not recorded.

Ganoderma adspersum

Within reaction zones, whether artificially inoculated or naturally colonised, preferential degradation of tyloses and polyphenols (Fig. 4c) within the lumina of axial parenchyma and fibre-tracheids always preceded cell wall degradation. After fourteen weeks incubation period, most polyphenols within the lumina of axial parenchyma and fibre-tracheids were degraded. Localised degradation of polyphenols was apparent

(Fig. 4c). In contrast to healthy wood, fragments of degraded tyloses within vessels did not exhibit autoflourescence. Single, brownish hyphae, 1 - 2 µm in diameter, were apparent in the lumina of most fibre-tracheids and axial parenchyma cells. Hyphae freely penetrated formerly occluded pit chambers (Fig. 4c).

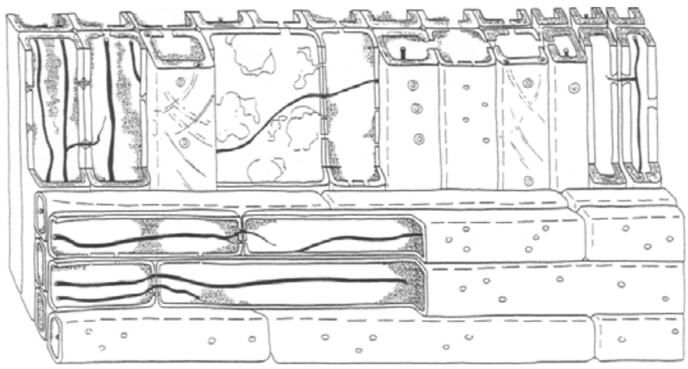

Fig. 4c: *Ganoderma adspersum* initially degrades polyphenols allowing subsequent hyphal growth through the cell lumina.

Some localised growth and hyphal tunnelling within secondary walls was also observed in formerly occluded fibre-tracheids. Cavities were 1 - 4 µm in diameter and often branched within the secondary wall (Fig. 4c). In close proximity to cavities the secondary wall was distinctly discoloured. In longitudinal sections cavities appeared as tunnels and occasionally diverted from the alignment of the cellulose microfibrils (Fig. 4c). Typical signs of white rot within cell walls of fibre-tracheids and axial parenchyma was only observed after most polyphenols were degraded. In healthy sapwood, selective delignification of fibre-tracheids commenced from the cell lumen inwards and resulted in a distinct colour change of the secondary wall (Fig. 4c). When stained with safranine and astra blue, in the absence of lignin, delignified cell wall regions appeared blue (Fig. 4c). At advanced stages of decay, delignification of middle lamellae resulted in the separation of fibre-tracheids from one another (Fig. 4c).

Fomitopsis pinicola

Although the surface of all artificially inoculated wood blocks were colonised by *Fomitopsis pinicola*, fungal spread and modes of degradation were not recorded within the wood. Neither hyphae, nor characteristic features of early stages of brown-rot decay i.e. loss of birefringence were detected within wood blocks.

Discussion

Reaction zones in beech were successfully defeated either (i) via soft rot hyphal tunnelling, bypassing blocked cell lumina without substantial decomposition of cell walls and polyphenols (*Inonotus hispidus*) or (ii) by the preferential degradation of polyphenols (*Ganoderma adspersum*) or (iii) via soft rot and preferential degradation of the secondary walls without significant decomposition of polyphenols (*Ustulina deusta*). Reaction zone penetration by *I. hispidus*, in artificially inoculated wood blocks of beech, was reminiscent of the soft-rot mode formerly described in naturally infected London plane (SCHWARZE AND FINK, 1997). Although not generally recognised in the past, soft rot is a common feature which has been described for a range of wood decay basidomycetes (NILSSON AND DANIEL, 1988; DANIEL, VOLC AND NILSSON, 1992; SCHWARZE, LONSDALE AND FINK, 1995a; WORRALL, ANAGNOST AND ZABEL, 1997; SCHWARZE AND FINK, 1997, 1998). Thus, reaction zones were effectively defeated by hyphal tunnelling and transversely growing penetration hyphae within the secondary walls of fibre-tracheids and xylem ray parenchyma. As formerly described, this mode of growth within cell walls allows hyphae effectively to escape adverse conditions within the lumina of cells (SCHWARZE AND FINK, 1997). As cells occluded with polyphenols are only partially degraded within regions of host response, reaction zone relicts persist within the otherwise strongly degraded wood (PEARCE, 1991; SCHWARZE AND FINK, 1997).

In contrast to *I. hispidus*, reaction zones in artificially inoculated and naturally infected beech wood defeated by *Ganoderma adspersum*, showed distinct differences. During early stages of colonisation, *G. adspersum* showed an extraordinary preference to degrade polyphenols within the cell lumina of axial parenchyma and fibre-tracheids. Thus, after fourteen weeks incubation most polyphenols within reaction zones were almost completely degraded. Substantial degradation of polyphenols by *G. adspersum* and *Gano-*

derma resinaceum Boud. in Pat. has also been observed in a range of other broad-leaved hosts (Schwarze, unpublished). Some volatiles do not only stimulate overall growth of *Ganoderma* spp., but some may grow preferentially towards such sources of these substances (RAYNER AND BODDY, 1988). Thus, FRIES (1961) observed preferential growth of *Ganoderma applanatum* (Pers.:Wallr.) Pat. towards a vessels containing the volatile nonanal. Interestingly, localised hyphal tunnelling in the secondary wall of formerly occluded fibre tracheids, by *G. adspersum*, resulted in the formation of cavities within secondary walls tracheids. Hyphal tunnelling and sequential degradation of cellulose as a rich carbon source within the secondary walls by *G. adspersum* may aid in modification and degradation of accumulated polyphenolic deposits. In addition to the preferential degradation of polyphenols, selective delignification of the middle lamellae within secondary walls of xylem ray parenchyma was recorded. Selective delignification is well documented for *Ganoderma* spp. (BLANCHETTE, 1984) and corresponds with their ability to preferentially degrade other polyphenols. Therefore the preference of *G. adspersum* to degrade both lignin and polyphenols can be explained by their similar chemical composition. Preferential degradation of middle lamellae in xylem ray parenchyma also enables fungal spread through the reaction zone in a radial direction. Thus, the ability of *G. adspersum* to degrade accumulated polyphenolic deposits seems to be a fundamental feature which may in part account for its classification as a strongly invasive decay fungus (PEARCE *et al.*, 1997).

In contrast to reaction zones invaded by *G. adspersum*, polyphenols persisted within reaction zones defeated by the ascomycete *Ustulina deusta.* The inability of *U. deusta* to degrade accumulated polyphenolic deposits may in part account for its classification as a weakly invasive decay fungus (PEARCE *et al.*, 1997). The limited ability of *U. deusta* to degrade polyphenols corresponds with its inability to degrade the compound middle lamellae (NILSSON *et al.*, 1989; SCHWARZE, LONSDALE AND MATTHECK, 1995 b). Former studies in different hosts revealed that hyphal penetration of *U. deusta* occurs exclusively by means of pits and never by bore holes (WILKINS, 1936; 1943; SCHWARZE, *et al.*, 1995 b). Therefore it was postulated, that the latter inability would ultimately restrict the formation of transversely orientated penetration hyphae, which would otherwise allow penetration through the cell walls, thus bypassing the blocked lumina (SCHWARZE AND FINK, 1997). However the isolate of *U. deusta* used in the present study did cause destruction of the compound middle lamellae. As bore holes were not observed it seems conceivable that localised punctuation by hyphae was induced mechanically. Moreover abundant hyphal growth and soft rot within the secondary walls of xylem ray parenchyma, previously not observed, was also recorded. Hyphal growth within secondary walls of xylem ray parenchyma at the host-pathogen interface, will effectively allow reaction zone penetration and lesion expansion. Although studies with a greater number of isolates are necessary, it seems conceivable that hyphal growth within secondary walls of xylem ray parenchyma my be due to intra-specific variations and may distinguish strongly invasive from mildly invasive isolates of *U. deusta*.

Interestingly, the brown rot fungus *Fomitopsis pinicola* was not able to invade and defeat reaction zones in artificially inoculated wood blocks of beech after 14 weeks of incubation. *Fomitopsis pinicola* is an important member of the coniferous forest ecosystem because it decays dead trees and logging slash (SINCLAIR, LYON AND JOHNSON, 1987). In America it is more important in old growth western conifers, but acts slowly and perhaps for this reason is not among the major decay pathogens of second-growth forests (SINCLAIR *et al*., 1987). In Europe, beech is also a natural host of *F. pinicola* and under controlled conditions colonisation and degradation of wood occurs rapidly (SCHWARZE, 1995). The inability of *F. pinicola* to defeat reaction zones after 14 weeks incubation period is perhaps related to its ecological behaviour and its limited enzymatic ability to modify and degrade polyphenols. Thus, host response in dying or dead trees is limited and fungal colonisation of wood not greatly inhibited by the presence of polyphenols. Abundant occlusion of cell lumina within reaction zones in artificially inoculated beech wood and the inability of *F. pinicola* to grow within the cell wall seems a reasonable explanation why penetration failed within the incubation periods.

The present study illustrates that further investigations at the microscopic level are inevitable, if one wants to attach real value to observations attempting to explain the limitations of colonisation at the host-pathogen interface, purely by the macroscopic description of discoloration and decay.

<u>Summary</u>

Fungal growth within reaction zones of beech (*Fagus sylvatica* L.) challenged by three basidiomycetes *Inonotus hispidus* (Bull.:Fr.) Karst., *Ganoderma adspersum* (Schulz.) Donk, *Fomitopsis pinicol*a (Fr.) Karst. and one ascomycete *Ustulina deusta* (Fr.) Petrak, was studied in naturally colonised and artificially inoculated wood. With the exception of *F. pinicola* all the other decay fungi successfully defeated reaction

zones. The mechanisms, however, of reaction zone penetration by these species were all somewhat different in nature. *Inonotus hispidus* defeated reaction zones via soft rot, bypassing blocked cell lumina and without causing substantial decomposition of cell walls and polyphenols. Invasion of reaction zones by *Ganoderma adspersum* was characterised by the preferential degradation of polyphenols. In contrast, *Ustulina deusta* defeated reaction zones by soft rot and preferential degradation of the secondary walls without decomposition of polyphenols. Failure of *Fomitopsis pinicola* to invade and defeat reaction zones is apparently related to the limited enzymatic ability and inflexible behaviour of brown rot fungi. Mechanisms of lesion expansion, illustrated and summarised in schematic diagrams, support former observations that reaction zones in beech are static boundaries, which may be successfully defeated by white- and soft rot fungi.

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The aggression factor: a new concept to value the real aggression on wood structure by wood decay fungi

Introduction

Environment safety is becoming more and more important in every activity.

Similarly, the inspection on tree stability is today fundamental both in the maintenance of public open-spaces and of private gardens, in order to prevent any serious accident caused by tree fall.

The educational background of the people who are requested to test the tree stability is generally very different and their investigation may be partial. A very few of them studied Wood Anatomy, Physiology, Biology as well as the relation between the hosting tree and the fungus on wood decay process.

The tools that are today available on the market make the investigation easier, even though the negative effects coming from the use of these tools is not yet outlined as it should be.

From the genetic point of view, every tree has its own genetic code and its reactions against external organisms (as an example, the wood decay fungi) may be different. Similarly, every fungus has its own genetic code. In other words, the possible genetic combinations between the hosting tree and the fungus are infinitive and they can then cause infinitive irregular cases.

From the scientific point of view, the evaluation of the tree stability can take a long time, it may be quite complicated, the test reports can be partial and not conclusive. Should the test reports do not give irrefutable results, arboriculturists have better state that the investigated tree is dangerous and has to be cut down. The tree cut prevents from any possible consequences coming from an evident evaluation mistake.

From the point of view of public safety, the choice of cutting the tree is definitely acceptable even though healthy trees too could be cut down. Further to several tests reports, the decision of the tree cut was based simply on the presence of a fruit body at the level of either the root crown, of the trunk or even of the branches.

As stated before, the relation between the hosting tree and the fungus cannot be simply reduced to a general statement. Besides, this relation could be properly investigated provided that a correct database is given to the arboriculturists who have to inspect the trees.

This investigation aims at providing new evaluation criteria to test the trees with traces of wood decay. The given criteria could help in the investigation about the decay speed caused by fungi on the xilematic tissue: the aggression factor.

Materials and Methods

The research was carried out on 36 samples of *Tilia cordata*.

These 2 lines of Tilia lie on both sides of the urban boulevard, in the small village of S.Lazzaro di Savena, next to the town of Bologna, Italy. The trees date back to 1935-1940.

Every tree was identified with a number and then classified according to its characteristics. The Tree Card describes the height, the diameter of the trunk at a distance of 1 metre from the ground, the description of the tree's peculiarities such as the presence of fungi, pests, tree deterioration, etc.

The Polyporacea *Ganoderma resinaceum* was present on 13 lime-trees, as shown by its fruit body on the collar level.

The tests on trees were carried out from November 1994 to November 1999.

At the beginnings, the tests on trees were carried out by means of several tools (Hammer, Electronic-impulse Hammer, Penetrometer) in order to detect the presence of cavities inside the trees.

The Penetrometer tested 20 trees having cavities and its data were applied to mathematics models to detect the cavity shape and the thickness of the left trunk. The cavity surface (in cm^2) has been proportionally calculated, that is to say the percentage rate against the whole transversal section.

Three different groups (A, B, C) were selected according to the dimensions of cavities, namely:

A - trees having the cavity at the collar level > 50% than the surface of the transversal section;

B - trees having the cavity at the collar level ranging between 30% and 50% than the surface of the transversal section;

C - trees having the cavity at the collar level < 30% than the surface of the transversal section.

The presence of wood decay without the fruit body was detected on 7 trees. On these trees, a sample was taken by means of a borer at the collar level. The taking was carried out some 15 cm. higher than the holes left by the Penetrometer in order not to alter the conditions on the investigation area. The sample was then isolated in a moist chamber to push out the fungus.

All the trees with cavities were inspected once a year and all the analysis repeated. The test reports gave the changes in cavities' dimensions as well as the growth of the tree; these values are given as percentage rates.

The average value of the changes in cavities' dimensions shows an increasing rate since the first year (1995). Similarly, the average value of the tree growth shows an increasing rate since the first year (1995); the trunk diameter was measured at 1 metre from the ground. The result of the tree growth was first proportionally calculated and given as a percentage rate; then, this result was compared to the result given from the tests on cavity increase.

To find the thickness situation of the left trunk, one should take off the increasing rate of the cavity from the increasing rate of the tree growth.

In December 1999, some 8 trees had to be cut down in order to inspect visually the results coming from the past tests.

Table 1: cavities dimensions (percentage rate against the whole transversal section), where:
n° = tree number, A,B,C = different groups selected according to the dimensions of cavities
1995, 1996, 1997, 1998, 1999 = cavities dimensions (percentage increasing rate since 1995)

n°	A	B	C	1995	1996	1997	1998	1999	AVERAGE
2		X		36	38	40	41	42	1,5
5		X		45	46	48	49	51	1,5
6			X	12	12	12	13	13	0,25
9	X			63	65	67	68	69	1,5
11		X		46	48	50	51	53	1,75
14	X			74	76	78	79	80	1,5
18	X			61	62	64	65	66	1,25
23			X	4	4	4	4	5	0,25
24	X			72	74	76	77	80	2
25	X			53	55	56	58	60	1,75
28			X	23	23	24	24	25	0,5
30		X		45	47	49	50	52	1,75
32		X		32	33	34	34	35	0,75
34	X			66	68	70	72	73	1,75
35		X		40	41	43	44	46	1,5
36			X	14	14	15	15	15	0,25

Results

Amongst the 20 lime-trees, 16 of them suffer from *G. resinaceum*. The registered data refer only to these trees. The results are given in detail below:

Table 2: tree growth (in cm, measured at 1 metre from the ground every year, average and percentage increasing rate since 1995)

n°	A	B	C	1995	1996	1997	1998	1999	AVERAGE	%
2		X		46,4	46,7	47,1	47,4	47,7	0,325	0,70
5		X		38,1	38,5	38,8	39,1	39,3	0,3	0,79
6			X	44,4	44,8	45,1	45,5	45,9	0,375	0,84
9	X			51,3	51,3	51,7	52	52,3	0,25	0,49
11		X		33,7	33,7	34,2	34,6	35	0,325	0,96
14	X			46,6	46,6	46,8	47,2	47,5	0,225	0,48
18	X			50,8	50,8	51,2	51,4	51,7	0,225	0,44
23			X	45,4	45,4	45,9	46,5	46,9	0,375	0,83
24	X			39,2	39,7	40,1	40,4	40,7	0,375	0,96
25	X			42,6	42,9	43,3	43,7	44,1	0,375	0,88
28			X	38,6	40,1	40,5	40,9	41,5	0,725	1,88
30		X		47,1	47,5	47,8	48,2	48,5	0,35	0,74
32		X		41	41,6	42,1	42,5	42,8	0,45	1,10
34	X			48,9	49,4	49,8	50,1	50,4	0,375	0,77
35		X		39,5	40	40,5	40,4	40,8	0,325	0,82
36			X	52,5	52,9	53,4	53,7	54	0,375	0,71

Table 3: aggression factor

n°	A	B	C	cavity (%)	growth (%)	aggression factor
2		X		1,5	0,7	-0,8
5		X		1,5	0,79	-0,71
6			X	0,25	0,84	0,59
9	X			1,5	0,49	-1,01
11		X		1,75	0,96	-0,79
14	X			1,5	0,48	-1,02
18	X			1,25	0,44	-0,81
23			X	0,25	0,83	0,58
24	X			2	0,96	-1,04
25	X			1,75	0,88	-0,87
28			X	0,5	1,88	1,38
30		X		1,75	0,74	-1,01
32		X		0,75	1,1	0,35
34	X			1,75	0,77	-0,98
35		X		1,5	0,82	-0,68
36			X	0,25	0,71	0,46

Class A: the trunk thickness becomes thinner and thinner year by year, at a percentage rate ranging from 0,81% to 1,04%;

Class B: the trunk thickness becomes thinner and thinner year by year, at a percentage rate ranging from 0,35% to 1,01%; as the extreme values are one next to the Class C and the other partially at the middle of the Class A, the reduction percentage rate therefore ranges from 0,68% to 0,8.

Class C: the trunk thickness becomes thinner and thinner year by year, at a percentage rate ranging from 0,46% to 1,38%.

Discussion

Further to the given results, there is a relation between the cavity dimension and the trunk thickness.

At the beginnings the tree struggles against the pathology since the tree growth speed is higher than the decay rate of the internal tissue. As time goes by, this relation reverses, that is to say the trunk thickness progressively reduces because the trunk decay is faster than the annual growth of new tissues resulting from the cambium.

When the cavity dimension becomes as wide as at least 50% of the whole transversal surface of the tree, the aggression factor gets regular values.

Before the rate of 50%, the aggression factor can change

This fact could be clarified by the investigation of the internal conditions of the cavity. When the cavity becomes large enough, the internal moistness and oxygen rates ensure the conditions for the optimal growth of the fungus.

Conclusions

In case the *Tilia* spp. tree suffers from the *G. resinaceum*, the aggression factor can be identified.

Arboriculturists may suppose that the tree has a cavity at the collar level. If the cavity dimensions are equal or higher than 50% of the tree transversal section, the portion of the trunk that is valid from the mechanical point of view reduces at a rate of 1, while the annual growth of cambium is equal to 0,5. In other words, the wood decay is two time rapid than the growth of the new tissues which develops according to the tree cambium.

Obviously, the given results are quite correct provided that the internal tree conditions are not modified by new injuries or by any tool perforations.

This research found that even though both the hosting tree and the fungi have infinitive genetic codes, under some specialist conditions the growth speed of the fungus on the xilematic tissue has regular values.

In view of this result, every relation between the hosting tree and the fungus can be described on a Tree Card by means of the above mentioned methods. These information could become a correct database that can be used when investigating the tree stability.

Abstract

When investigating the tree stability , the relation between the hosting tree and the fungus is often forgotten. As a consequence, the final decision on tree stability is often partial and superficial.

The arboriculturists need a correct database on the interaction between the specific hosting tree and the fungus. Even though both the tree and the fungus are living organisms with a specialist genetic code, uniform results were achieved on the investigation of the *Ganoderma resinaceum* on the *Tilia s.pp*. This investigation was carried out in the *Pianura Padana*, a large plain area in the north of Italy.

The monitoring of the fungus speed growth on the tissues of the hosting tree show that, after the starting period, the progressive growth becomes regular and therefore gives useful data that can be used in case of similar investigations.

This is called the “aggression factor”, that is the speed factor that determine the tree loss of tissues which are mechanically valid. The aggression factor is given under a percentage rate and shows to the difference between the decayed tissues and the new tissues that produced by cambium during the same period of time.

The given result is the aggression factor, both positive or negative.

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Root and butt decay of Robinia pseudoacacia caused by Perenniporia fraxinea

Introduction

Black Locust *(Robinia pseudoacacia* L.), originating in North America and introduced to Europe ca. 1635, is one of the most commonly planted tree species worldwide (KERESZTESI 1989; SEELING 1996, 1997). The species is subject to various disease agents in its natural distribution area (BUCHANAN 1964; FARR et al. 1995), but in Germany it is planted widely in urban areas since it reportedly tolerates urban climate stress (MEYER 1982) and is relatively resistant against pests and diseases (PEACE 1962). However, since several years a root and butt decay has been observed on *R. pseudoacacia* and its cultivars in Germany, leading to mechanical failure of trees. The problem is exacerbated by the fact that not only old trees are affected, but also younger ones which have occupied a site only for two or three decades. Preliminary investigations showed the basidiomycetous fungus *Perenniporia fraxinea* (Fr.) Ryv. (synonym: *Fomitopsis cytisina* [Berk.] Bond) to be responsible for the white rot observed in the lower trunk and woody roots of Black Locust (KEHR et al. 1999). Diseased trees only rarely exhibit conspicuous symptoms, so the damage is hard to diagnose and a possible danger for public safety due to hazard trees may not be noticed in time. This article gives information on the diagnosis of the causal organism, the type and effect of the wood decay and also compares the damage and symptoms to those of other important decay fungi on Black Locust.

Disease symptoms and type of wood decay

The symptoms associated with *P. fraxinea* on *R. pseudoacacia* are usually very inconspicuous, since defect symptoms at the base of the stem and a decrease in crown vigour (e.g. small leaves or leaf shedding) are often absent. Alterations in the normal bark pattern especially at the stem base and between the main roots and also a bottle-like shape of the lower trunk can be indications of decay in this part of the stem. However, inspection of Black Locust for damage is difficult due to the production of thick bark plates and irregular root collar zones even in young trees. Therefore, intense scrutiny of the tree base and root collar is needed to reveal the first signs of a hazard tree (KEHR et al. 1999; WOHLERS et al. 2000).

The decay action of *P. fraxinea* can cause death of main roots and the cambial area between the main roots at the tree base. After removal of the bark plates at these points, the decayed wood can be seen. The fungus causes an intense white rot in the heartwood of the tree base and also in the butt and main roots. In many cases, a white rot of sapwood can be found in affected trees, but only in the region close to the ground. In urban areas the heartwood decay usually reaches a height of only up to app. 50 cm in the tree base (KEHR et al. 1999, 2000), but in forest trees heartwood decay up to a height of 2,50 m has been registered (IGMANDY 1961, 1962). There are indications that the fungus can also cause direct damage to the cambium, similar to *Armillaria* or some *Phellinus* species, but this has yet to be substantiated. Our observations to date show that conspicuous crown damage (shedding of leaves, top dying) occur only after a considerable portion of the roots and the tree base has been killed.

The causal organism

Ecology, origin and distribution

Oak *(Quercus* spp.), ash *(Fraxinus* spp.) and Black Locust are given as the main hosts of *P. fraxinea* in literature, but it can also occur on several other deciduous tree species (BREITENBACH and KRÄNZLIN 1986; KREISEL 1961; RYVARDEN and GILBERTSON 1994). The fungus is regarded as a wound parasite, gaining entrance to young trees through wounds at the root collar or base of the tree (IGMANDY 1961, 1962). It is widespread both in Europe and in North America. Heavy damage associated with the fungus has been recorded for several decades especially in Hungary, where Black Locust plays an important role in forestry. Earlier investigations in Hungary revealed stands of less than 30 years of age to have a disease incidence of app. 10-12 %, and in older stands the strong decay of heartwood led to the loss of app. 20-25 % of marketable wood mass (IGMANDY 1961, 1962). In Germany, where the fungus was first found only a few decades ago (MÜLLER and JAHN 1966), the situation is not as serious yet, especially since Black Locust does not play a great role in forestry. However, over 60 year-old Black Locusts in forests are increasingly being damaged by *P. fraxinea* and also *Laetiporus sulphureus* (Bull.:Fr.) Murrill (SEELING 1997).

Within Europe the fungus is common mainly in warmer regions (KREISEL 1961; RYVARDEN 1978; RYVARDEN and GILBERTSON 1994), whereas in Northern Germany it was so rare in the past as to be placed on the Red List of Endangered species (WÖLDECKE 1998). Preliminary investigations on urban trees in Southern Germany (Mannheim) and in Northern Germany (Bremerhaven) indicate that *P. fraxinea* is spreading within Germany and is also becoming more common in those areas already colonized, which could be due in part to the increasing susceptibility of Black Locust planted in the 1970s, especially in urban areas. This is indicated by the fact that most of the diseased trees we investigated were growing in densely compacted soils with little soil space available for root development, many of them only 20-30 years old. According to our observations, the occurrence of the disease is apparently not limited to certain species or cultivars of *Robinia*.

Production and appearance of fruit bodies

P. fraxinea is a polyporaceous basidiomycete, producing basidiospores in numerous pores on the underside of tough, perennial bracket-like fruit bodies, old specimens of which can be found year-round. Only the young fruit bodies, formed from late summer onward, are rather conspicuous. These almost always appear in small groups of brackets at or near the tree base, especially between the root buttress, and measure app. 10-20 cm in diameter, sometimes up to 50 cm, and up to 8 cm thick where they join the substrate. The irregular surface is slightly velutinate and cream to light brown colored in young fruit bodies. The surface of older fruit bodies is glabrous and the colour turns to dirty brown, gray or even blackish. The context is tough and corky, also resembling cork in color. The pore surface is cream-colored in young fruit bodies, turns brownish-violet when injured, but in older brackets it is cork-colored, sometimes with a violet tint. There are usually 4-6 roundish-edged pores per mm. During the period of spore production, spore masses appear white and settle on the fruit body and its surroundings. In agreement with observations from Hungary (IGMANDY 1962), we found fruit bodies only on a small proportion of affected trees, which adds to the difficulty of diagnosing the disease. In many cases, reliable identification of the fungus is possible only by isolating it from affected tissue and growing it in pure culture (KEHR et al. 2000).

Microscopical features and cultural characters

Basidiospores are hyaline, subglobose to drop-shaped and measure 5-6,5 x 6-8,5 µm. Colonies on malt agar grow app. 3,5 mm per day at 22 °C and appear white initially, later cream-colored and thin, but with tough mycelial mats. Growth is optimal at 26 °C and is still rather high at 30 °C, whereas temperatures below 10 °C lead to very restricted growth rates. MONTGOMERY (1936) found 33 °C to be the maximum. This explains why in literature the fungus is reported to be a “warm-climate-species”. The temperature range of the fungus, however, is wide enough to allow it to become established in moderate climates as well. After a few weeks in culture, round to lemon-shaped chlamydospores are produced, measuring app. 8-15 x 5-10 µm. In older cultures the production of pores and even occasionally of basidiospores can be observed.

The decay rate by *P. fraxinea* is higher in sapwood than in heartwood, possibly due to the higher amount of starch and the lack of decay-resistant heartwood polyphenols (MONTGOMERY 1936). This would explain the affinity of the fungus for roots and sapwood tissues of the lower trunk and the slow vertical spread of the decay in the heartwood. Our trials have also demonstrated that in pure culture *P. fraxinea* acidifies the substrate to a greater degree than other decay fungi of *Robinia*, a factor which could enhance substrate utilization and keep competitors at bay. Antagonism trials in pure culture also indicate the fungus to be antagonistic towards *Armillaria* spp. and *Laetiporus sulphureus*, two fungi common on *Robinia*.

Possible effect of nitrogen supply on the disease

The single most important factor responsible for the intense destruction of woody roots could be the nitrogen supply of the soil surrounding the tree. Nitrogen is needed in great amounts for sporophore production of decay fungi and is generally recognized to influence the decay rate (SCHMITZ and KAUFERT 1936; HUNGATE 1940; COWLING and MERRILL 1966). Wood contains C:N ratios of between app. 300 and over 1000, depending on the tree species and tree nutrition, whereas the optimum for decay fungi on artificial media is app. 100-170:1, and it has been postulated that decay fungi derive part of their nitrogen requirements either from the transpiration stream of living trees or from sources outside the tree, such as soil (COWLING and MERRILL 1966; MERRILL and COWLING 1966). Several studies have shown higher decay rates in root wood compared to stem wood to be positively correlated with higher nitrogen and reserve carbohydrate content of woody roots (PLATT et al. 1965; ENGELS 1998). Trials with nitrogen fertilization of soils have demonstrated higher nitrogen levels to lead to an increased susceptibility of Spruce *(Picea abies)* to "Fomes" root rot caused by *Heterobasidion annosum* (Fr.) Bref. (HOPFFGARTEN 1933; ALCUBILLA et al. 1971). Experiments with the timber rot fungus *Coniophora puteana* showed that the fungus was able to decay trial wood much faster when it was surrounded by nitrogen-rich loam soil, even leading to the recommendation for home builders to avoid loam packings beneath the wooden flooring (ZYCHA 1939, 1940).

Nitrogen has been proven to be a limiting factor for the production of wood-degrading fungal enzymes of *P. fraxinea* in vitro (MONTGOMERY 1936). First results of the effect of nitrogen supply on the decay rate in vitro (Tab. 1) show that *P. fraxinea* and *Ganoderma adspersum* (S. Schulzer) Donk, also a common and dangerous decay fungus in woody roots of urban trees, react very positively to an increase in nitrogen supply, whereas *Laetiporus sulphureus*, a brown rot fungus, usually limited to the heartwood of the trunk, reacts negatively, at least to nitrogen in the form of CH_4N_2O.

Table 1: Influence of nitrogen supply on dry weight reduction of birch wood shavings by three decay fungi after 11 weeks at 24 °C and darkness (each value is the mean of five measurements; initial moisture percentage at the onset of the trial was identical for the three media types).

	Reduction in dry weight (%)		
	wood shavings	**wood shavings amended with 2 % malt agar solution**	**wood shavings amended with 2 % malt agar solution and 2 % solution of CH_4N_2O**
Perenniporia fraxinea	3,8	5,2	9,5
Laetiporus sulphureus	3,3	4,9	2,3
Ganoderma adspersum	1,0	1,7	9,5
control	0,0	0,0	0,0

Robinia belongs to the nitrogen-fixing trees and is therefore able to increase its supply of this element. Since the woody roots in most tree species in general possess higher nitrogen levels than trunk wood (ENGELS 1998) this would explain the affinity of *P. fraxinea* to the main roots and root collar zone. In urban areas the nitrogen amount is further increased by the substantial amounts of dog urea being deposited at the base of trees, a problem which has been addressed for some years (BALDER 1990). In theory dog urea leads to direct cambial damage and infection courts for pathogenic organisms in susceptible tree species, to which *Robinia* is said to belong (BALDER and WÖLLNER 1994), but it seems probable that the decay rate by *P. fraxinea* is increased by the nitrogen amount present in soil and in the woody roots and that the symptoms presented by the above authors as direct "dog-urea-damage" to *Robinia* may well be the result of decay by *P. fraxinea*.

<u>Differential diagnosis of other decay fungi on *Robinia*</u>

P. fraxinea is only one of several decay fungi occurring on *R. pseudoacacia*. In the absence of fruit bodies, differential diagnosis of the various decay caused by these fungi is difficult in living trees, in many cases necessitating the isolation and identification of pure cultures. However, if fruit bodies are present, identification of the most common decay fungi on *Robinia* is fairly easy. A few frequently occurring fungal species and their identification characters are described below.

The "Sulphur Polypore" (*Laetiporus sulphureus* [Bull.:Fr.] Murrill) is a very common fungus on *R. pseudoacacia*. It usually colonizes older trees, causing a brown rot of the heartwood, and the fruit bodies can appear at various heights on the stem. Very young fruit bodies of *P. fraxinea* could possibly be confused with *L. sulphureus*, but in the course of further differentiation, the two species are easily distinguished. *L. sulphureus* produces annual, thin, bright yellow brackets. The fruit body tissue is soft and wet when fresh, in contrast to the tough, corky consistency of the perennial fruit bodies of *P. fraxinea.*

Various species of the genus *Phellinus* occurring on *Robinia* produce a white rot. According to IGMANDY (1986, 1988), *P. robustus* (Karst.) Bourd. and Galz is the second most common decay fungus on trunks of *Robinia* in Hungary, after *L. sulphureus*. It causes a white rot mainly of the heartwood, but can also attack sapwood and the cambium to some extent, sometimes leading to canker-like disease symptoms. *P. robustus* produces perennial, compact fruit bodies mainly at higher parts of the main stem or on thick branches. Initially, the fruit bodies are knobby and brownish; later they appear as compact, fist-sized brackets up to 20 cm thick at the base. Older specimens often possess a greenish upper side due to algae. The underside is finely porous, initially yellow-brownish, turning rusty-brown. In contrast to *P. fraxinea*, the context is very woody, tough, zonate and yellowish-brown. The spores appear whitish in mass, as is the case for *P. fraxinea*.

Several species of the genus *Ganoderma* occur on Robinia, causing a white rot of the woody roots and stem base, similar to *P. fraxinea*. *G. adspersum* (S. Schulzer) Donk is the most common of theses species on *R. pseudoacacia*. It produces perennial fruit bodies at the base of the stem. They are initially thick and elongate, turning into brackets up to 40 cm wide and 4-10 cm thick at the base. The irregular upper side is brownish with a tough crust. The fine, white to cream-colored pores on the underside produce large amounts of dark brown spores which are deposited on the fruit bodies and their vicinity. The most easily recognized difference between *G. adspersum* and *P. fraxinea* are the brown spores and reddish-brown to dark brown context of *G. adspersum*. In the absence of fruit bodies, however, the decay caused by these two and other fungi in the woody roots and tree base are impossible to distinguish without the isolation of pure cultures.

A further fungus reported to be common on *Robinia* in Eastern and Southern Europe is *Phellinus torulosus* (Pers.) Bourd. and Galz (IGMANDY 1986, 1988). In Germany, its occurrence should be limited to the warmer parts with a wine-growing climate. A typical characteristic of this fungus is the occurrence of a white pocket rot in the heartwood.

Several species of Honey Fungus *(Armillarea mellea* agg.) can also cause a white rot of woody roots and heartwood of the lower trunk. The presence of black rhizomorphs and mycelial fans in the cambial zone of diseased roots and stems are an indication of infection by *Armillaria* spp. The *Agaricales*-type fruit bodies with ringed stems, domed cap with dark scales and light colored spore masses usually appear in late fall.

Conclusions

P. fraxinea is an aggressive white rot fungus of the woody roots and lower stem of *R. pseudoacacia* which can greatly reduce the mechanical stability of affected trees without causing conspicuous defect symptoms at the stem or in the crown. The genetic characteristics and also growth rate of trees apparently play a certain role in regard to infection susceptibility and disease progression. Older American studies (HIRT 1938; SCHEFFER and HOPP 1949; SCHEFFER et al. 1944) have shown that certain varieties of *R. pseudoacacia*, for instance "Shipmast Locust", possess higher natural decay resistance of heartwood. In general, the decay resistance of heartwood increases from the stem base upward in *R. pseudoacacia*, and slow-growing trees of a given variety are more decay resistant than fast-growing ones (SCHEFFER and HOPP 1949). In addition, the site characteristics are apparently very important, since our observations to date have shown the disease to be more prevalent on "stress-sites" with compacted soil and/or limited space for root development. Future plantings of *R. pseudoacacia* should take the site characteristics and available growing space into special consideration. The experience with *Robinia* in recent years has already lead to recommendations for planting the cultivars \`Bessoniana´, \`Monophylla´ und \`Sandraudiga´ only on sites enabling a sufficient development of the root system. Otherwise, these cultivars are threatened by root decay and mechanical failure from app. their 20th year of age onward (TAUCHNITZ 1999). For notes on disease diagnosis in regard to the routine inspection of Black Locust trees for public safety see WOHLERS et al. (2000).

Further studies on *P. fraxinea* are necessary for a more reliable diagnosis of the initial disease stages and the assessment of the influence of decay on mechanical stability of trees in regard to public safety. The mechanism by which the cambium of woody roots and the tree base is killed must also be investigated, especially in respect to contributing factors such as other microorganisms. Excess nitrogen, mostly in the form of dog urea in cities, could be a major contributing factor to decay development of *P. fraxinea* and possibly also other prevalent decay fungi of the root system such as *Ganoderma adspersum* and its effect must be investigated.

Summary

In recent years, root and butt decay of Black Locust *(Robinia pseudoacacia* L.) has been observed in several German cities, leading to mechanical failure even in young trees. The polyporous fungus *Perenniporia fraxinea* (Fr.) Ryv., which causes a white rot of heartwood, sapwood and woody roots, is responsible for the damage. The disease is difficult to diagnose since stem and crown of affected trees usually do not show conspicuous defect symptoms, so possible consequences for public safety caused by hazard trees may not be registered in time. Due to the frequent use of Black Locust in urban areas in Germany, this poses a con-

siderable problem. This article gives a description of the fungus, the decay type and damage it causes and compares it with other decay fungi occurring on Black Locust.

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Canker stain of plane-trees: a serious threat for North-European urban plantations

Onset and Spread

Canker stain of Plane-tree is one of the most serious diseases to strike Plane in the past few decades. Reported for the first time in the USA in the 1930s (Jackson and Sleeth 1935), the disease spread mainly into the major Atlantic coast cities, where it caused severe die-off of urban tree plantings composed essentially of *Platanus x acerifolia* (Ait.) Wild (London Plane). The great forests of *Platanus occidentalis*, the native Sycamore, seem to have been relatively unaffected.

It has been hypothesized that the disease reached Europe from the United States as a result of exchanges that occurred during the second world war (Cristinzio *et al.* 1973). However, the first known report from the Old World came from Italy in the early 1970s (Panconesi 1972, 1973). At the same time as it spread throughout Italy (AA.VV., 1996), the disease also appeared and began to spread in France (Ferrari 1974, Vigouroux 1986), Spain (Fernandez *et al.* 1977, Ruperez and Muñoz 1980, Cadahia 1983), and Switzerland (Gessler *et al.* 1987). Other unconfirmed reports have indicated its presence in Belgium and Algeria. Recently its presence was also documented in the region of Erevan in Armenia (Simonian 1982).

Biological Aspects, Conservation into the Tissues and Entry into the Host Plant

The pathogenic agent responsible for canker stain of Plane-tree is the fungus *Ceratocystis fimbriata* (Ell. et Halst.) f. sp. *platani* (Walter 1946, Marziano 1988), a wound parasite that can rapidly kill the trees it attacks. Severity of the disease is due partly to the aggressive nature of the pathogen, host species susceptibility and the diversified modes of spread, but also to the considerable difficulty encountered in controlling the disease. The pathogen may spread through wound site contamination or root anastomoses between contiguous trees (Mutto Accordi 1986). However, man himself is the main driving force behind the spread, by failing to exercise due care and caution, or indeed by downright negligence. This may occur either during pruning, or when parts of the root system are cut out in order to make space for other objects in the ground (pipes, cables, etc.), and above all when operations are carried out to treat or eliminate diseased trees. During such operations large quantities of sawdust or wood shavings of varying size are produced, within which the parasite remains viable. This infected tissue can be transported over considerable distances, thereby contributing to further spread of the disease. Transport of such fragments may be windborne, or by vehicle traffic or watercourses. Slightly less frequent but non negligible is the risk of disease spread by means of insects, birds and small mammals (rodents).

Infected or dead plants that remain standing not only supply the above-described carriers with a reservoir of inoculum, but they also allow the mycelium of the parasite to move into the root system of contiguous anastomized trees. This is particularly likely to occur when trees are growing close together. Furthermore, the longer an infected or dead tree is left standing before removal, the greater the risk of infecting adjacent trees.

Protection

Such a situation underlines the importance of immediately eliminating all sources of contamination, i.e. each dead or diseased tree. At the same time, it is vital to avoid inflicting any kind of wound on trees, either on the above-ground portion or the root system. But elimination of infected trees proves to be a double-edged sword: by seeking to eliminate the source of inoculum, considerable quantities of infected sawdust or wood shavings are produced, and these constitute one of the main sources of disease spread. It is therefore necessary to take all possible precautions during tree felling operations, including carefully gathering up all the sawdust, which should be destroyed together with the other infected material. Such a procedure can be done fairly easily in cutting operations carried out from ground level, but it becomes virtually impossible when working on the higher portions of the tree. The need has thus arisen to acquire knowledge of the duration of parasite viability in infected tree tissue, in order to ascertain whether and if it is possible to undertake felling without the risk of producing infected sawdust.

It has now been shown that the viability and infection capacity of the parasite in infected tissue and in fragments scattered on the ground (shavings) can be persistent, lasting even up to several years (Grosclaude *et al.* 1996). It is conceivable that a vehicle transiting through a site where infected trees are being cut down could become contaminated (eg. the tyres) with fragments of infected wood, and then transport them into disease-free areas within a short space of time. During such a trip, it is perfectly possible that the infected fragments could be deposited on the exposed roots of a Plane-tree, since the roots are the parts most frequently exposed and wounded by passing vehicle traffic.

If, on the other hand, the disease comes from above and the mycelium has not yet reached the root system, the tree can be felled at the base, thus separating the healthy from the diseased portion without production of infected wood sawdust. If the diseased trunk is to be sawn up, this should be done on special groundsheets in order to avoid any further risk of producing infected sawdust. The healthy stump can then be left in place because it no longer represents a danger for adjacent or anastomized trees. But whenever possible it is good practice to remove the stump because it can still become infected during felling operations and also in order to avert the danger of root rot, which over time can compromise the stability both of older and more recent trees.

If disease has already attacked the tree collar or the first branching level of the root system, the tree must be felled and rooted out immediately. In addition, mere felling of healthy trees adjacent to the diseased or dead tree, which until recently was the standard recommended practice, frequently fails to solve the problem of contamination because the root systems of these trees remain alive for prolonged periods of time. The parasite can pass from diseased roots to the healthy roots of adjacent healthy felled trees and hence to adjacent healthy standing trees. Therefore it is not sufficient to cut trees with infected roots and to proceed likewise with adjacent healthy trees: rather, they should be rooted out or killed. However, for technical or economic reasons, the stumps are hardly ever removed; consequently, it has commonly been suggested that inducing early death of the diseased tree may represent a valid alternative to removal. Killing the tree, it is argued, can favor the development and antagonist action of some commensal fungi whose saprophytic action of colonizing dead tissue is thought to halt the progression of *C. fimbriata* towards the roots of healthy adjacent trees.

Diseased or healthy trees can be killed by using the herbicides Tordon and Glyphosate, which can be administered by pressure injection or adsorbed through holes drilled in the sapwood, or by treating the stump wound surface. But even when diseased trees are killed with herbicides or other products or mixtures exerting a fungicidal action, the parasite is still not prevented, as least in the short run, from entering healthy host tissue. Furthermore, the practice of using herbicides to kill healthy trees standing next to diseased trees often inflicts very severe damage on those that are anastomized with these trees. And the closer the trees are growing together, the greater the likelihood of damage.

It is therefore clear that rooting out the diseased tree and adjacent healthy trees, or possibly the physical separation of diseased from healthy trees by trenches dug into the ground, still represents the safest means to prevent spread of the disease through the root system. Every effort should therefore be made to overcome any technical or economic impediment to stump removal, especially in urban environments. This is of particular importance in areas or stands in which the disease makes its appearance for the first time.

Surgical Treatment

Restoration of healthy status by eliminating infected branches is an extremely arduous operation. The parasite mycelium that has developed in the marginal areas of the canker is difficult even for an experienced operator to identify. It is hard to establish a clear-cut border between diseased and healthy tissue because the disappearance of the last visible symptoms within the woody cylinder, namely the small bluish lenticular-shaped spots, does not fully correspond to the border with healthy tissue.

Some authors have suggested that conidia, above all in saplings and seedlings, are capable of travelling along the conducting vessels by penetrating through perforation plates. In adult trees the vessels are smaller and conidia encounter greater difficulty in attempting to enter through the perforation plates. We believe that conidia travel through the vessel in the sap flow, but on reaching the obstacle of the perforation plates they stop and germinate. The hyphae then pass through them and are immediately transformed into the conidiophores that produce new conidia, which repeat the mechanism as they move upwards.

Chemical Control

Research into methods and chemical products capable of assuring effective control, prevention and cure of this dangerous fungal parasite began as soon as presence of the canker stain was reported in Italy. At first, the "in vitro" efficacy of an extensive series of chemical products was tested. Best results were obtained with benzimidazoles (Thiabendazole, Carbendazim). The same products were subsequently further tested by using traditional treatment methods (canopy spraying). However, no appreciable results were achieved with such "external" treatments. Experiments were thus conducted with alternative techniques, seeking to place the fungicidal chemical directly in contact with the parasite mycelium, which preferentially vegetates on conducting tissues of the sapwood. These experiments led to identification of several fairly effective products (Carbendazim, Imazalil sulfate) and a successful distribution technique (pressure injection). But the treatments, although applied repeatedly, did not give the expected results. Temporary blockade of the infectious process was achieved, but it was not eradicated (Panconesi 1988, 1999).

Genetic Improvement

Virtually all cultivated trees in European stands of Plane-tree are composed of the hybrid *Platanus x acerifolia*, a rapid-growing species that is well adapted to our environment and widely used in urban tree plantings throughout Europe. Epidemic diffusion of the canker stain is favored by the extreme susceptibility and genetic uniformity of this species, which owes its origin to a restricted number of individuals mainly reproduced agamically (by self-rooting). Considerable difficulty is encountered in undertaking selection and genetic improvement, due to the pronounced canker stain susceptibility of *P. acerifolia*, its reduced variability and the tiny number of species belonging to the genus *Platanus*. Few studies are available in the literature, apart from work carried out by McCracken (unpublished data) in the USA and El Modafar *et al*. (1995) and Vigouroux *et al*. (1999) in France.

Vigouroux and co-workers, working on individuals of *P. occidentalis* selected by McCracken in the USA and resistant to *C. fimbriata*, successfully constituted a canker-resistant hybrid which also had a good degree of resistance to anthracnose (*Gnomonia platani*). The *P. occidentalis* selected by McCracken showed considerable difficulty in adaptation, a phenomenon which, together with its susceptibility to *G. Platani*, prevented it from being cultivated directly in Europe.

Research carried out during the same period but with biochemical criteria (El Modafar *et al.*, 1993), inoculating Plane leaves, detected more rapid production of two phenolic phytoalexins (scopoletin and umbelliferon) in *P. occidentalis* as compared to *P. orientalis*. This is thought to be correlated with resistance, as it sets in motion the compartmentalization processes that eventually halt the infectious process. This rapid, non-destructive biochemical system cannot yet be used for practical applications, but further research is in progress in order to adapt it for mass selection. Study on early tests is of the utmost importance in allowing acceleration of the stage of individual selection. This contrasts with traditional methods, which were extremely lengthy, as was the case in the pathosystems Cypress – *Seiridium cardinale* and Elm – *Ophiostoma novo-ulmi*.

Another factor that should not be underestimated is parasite variability. Knowledge on this aspect is of major importance for genetic improvement work. *C. fimbriata* f. sp. *platani* populations are known to be composed of a great range of strains endowed with different characteristics. Numerous strains are already known (self-sterile, self-fertile, perithecial-sterile, self-sterile protoperithecial, etc.) and their pathogenicity has been evaluated, but there are probably many more of which little or nothing is known.

A susbstantial contribution to assessment of the degree of pathogen genetic variability is expected to come in the next few years from application of DNA-based techniques. The great leap forward achieved in recent years in the field of molecular genetics provides forest pathologists with an extensive range of powerful new techniques to study the quantity and distribution of forest pathogen variability, investigate evolutionary relations, resolve taxonomic questions, and devise sensitive and effective diagnostic assays (Henson and French 1993; Leung et al., 1993; Rosewich and MacDonald 1994; MacDonald 1997).

Use of molecular analysis in developing diagnostic assays, which should proceed in parallel with analysis of population diversity, could lead to revolutionary progress in control of this difficult disease. Protocols have already been drawn up, based essentially on use of PCR, which allow accurate, precise and unequivocal detection of various pathogens in infected but still asymptomatic host tissue (Nazar et al. 1991; Moukhamedov et al. 1994; Moricca et al. 1998). The sequence of hypervariable DNA regions should make it possible to set up specific primers to be employed in site-directed PCR for differential identification of pathogen strains. The use of DNA-based methods not only would ensure early diagnosis of canker stain, but it would also facilitate investigation into the advancing front of the disease as it moves towards northern Europe and monitoring the diffusion and spread of the most aggressive strains within this front.

Such methodologies would be crucial in overcoming the most severe problem encountered in combating the spread of *Ceratocystis fimbriata* f. sp. *platani*: the inability to achieve prompt identification of the pathogen at the early stage, before symptoms become noticeable to the naked eye. Once symptoms do become visible, control measures become virtually ineffective, and this has been one of the main causes of the epidemic spread of the pathogen. In addition, as already mentioned, molecular applications could also shed light on some unclarified aspects of the epidemiology of canker stain. Taken together, these achievements could lead to better control of the disease.

Further research into these as yet unclarified aspects should focus on biology of the pathogen, conventional disease control methods and practical applications of the most innovative biomolecular techniques, with the aim of devising an effective means of preventing canker stain from spreading to Northern Europe from Mediterranean countries. The overall goal is to ensure that Plane selections do not undergo the same fate as Elm clones that were selected for resistance to *Ophiostoma ulmi* but then failed to resist outbreaks of the more aggressive variant *Ophiostoma novo-ulmi*.

Such a risk is heightened in the present pathosystem by the elevated degree of genetic uniformity characterizing Plane-tree in European cities. It should be kept in mind that the genus *Platanus* is unusual among trees inasmuch as the interspecific, vigorous and fertile hybrid *Platanus x acerifolia*, accidentally obtained in the Oxford botanical garden in 1670, is more widely cultivated than either parent species (*P. occidentalis* and *P. orientalis*) or any other species in the genus. While in the United States Plane-tree production has been largely by seed, in Europe the London Plane and its derivatives have generally been clonally propagated. The high level of genetic uniformity, together with the extensive diffusion of London Plane in urban plantings of the major cities of the northern emisphere and the difficulties encountered in controlling the disease, indicate that a major interdisciplinary thrust is required. Plant breeders, plant pathologists, molecular biologists, tree growers, ecophysiologists and experts in urban tree management are called upon to undertake a combined effort to stop the spread of the disease northwards.

Summary

The Authors report on the biological and epidemiological characteristics of the agent of canker stain of Plane-trees and the difficulties involved in controlling the disease. Technical problems and adverse aspects of operations designed to cut down diseased trees, as well as the usefulness and limitations of chemical control of the pathogen, are described. The article underlines the importance of genetic improvement for disease control and the need to use a wide germ plasm base in selection work, in order to avoid genetic uniformity. It is argued that molecular markers constitute an important tool for analyzing the degree of pathogen genetic variability and investigate as yet unknown epidemiological aspects. In addition, molecular applications should allow more prompt and effective disease diagnosis. Finally, a major interdisciplinary effort is required, with experts of different fields working in close partnership, in order to develop appropriate control measures to avoid a catastrophic expansion of canker stain towards Northern European countries.

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Bionomics of *Eotetranychus tiliarum* as influenced by key factors*

Introduction

Eotetranychus tiliarum Hermann is an important pest of lime-trees. The mites are living on the under leaf surface along the midvein and destroy the epidermis cells. In the beginning of the infestation the upper leaf surface shows light-coloured spots. The spots turn to bronze if the density will be higher. Especially with drought the leaves become brown coloured and fall (FRITZSCHE, 1964). *E. tiliarum* belongs to the family Tetranychidae, to the subfamily Tetranychinae and to the genus *Eotetranychus*. Host plants are *Tilia* sp., *Acer* sp., *Aesculus* sp., *Alnus* sp., *Crataegus* sp., *Fraxinus* sp., *Platanus* sp., *Populus* sp. and *Salix* sp. (SCHWENKE, 1972). The mite was found in whole Europe and on *Tilia* in America.

The females of *E. tiliarum* with a length of 0,4 mm are in general smaller than *Tetranychus urticae*. The males have a length of 0,32 mm. They have 3 to 5 generations during the year. The body is oval formed, pale yellowish green and the eyes are red. Diapausing adult females change the body colour to pale yellowish orange. They search hiding-places under rot leaves, moss and the ground of the trees. They also go into the upper soil layer (FRITZSCHE, 1964; SCHWENKE, 1972).

KROPCZYNSKA et al. (1988) investigated biological parameters of *E. tiliarum* collected from street trees and from natural habits. They found that the mites collected from street trees increased faster and higher in their population. They concluded that this observation is caused by the different nutrient values of leaves on street trees. The street trees are getting the nutrients from the salt content in the soil from snow control in winter.

The present paper reports on the effect of key factors, which influence the development of *E. tiliarum.* This paper deals with four key factors, which will be explained in the following text. One important parameter is the climate. High temperature and low humidity in general support the population development. The microclimate is influenced by the tree-top and the planning of the environment. Therefore the pest population can be reduced or stimulated. The development will also be influenced by the predators. In the program was found out that the main predators of *E. tiliarum* are predatory mites (BALDER et al., 2000). Moreover, the species of the lime-tree is very important, for example *T. platyphyllos* is predisposed to the mites (GALK, 1995).

Materials and methods

Investigations on the bionomics of *E. tiliarum* were carried out in the year 1998 and 1999. To find out the importance of the key factors three different locations with street trees in urban conditions were chosen. The locations were in a small area of the city of Berlin. Each place consisted of three repetitions. Samples were taken from young *T. x europaea* \`Pallida´.

The locations 1 and 2 were characterized by small tree-grids. The trees were standing in a main road with high traffic. The environment was asphalted. The location 1 was at the north side of the street and the trees got sun nearly the whole day in the summer (planting year: 1995). In contrast, location 2 was at the south side of the street and got less sun (planting year: 1992). The trees of location 3 stood at the north side of a small side street and the tree-grids were planted (planting year: 1992). In the vicinity were some front gardens.

The infestation of the trees was estimated every second week from May to October in 1998 and every fourth week in 1999. At each valuation 10 leaves per tree were taken, pests and beneficial organisms were counted in the laboratory. Insects were caught with a cotton sack by beating the branches. The climate of the city area was measured by an institute of a Berlin university.

Biological parameters of *E. tiliarum* were investigated on cuttings of *T. platyphyllos* and *T. cordata.* The experiment took place at 20 °C and 12 C°, 65 % +/- 10 % humidity and with a 16 L-8 D photoperiod. Both,

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the development and the egg production were assessed three times a week. The development of hatched larvae on both host plants was observed. The investigation of the egg production is just in the beginning and until now there are only 10 repetitions from each host plant.

Results

Key factors

Climate

The density of *E. tiliarum* at location 1 as well as at location 2 is much higher in 1998 than in 1999 (Fig. 1). In the year 1998 the spider mites could build high populations at both locations. In contrast to that in 1999 the spider mites were not able to colonize the trees.

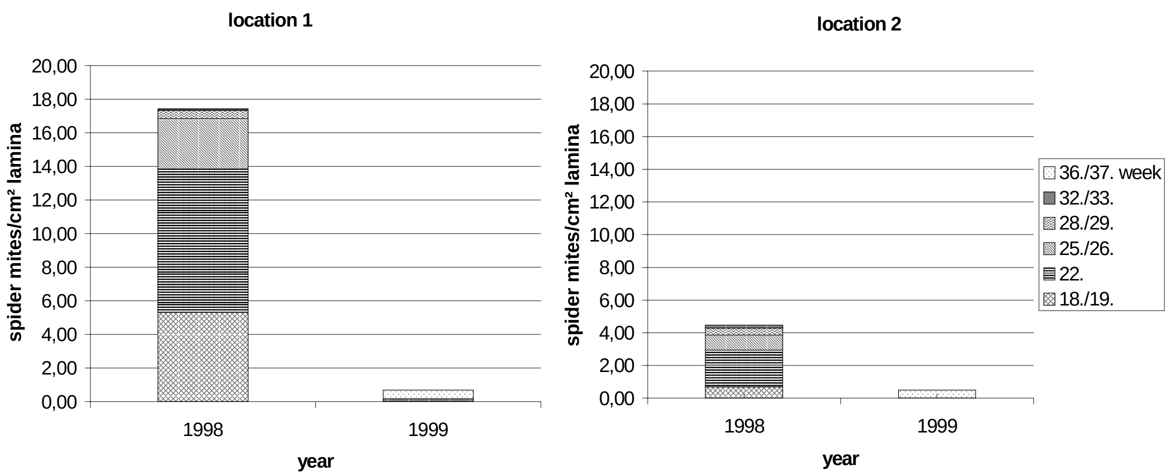


Fig. 1: Comparison of the population of *Eotetranychus tiliarum* on *Tilia x europaea* `Pallida´ in 1998 and 1999. The locations are at the north side (location 1) and the south side (location 2) of a main road.

The infestation of the trees was higher at the sunny north side than at the south side. In 1999 only a low pest population was observed at the north side. The pest population reached a peak mainly in May and June of 1998. The high density is caused by the temperature in these months (Table 1). Both, the temperature and the duration of the sunshine were higher. The difference amounted in May and June to 2 and 3 °C, respectively. In the middle of May the temperature reached more than 15 °C and the sun was shining more than 12 hours a day. In the beginning of June the temperature rose above 20 °C. In the following year 1999 the temperature reached 15 °C first at the end of May and the sun was only shining for 9 hours a day. Not before July 20 °C was reached.

Table 1: Comparison of the climate data (temperature, humidity and duration of the sunshine) in 1998 and 1999. Three values are given for each month.

month	Temperature [°C]		Humidity [%]		duration of the sunshine [h]	
	1998	1999	1998	1999	1998	1999
May	14,4	12,5	69,1	58,7	5,7	8,9
	16,1	13,1	56,6	64,5	11,2	8,8
	15,3	17,1	68,2	64,4	2,3	7,6
June	19,5	16,2	67,7	69,0	7,3	7,3
	15,2	16,5	71,7	72,4	5,2	5,9
	17,7	16,0	74,4	65,5	6,1	7,3

Locations

The comparison of the two locations 1 and 3 makes the effect of the different architectural and landscape planning on the development of *E. tiliarum* understandable (Fig. 2). In the side street no pest population developed during the whole vegetation period. The density reached a peak in June with less than 1 spider mite/cm² lamina. In the main road the initial population of *E. tiliarum* amounted to above 5 mites/cm² lamina and increased to a value of nearly 9 mites/cm² lamina in May. In June the population decreased and in July it was nearly zero.

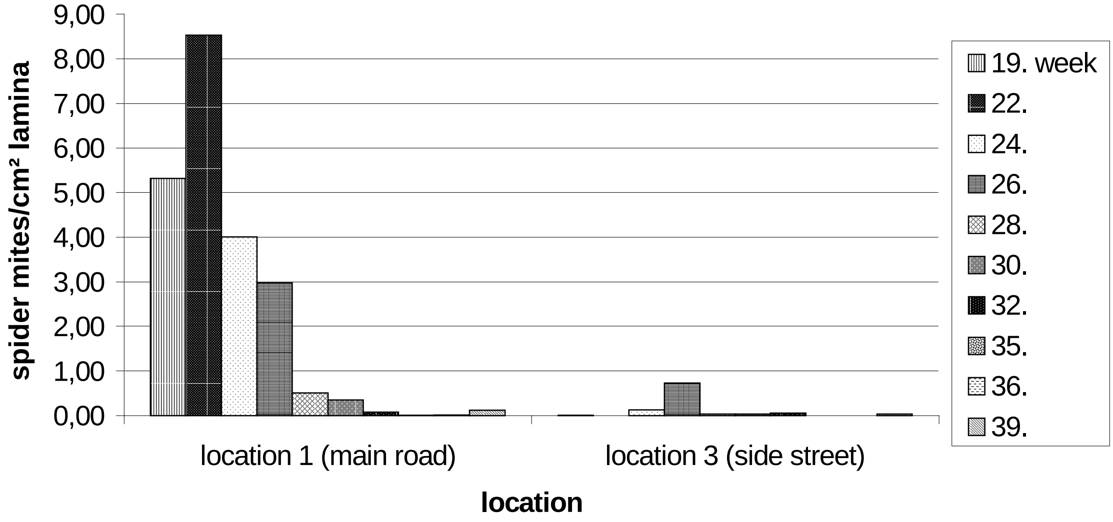


Fig. 2: Comparison of the population of *Eotetranychus tiliarum* on *Tilia x europaea* `Pallida´ at two locations with different planning in 1998. Location 1: main road, north side, asphalted. Location 3: side street, north side, front gardens.

Predatory mites

The increase of the population of *E. tiliarum* depends on the appearance and the efficiency of the predaceous mites. The best kind to describe the relationship between predator and prey may be to build the relation of spider mites and predatory mites: the lower the value the lower the damage. It can be seen from Table 2 that the relation for location 1 (north side of the main road) is the highest and the relation for location 3 (side street) is the least. For example, the relation at location 1 in the 22nd week is 901 spider mites to 1 predatory mite. On the other hand more predaceous mites than spider mites were recorded at this time in the side street. Therefore the result of this relation is zero.

Species of the host plant

The species of the host plant may influence the population of the spider mite. For this reason some species of older lime-trees were chosen for studying: *T. platyphyllos*, *T. cordata*, *T. tomentosa* and *T. x euchlora*. The trees were standing in a park under similar conditions. *T. platyphyllos* and *T. cordata* were first assessed in the 18th week and *T. tomentosa* and *T. x euchlora* in the 30th week..

The highest population of *E. tiliarum* was observed on the most predisposed species *T. platyphyllos* (Fig. 3). Besides, visible damages were only found there. However, the initial population of the spider mite was higher on *T. cordata*, but the further development was relatively low. No pest population could arise on *T. tomentosa* and *T. x euchlora*.

Table 2: Relation of the spider mite *Eotetranychus tiliarum* and predatory mites on *Tilia x europaea* \`Pallida´ at three locations with different environments, 1998.

week	location 1 north side of the main road	location 2 south side of the main road	location 3 side street
19.	267	54	1
22.	901	130	0
24.	122	51	2
26.	40	11	12
28.	17	6	1
30.	6	21	6
32.	20	14	19
35.	1	1	0
36.	7	0	0
39.	14	0	8

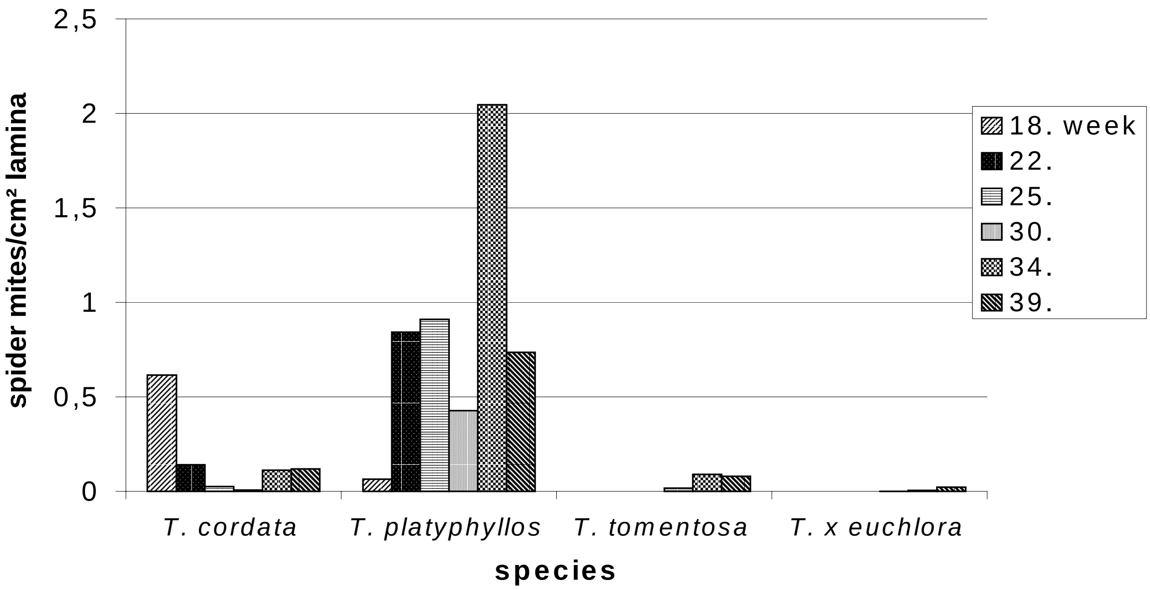


Fig. 3: Comparison of the population of *Eotetranychus tiliarum* on different species of lime-trees, 1998.

Laboratory investigations

The development of *E. tiliarum* was examined under different temperature conditions and on two *Tilia* sp.

20 °C

The development of *E. tiliarum* on *T. platyphyllos* and *T. cordata* was nearly similar (Fig. 4). After 7 days only 5 % of the eggs were produced. Approximately 75 % of the developmental stages were larvae and the part of the nymphs amounted to 25 %. On *T. cordata* the last larvae hatched at day 11 and on *T. platyphyllos* at day 14. Adults began to hatch at day 11. From 140 hatched larvae on *T. platyphyllos* a number of 109 (77,9 %) reached the adult stage, from 138 hatched larvae on *T. cordata* became 104 (75,4 %) adults, respectively.

On both species the daily egg production reached a peak at day 8 with 4,5 eggs/female/day (1,1-7,2) on *T. platyphyllos* and 3,7 eggs/female/day (2,0-5,8) on *T. cordata*); n=10. From day 31 the daily egg production decreased to a value under one. The total number of eggs produced by females on *T. platyphyllos* and on *T. cordata* amounted to 46.9 eggs/female and 40,2 eggs/female, respectively.

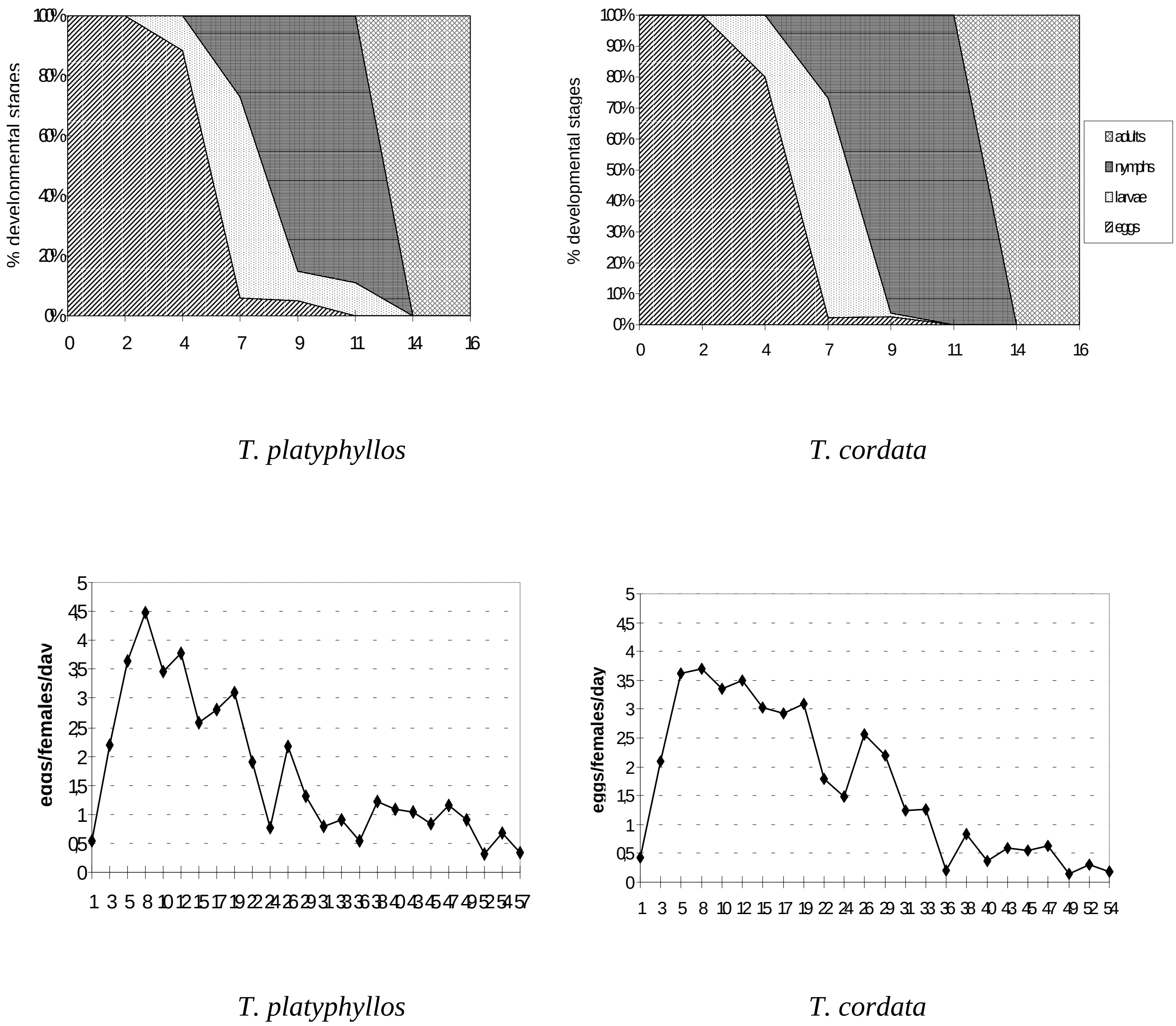
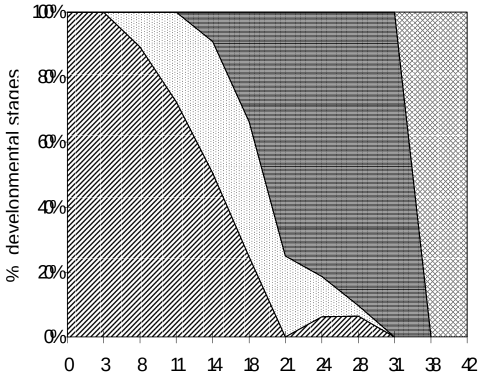


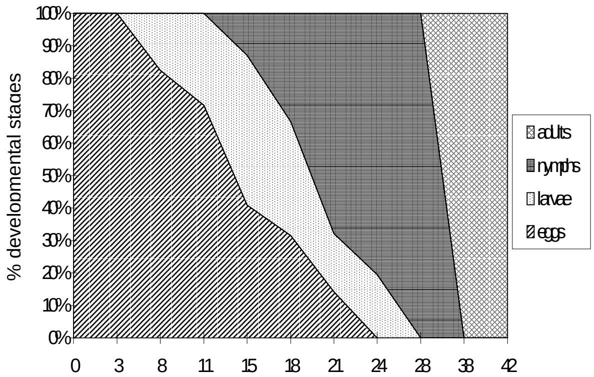
Fig. 4: Developmental stages in % and the daily egg production of *Eotetranychus tiliarum* on *Tilia platyphyllos* and *Tilia cordata* by 20 °C and 65 % +/- 10 % humidity; researched three times a week.

<u>12 °C</u>

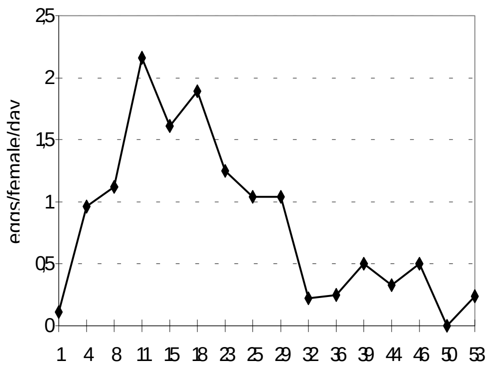
The spider mite development was nearly identical on both species. The first larvae hatched at day 3, the first nymphs at day 11 and the first adults at day 35 (Fig. 5). On *T. platyphyllos* 140 larvae hatched and 116 (82,9 %) of these became adults. On *T. cordata* 137 larvae hatched and 102 (74,5 %) reached the adult stage.

The highest value of egg production was reached at day 11 on *T. platyphyllos* and at day 23 on *T. cordata*; n=10. 2,2 eggs/female/day (0,8-3 on *T. platyphyllos*; 1-3,4 on *T. cordata*) were laid on both host plants. The sum of eggs laid per female amounted to 13,2 on *T. platyphyllos* and 15,6 on *T. cordata.*





T. platyphyllos *T. cordata*



T. platyphyllos *T. cordata*

Fig. 5: Development stages in % and the daily egg production of *Eotetranychus tiliarum* on *Tilia platyphyllos* and *Tilia cordata* by 12 °C and 65 % +/- 10 % humidity; researched three times a week.

Discussion

The results of the field studies revealed that the population of *E. tiliarum* on lime-trees lining streets, for example on *Tilia x europaea* `Pallida´, is influenced by some key factors. This paper deals with four measurable factors: 1. climate, 2. locations, 3. predatory mites, 4. species of the host plant.

High temperatures in the beginning of the vegetation period cause an increase of the mites population. Therefore it is important whether the trees are standing at the hot side or the cooler side of a street. The temperature is influenced by reflections of buildings and sealed areas as well as the local time of sunshine.

Furthermore, the environment of the location has an influence on the pest population. It is imaginable that, for example, planted tree-grids or front gardens with different plants in the surroundings, can allure predators. The green habitats may change the microclimate and provide food or places to retreat, for example.

The relationship between spider mites and predatory mites can be described with the value of the relation. A high value means a multiple of spider mites. The results of the investigation were very different. The highest value of the relation amounted to 901 for the north side of the main road. Lower values were received for the south side of the main road (cooler part) and the relation for the side street was nearly zero.

The comparison of the population of *E. tiliarum* on different species of lime-trees showed that the predisposed species *T. platyphyllos* was most infested. On *T. cordata* only a high initial population was observed but the further development was low. *T. tomentosa* and *T. x euchlora* were examined later and no spider mite population could arise there.

For each host plant and temperature stage the development of approximately 140 hatched larvae of *E. tiliarum* was observed. At 20 °C the development on *T. platyphyllos* and on *T. cordata* was nearly similar. The same observation was made at 12 °C for both species. Differences may be in the egg production of the females. Till now the results include only 10 replicates of females. Therefore at 20 °C the egg production per female as well as the total egg production per female is higher on *T. platyphyllos* than on *T. cordata*. At 12 °C the peak of the daily egg production is similar on both species, but the total number of produced eggs per female is higher on *T. cordata.*

The data show that the development cannot be the cause for the higher intensity of infestation of *E. tiliarum* on *T. platyphyllos*. Probably this fact is due to the egg production of the females. Furthermore, it is conceivable that the feeding rate of the predatory mites is a very important factor and will be considered in continuing studies.

Summary

Under favourable conditions *Eotetranychus tiliarum* Hermann causes high damages on *Tilia* street trees. Key factors, which influence the bionomics of this mite, will be investigated within a program. Measurable factors are the climate, the environment and the landscape of the tree stands, the efficiency of the predators and the species of the host plants. High temperatures in the beginning of the vegetation period may support the pest population on trees under bad conditions, like small tree-grids, sunny asphalted places, location in a main road. Furthermore, the efficiency of the predatory mites is very important and will be expressed with the value of the relation of both.

The development and the egg production on *T. platyphyllos* and *T. cordata* were investigated at 20 °C and 12 °C with 65 % +/- 10 % humidity and a 16L-8D photoperiod. The development for each temperature stage was similar on both species. In contrast, the number of the egg production was different on both host plants: at 20 °C more eggs were produced on *T. platyphyllos* and at 12 °C more eggs were produced on *T. cordata*. However, this biological life-parameter up to now is investigated with only 10 repetitions.

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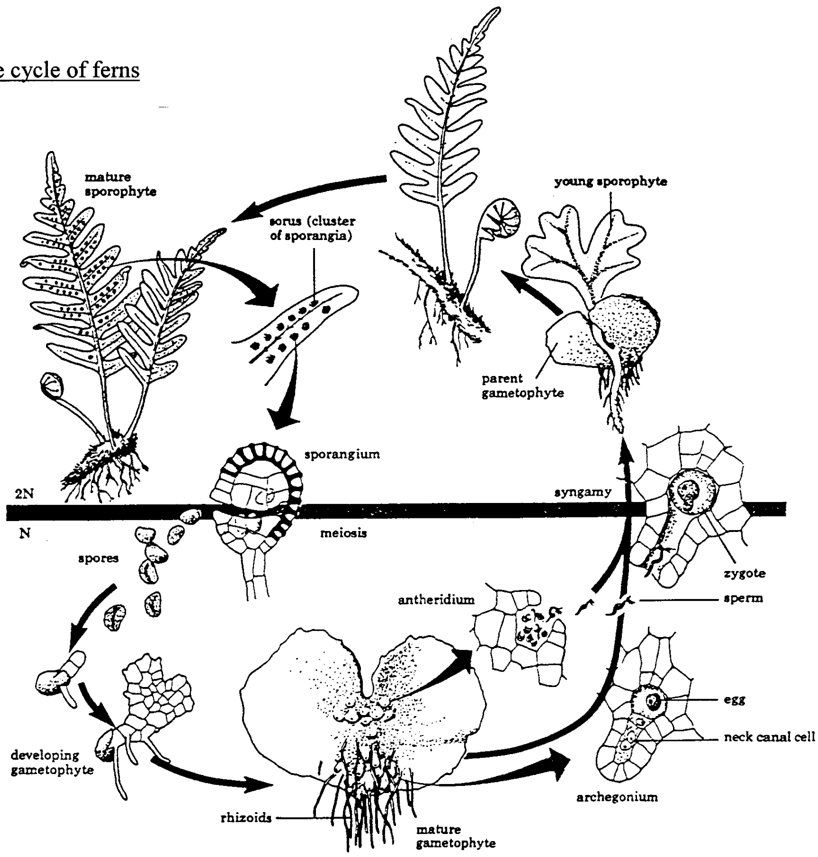
Ferns in urban horticulture - production, uses and phytopathological problems

Ferns in urban areas

When ferns are mentioned, most people think first of humid and shady places under trees or in the forest. These special habitats are actually typical for the indigenous representative ferns such as *Dryopteris filix-mas* and *Athyrium filix-femina.* In the taxon of ferns, many representatives have adapted to nearly all ecological niches. Many live in places where they are not expected. We can find them not only on warm and dry walls, but also in moors with low nutrient levels. Some ferns even have their habitat in the mountains at altitudes above the tree line. This versatility, together with their primitive and fascinating shapes make ferns ideal plants in horticulture. Nevertheless, the most well known ferns are not the most suitable in urban areas. The soils in the recent gardens are not jet convenient to cultivate typical forest ferns. Planted trees or bushes are still too small and give little shade. The soils have not enough organic matter and have not developed the necessary structure. Therefore, a typical forest fern will not achieve acceptable growth. This is a great challenge for the nurserymen: the choice is not wide enough, there remains much work to do.

We can find one of the most important freeland ferns, *Matteuccia struthiopteris*, in nearly all horticulture nurseries. But these ferns which spread too much in smaller urban gardens can be become a nuisance. On the other hand, ferns which like dry habitats are rare by available in nurseries. The market for special ferns is very good. This fact may animate the nurserymen to force and optimize the fern production. So far, there is much experience missing. Some of these problems will be discussed in this paper.

The life cycle of ferns



The life cycle of a fern involves an alternation between the diploid and fertile sporophytic (above the line) and the haploid gametophytic (below the line) generations. Mature sporophytes have structured clusters of sporangia an the under side of the leaves. The ribbed structure an a sporangium is the annulus; physical changes in the wall of the annulus help in the dehiscence of the sporangium RAGHAVAN (1974).

In the sporangia, there are many haploid spores developed by meiosis. The sporangium burst and these spores are hurled out and they will germinate an a suitable ground. A young gametophyte sprouts. Developing further, a mature heart shaped gametophyte is formed. After some weeks, the generative structures develop (the female archegonium and the male antheridium). The gametophyte is affixed to the ground by root-like rhizoids. Sperms from the antheridium and eggs from the archegonium combine into diploid zygotes. From this zygote the sporophyte (the "real fern") develop and the life cycle is closed.

The commercial production of freeland ferns

The collected and cleaned spores are sown in seeding cups (Ø 9cm) which are filled with the growing substrate. This substrate can be produced in one's own horticulture nursery. It consists of 30% fermented compost, 65% white peat and 5% Perlite. The composition of the compost may vary a little, depending on the season of its production. The spores germinate and the young plant (prothallium) develops. In this state the fertilisation has to take place. During this production phase it is very important that there is no microbial contamination in the working process. The plants remain in a special culture chamber (20ºC). Substrate and irrigation water are always sterilised.Some weeks after the seeding of the spores (the interval depends on the fern species) the plantlets are transplanted from the seeding cups into bigger culture dishes (19 x 13 cm). They remain there for several weeks and are then transplanted to fresh ones. Finally they are moved to the greenhouse where they will stay until they are sold.

This method of production of freeland ferns is considered to be very difficult and plagued with problems FRITZSCHE (1991). In Switzerland, this type of propagation is carried out only by a few nurseries. Most young ferns are imported from abroad.

Problems of fern propagation

Soon after the germination of the fern spores in the seeding dishes, there may be the first disease symptoms. Round necrotic zones appear on the prothallium lawn. Necrotic antheridia and archegonia will not form zygota. Most of the young ferns will die. The corresponding research has tried to determine the source of this problem. What are the causes of the disease? Is it a fungus infection? The disease symptoms seem to indicate so. To date it is unknown when infection takes place and the etiology is not jet clear.

The identification of the pathogens

A certain number of fungi were isolated from the diseased young ferns. Among them, the genera *Ascochyta*, *Phoma* and *Fusarium* SEITH (1998), GRIMM et al. (1999). The pathogenicity of these fungi was proved by artificial infections on healthy young fern plants. The mycelia and conidia of these fungi were homogenized and suspended in aq. dest.. Inoculation was done by applying 2 ml of the fungus suspension with a pipette to the culture dishes, between the plantlets. It was hoped to find the same symptoms of disease, as were observed on the plants from which the fungi were isolated (Postulate of Koch). The result of the tests showed that both *Ascochyta necans* and *Phoma matteucciicola* are virulent pathogens for the ferns *Dryopteris filix-mas* and *Blechnum spicant.*

Disease control and simplification of the production

In the early growth stages, young ferns are extremely delicate. During this phase it is difficult to control harmful fungi. The young plants hardly tolerate the necessary concentrations of fungicides needed for a successful control of pathogenic fungi. Nevertheless, applications of fungicides to artificially infected young ferns have shown a certain success SEITH (1998), GRIMM et al. (1999). The fungicides used in our experiments were Benlate® and Previcure®. They had a good prophylactic effect. Applied carefully at the right time, it was possible to reduce the infections of fungi on the young ferns SEITH (1998). To reduce production costs producers tend to sow fern spores directly in larger seed dishes (13x19 cm) in the greenhouse. This involves higher contamination risks with mosses and fungi. Therefore, the seedling dishes must be covered by glass plates.

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Image digitization in plant pathology - digital databases for research, teaching, and extension CD ROM series: Nemapix (Vols. l and 2), Entopix (Vol. 1), Mycopix (Vol. l)

The rapid development of digitization of Images for storage and display an personal Computers allows the production of large collections of Images that can greatly enhance research, teaching and advisory services of scientists, teachers, advisory personnel and other workers involved with plant pathology and other agricultural sciences.

Examples of collections of digitized Images in the field of Phytopathology stored electronically an CD ROMS are publications (Mactode Publications) in a CD ROM series which are mainly focused an phytopathology and plant nematology entitled, "Nemapix, 'A Journal of Nematomological Images', Vols. 1 (1997) and Vol. 2 (1999)," edited by J. D. Eisenback and U. Zunke, for general plant nematology including many genera and species of plant-parasitic nematodes; "Entopix, 'A Journal of Entomological Images, Plant-Parasitic Arthropoda and Their Natural Enemies, Vol. l (1999)'," edited by U. Zunke and J. D. Eisenback (ISBN 1-893961-OS-2), and "Mycopix, Vol l (2000), "A Journal of Images of Plant Diseases (Fungi, Bacteria, Viruses)", edited by U. Zunke and J. D. Eisenback.

Each CD-ROM within these series contain more than 1000 Images, mostly from the two editors, and other pictures from well known scientists from the US, Europe, Asia, Australia, and Central America, who added special Images to the collections from their own specialized fields of research, especially in Nematology and Plant Pathology , which were not published elsewhere and not available for others to use. Also, short digitized videos are presented an Nemapix, Vol. 2, as well as an archive of out of print books, research articles, and other items of general interests to nematologists. The Images and other resources are cataloged in a database which can be searched by keywords or from words used to describe each Image in a figure legend.

Entopix, Vol. l contains more than 1000 Images, an Index of the Images sorted systematically and a slide show with 200 lmages for use within research, teaching, and advisory Services. The photographs and micrographs of insects and their natural enemies were taken mainly by the first editor. This CD ROM also contains an Index listing each taxa by group including class, Order, family, genus and species. The Images include the organism and also typical plant damage. All of the Images are described in a figure legend and a list of key words which can be easily searched and accessed for esse of use. In addition, the user can build additional galleries of Images that were grouped according to specific searches of the main catalog.

The Images are stable and not subject to degradations such as fading, scratching, staining, etc. that are common with photographic Images. They can be observed directly an the Computer screen or they can be printed an paper, overhead transparencies, or even photographic film. The pictures can be used for presentations with a digital projector or overhead projector panel connected directly to a desktop or Laptop Computer (Windows 95, 98; Apple Macintosh compatible). In addition all Images are ready for placement an world wide web sites for research, education, and advisory services.

The Images can be viewed as follows: On PC's (Windows 95, 98) select and install the Portfolio Browser (browser.exe) an to the hard drive from "Portbrws" folder in the "For_PCs" directory an the CD ROM. Start the "portbrws.exe" application and open the catalog an the CD ROM entitled, "Nemapixl.fdb," "Entopix.fdb" or "Mycopix.fdb" (Fig. 1).

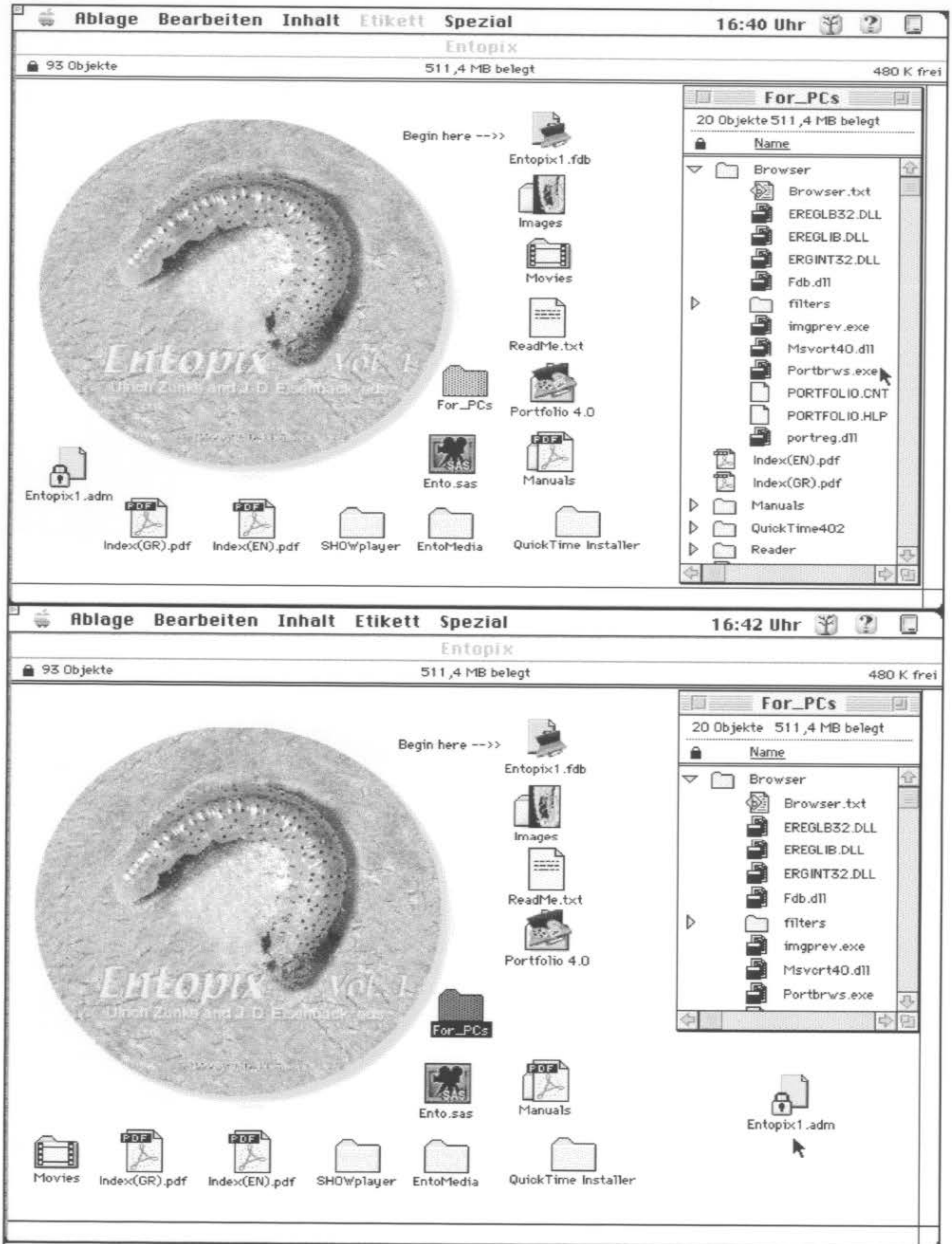


Fig. 1: Open folder "**For PC´s**" , install from folder "**Browser**" » "**Portbrws.exe**" , return to CD , than start "**Entopix.adm**" to open » "**Builing Gallery**" to view the Images 0001-1026

If the "Portfolio Browser" is properly installed, the catalog will open to show thumbnails an the Computer screen which can be scrolled up and down to reveal all of the Images. A full, screen-size picture can be seen by clicking an a thumbnail of the selected Image (Fig. 2).

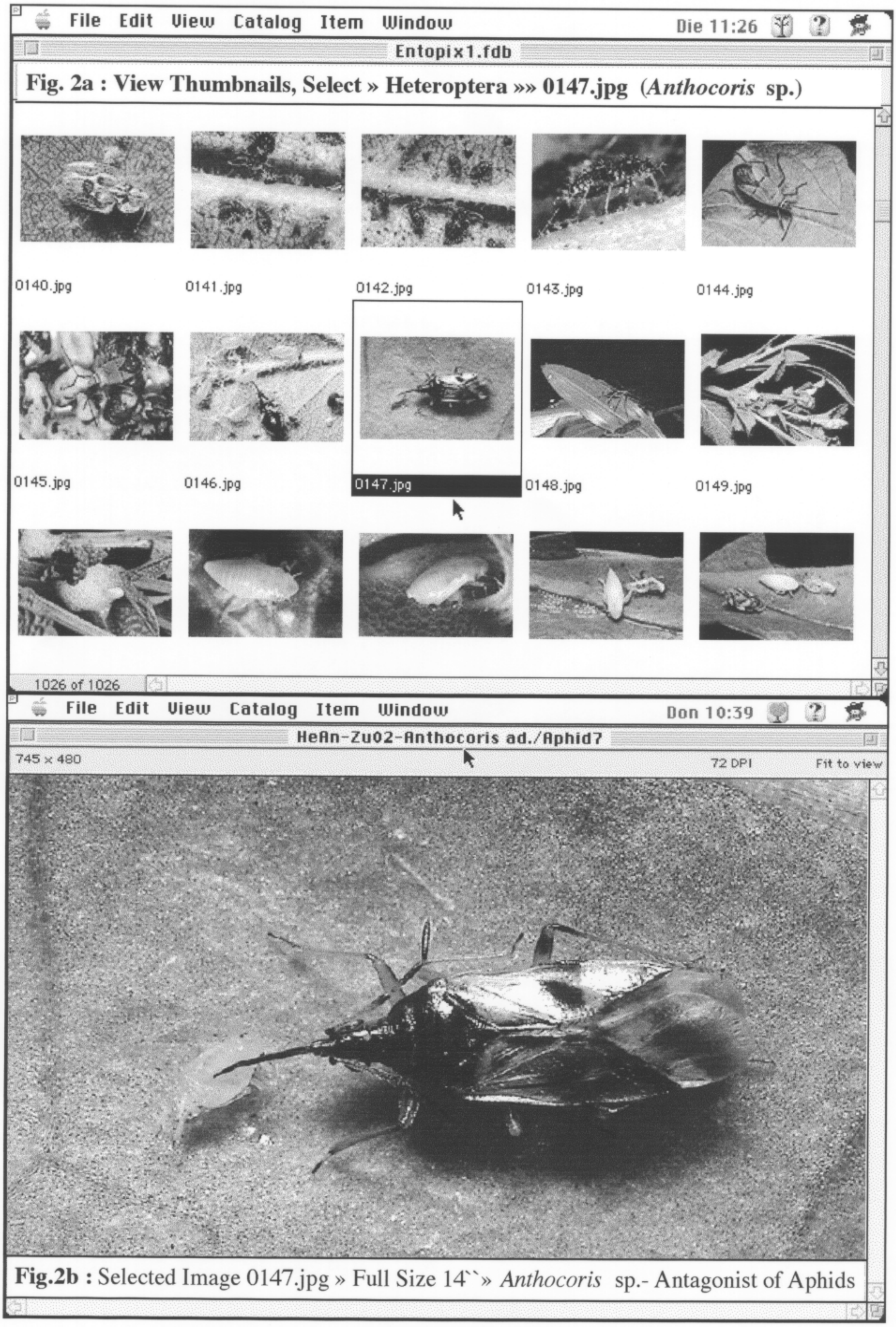


Fig. 2a : View Thumbnails, Select » Heteroptera »» 0147.jpg (*Anthocoris* sp.)

Fig.2b : Selected Image 0147.jpg » Full Size 14`` » *Anthocoris* sp.- Antagonist of Aphids

In Order to view a complete text DESCRIPTION select the menu VIEW, submenu CUSTOMIZE, and select only "Filename" and "Description" , dick an the "Apply" and "Save as Defaults" Buttons and finally dick an the "OK" Button. Next enlarge the "Description" field by dragging the frame all the way to the right of the screen. In addition the ITEM menu, submenu ITEM PROPERTIES can be selected to reveal the KEYWORDS and DESCRIPTION for each thumbnail selected (Fig. 3a, b).

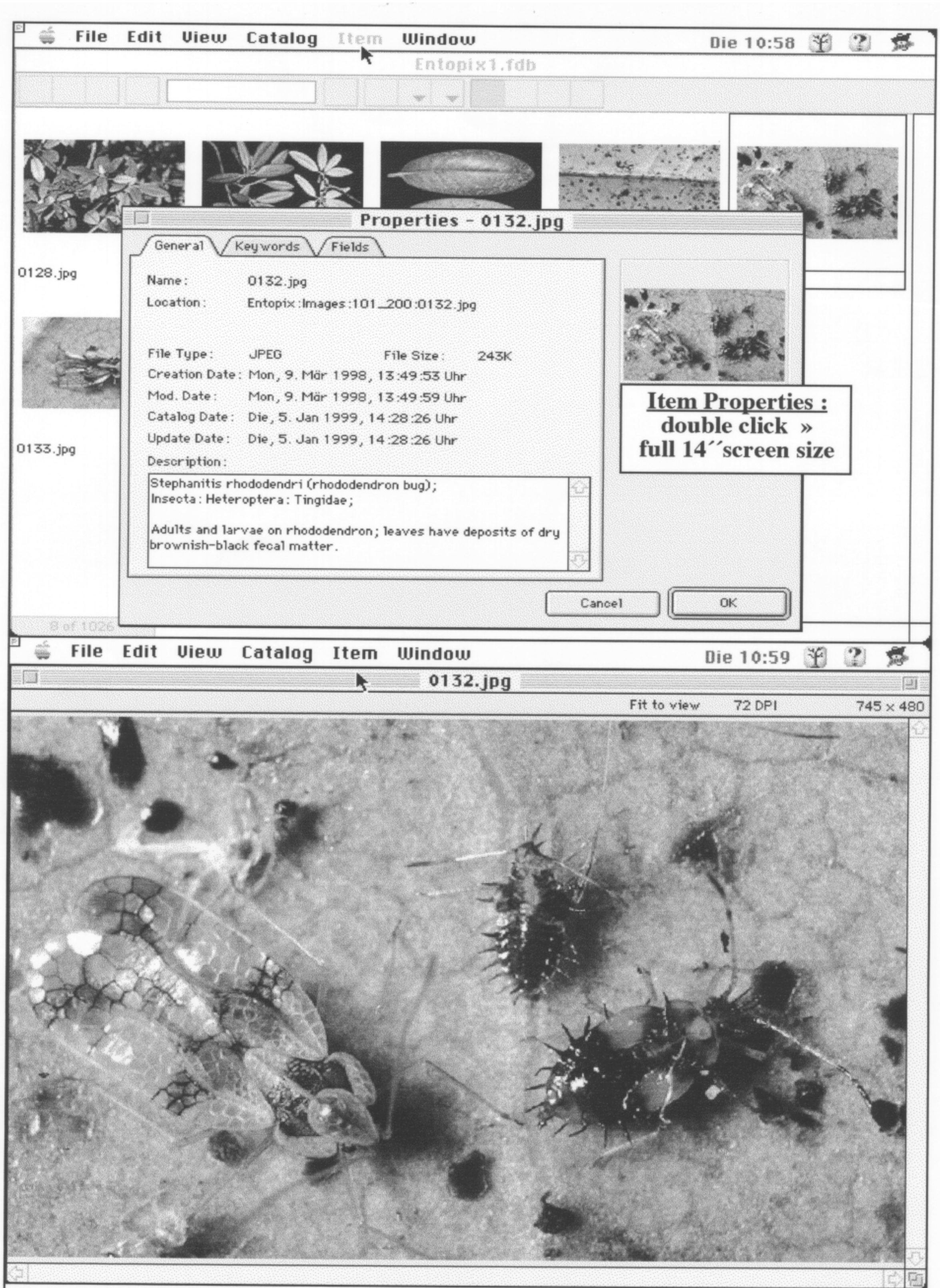


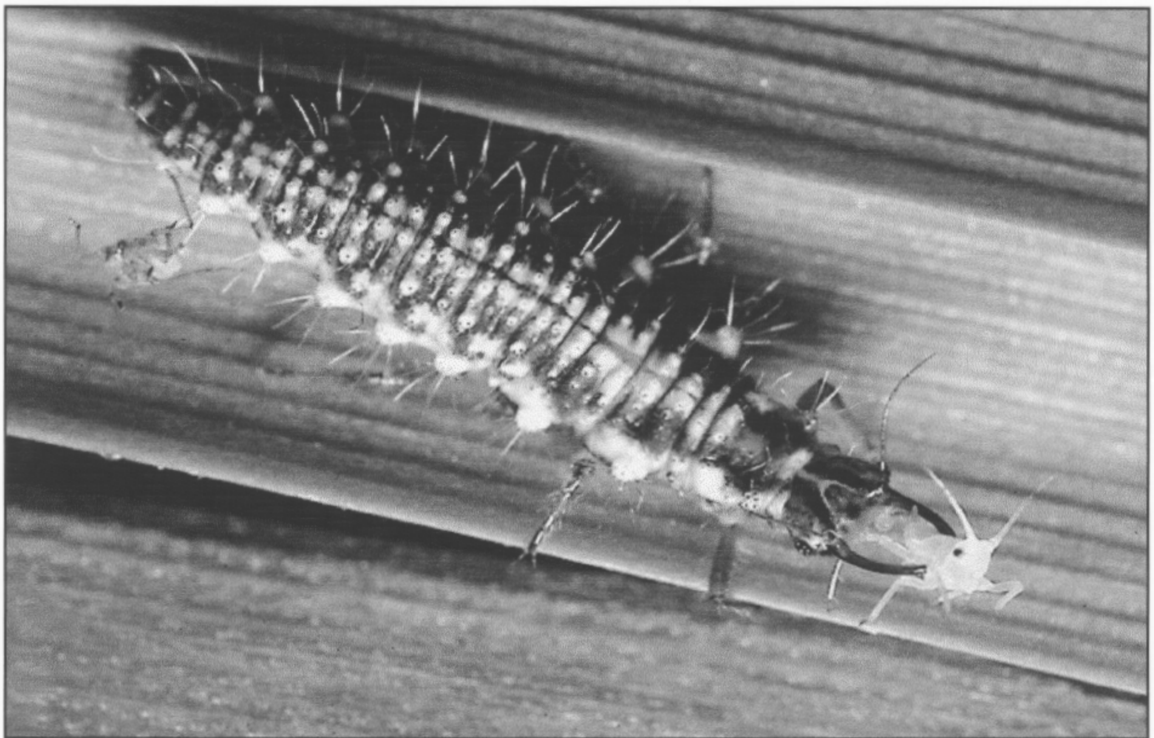
Fig. 3 : Item » ITEM PROPERTIES : *Stephanitis rhododendri* (0132.jpg) - Image and General Description , Thumbnail - Image ITEM PROPERTIES » Full Size 14´

Under the menu CATALOG, submenu FIND you can search from the lists of key words or words contained in the descriptions for e.g. genera/species. Searches can be viewed in a new GALLERY than can be saved for future references or the new GALLERY can be search again to reduce the number of selected Images to a smaller, more specific category. The selected Images can be viewed in a larger format as described earlier (Fig. 4).

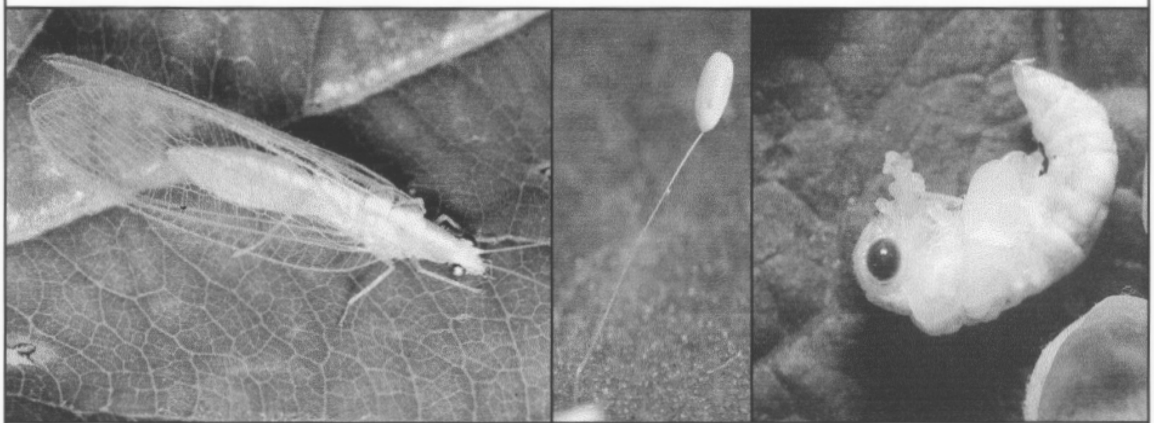
Fig. 4a : Catalog : FIND - selected KEYWORD » *Stephanitis* »» Fig. 4 b

Fig. 4b : FOUND » 8 Images (Thumbnails) from 1026 : *Stephanitis*, Heteroptera

As described, selected Images can be inserted into a desktop publishing (DTP) program for dass handouts or advisory brochures (Fig. 5), added to a multimedia presentation such as "Powerpoint" , or included an a web Page, etc. The entire collection of CD ROMs makes it possible to utilize Images from nematology, entomology, and plant pathology in any combination (Fig. 5). Very informative collections of Images can be assembled into one Image for effective teaching illustrations.



Chrysopa carnea (lacewing), **larva** (aphid lion); Insecta: Planipennia: Chrysopidae;
A larva drains an aphid; one larva can devour several hundred pupating aphids.
EntoPix, Vol.1: © 0848.jpg / Zunke



Chrysopa carnea, Planipennia: Chrysopidae; **Adult** with **greenish clearly veined wings**; adults and larvae lives as predators, mostly on aphids.
EntoPix, Vol.1: © 0845.jpg / Zunke

Chrysopa carnea, **Egg** (left) and **Pupa** (right) ; Pupa removed from the cocoon.
EntoPix, Vol.1: © 0849.jpg / Zunke
EntoPix, Vol.1:© 0850.jpg /Zunke

Fig. 5 : Selection of Images : Different Stages of Chrysopa carnea (DTP-Programm)

For Macintosh Computers (MacOS) simply dick an the "Nemapix.fdb," Entopix.fdb," or "Mycopix," icon that is labeled, "StartHere." The Portfolio Browser can also be installed an the hard disk. It is located in the folder entitled, "Install these only if you need them." Details of using the catalog are the Same as described above for the PC user.

The world wide response to the publications of the CD ROMs is reflected also in the cooperation between the editors and ETI (Biodiversity Center , University of Amsterdam; The World Biodiversity Database CD ROM Series, Interactive Scientific Multimedia; world wide distribution by Springer and UNESCO).

The Nematology CD ROM is published by
ETI (1999) as "Image Library for Nematology" (ISBN 3-540-14796-9),
ETI <http://www.eti.uva.nl/Products/frame_catalogue.htm> and
<http://www.amazon.com>.

You will find in the Internet the CD ROMs an the web side from Mactode Publications at
<http://www.dreamwater.com/biz/mactode>,
<http://www.zunke-photography.com> and other sites such as
<http://pppweb.clemson.edu/NematodeSites.html> and
also by using the common Internet search engines.

These CD ROMs make it possibe to choose from thousands of the Best available Images of parasites of plants or plant pathogens that are already digitized, enhanced and prepared for publications an paper, film, and in electronic formats. These tools are usefull for biodiversity databases to build taxonomic keys in biology with Images (see ETI, The World Biodiversity Database CD ROM Series -Catalog) or identification keys such as the "Identification Guide Thysanoptera " (MORITZ, G. and MOUND, L., 1998) .

Furtheron the Images of the CD ROMs can also be used in teaching programs for students at universities such as diagnostic courses in plant pathology such as those already held at the Institute of Applied Botany, University of Hamburg, Germany or the International Nematology Course, University of Gent etc.

TheAdvisory Serviceof the Plant Protection Service in Germany use digitized Images e.g. for brochures and bulletins with special Information about plant parasites and pathogens.

In Germany a CD ROM has already been published for "Advisory Service for the Garden" with an diagnostic key (Hoyer, 1999).

Images are also usefull for exhibitons in museums etc., and Gould be helpful for illustrations for CD ROMs, which are included with books (HONOMICHL, K. (1998) Jacobs/Renner; Biologie und Ökologie der Insekten (CD ROM, Windows). Overall there are many other possibilities for using digitized Images in entomology, nematology, plant pathology, and other areas of plant science.

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Session 3 Abiotic disease factors of plants in urban stands

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Phytotoxic effects of chemicals on plants in urban areas – an overview

The Institute of Ecological Chemistry deals with recording and evaluation of the long-term behaviour of chemicals, such as pesticides and their metabolites, nutrients, and noxious elements (e.g., cadmium, lead, or mercury), investigation on persistence within the environment (agro-ecosystems and urban areas) and research on non-parasitic plant disorders that serves as a basis for the identification of symptoms of damage in plants and for the development of treatment measures (Figure 1).

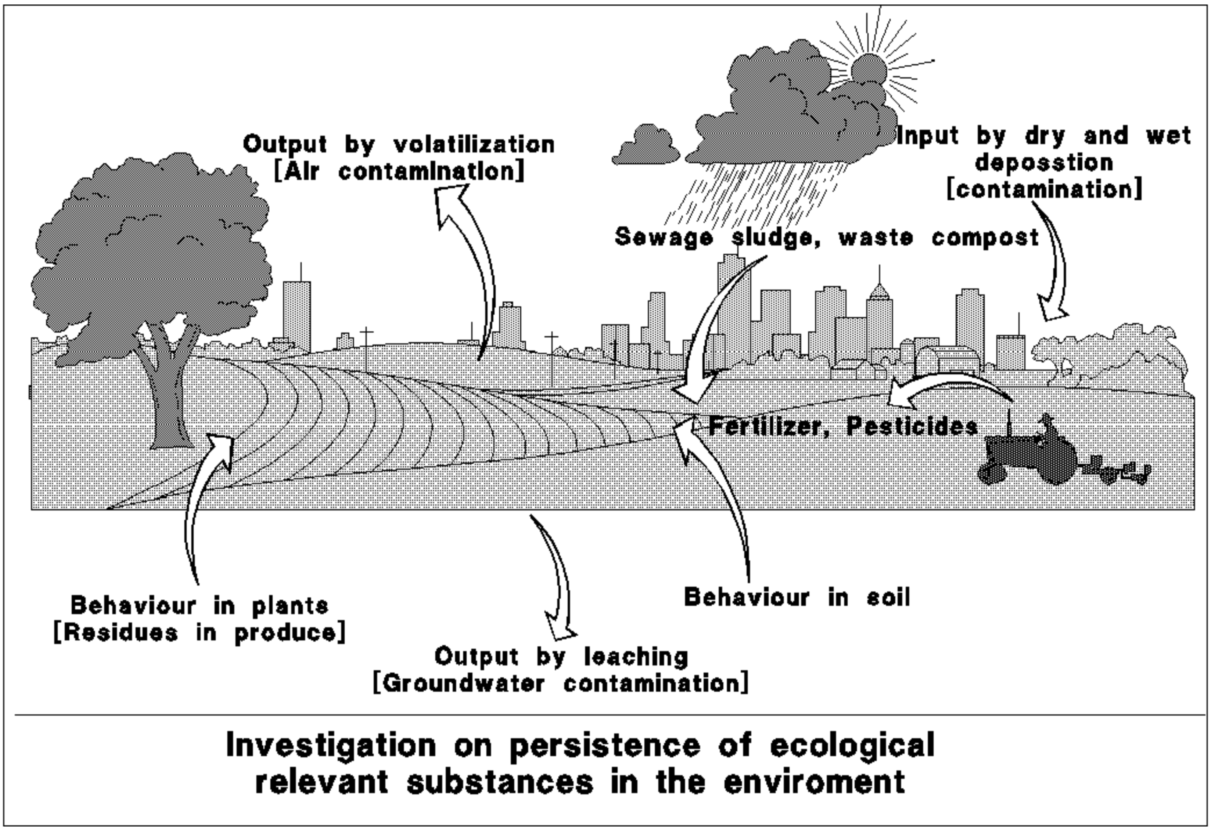


Figure 1: Input and output of chemicals in different compartments of agro-ecosystems and urban areas

Environmental chemicals are substances produced or introduced into the environment by human activities and are potentially hazardous to biota and humans. In this case, biota means all animals, plants, and microorganisms (GÜNTHER and PESTEMER, 1990). In this paper a short overview will be given on the potential phytotoxic effects of xenobiotics on higher plants, especially in urban areas. Phytotoxicology is defined as a field of study concerned with effects arising from chemicals and radiation taken up by plants via air and/or soil either unintentionally or intentionally.

The existence of xenobiotics influencing - like other growth factors - higher plants negatively not until a substantial exceeding of the natural exposure dose occurs. Positive effects of low exposure doses are occasionally observed, but without significant meaning for crop yields. The activity remains detectable for a certain period depending on environmental conditions. To estimate the potential phytotoxicity it is neccessary to have sufficient knowledge of the dynamics of xenobiotic substances.

Table 1: Horticultural and agricultural land management and potential loads of resources (mod. after PFADENHAUER, 1988, pers. com.)

Resources	Loads
Abiotic Resources	e.g.,
Water:	Nitrate, Phosphate, Pesticides, Xenobiotics (environmental chemicals)
Soil:	Input and accumulation of pollutants Alteration of physical, chemical and biological soil properties
Air:	Methane, Nitrogen oxide (NOx), Pesticides, Xenobiotics, Radioactive fall-out
Biotic Resources	e.g.,
Flora and Fauna: Individuals: Populations: Biocoenis: Ecosystem:	Weakening of the vitality Decrease of species numbers and spectrum (Biodiversity) Abstraction of viability (capacity for living)
Aesthetic Resources	e.g.,
Diversity of landscape elements and natural scenery: Agrarian structure: Hedges and fieldwoods with seam biotopes:	Landscape consumption and empty of the countryside Consolidation of arable land and elimination of interfering landscape components Enlargement of field sites and simplification of crop rotation

Table 2: Important compartments of ecosystems and xenobiotic dynamics

Compartment	Important influences	Important factors and processes
Atmosphere	movement of air, rainfall, temperature, radiation	climatic factors, photolysis, volatilization, drift, emission, deposition
Standing crop	microclimate	Ecoclimate, evapotranspiration plant cover, nutrient supply, plant diseases
Tillage zone	soil moisture and soil temperature	Edaphon (soil organisms), degradation, metabolism, sorption, convection, dispersion, diffusion, erosion
Root zone (unsaturated zone)	moisture content, water movement	Edaphon, rooting, macropores, leaching
Saturated zone	ground water table, ground water stream	sorption, convection, dispersion

Soil cultivation and land management could lead to a varying load of different resources, as shown in Table 1. The impact of water, soil and air (abiotic resources) and the direct influence of biotic resources contaminates crops and plant production as a whole with a number of environmental relevant chemicals including environmental radioactivity and radioactive fall-out. Aesthetic resources have no direct connection with this.

Different factors and processes, - like climate, soil moisture and temperature, physical-chemical behaviour of chemicals, soil parameter etc. - are responsible for the distribution of a substance within the compartments of an agro-ecosystem as shown in Table 2.

Xenobiotics reach the soil either intentionally, by direct application, or unintentionally through spillage. In both cases undesirable side effects occur, just as with many pollutants of the environment. Harmful substances are removed by different factors, thus cleansing the environment. The extent of harmful effects depends on the rate of break-down, as well as the leaching pattern of the substance, which is influenced by the soil characteristics, like organic carbon and water content or pH-value varying in the soil profile.

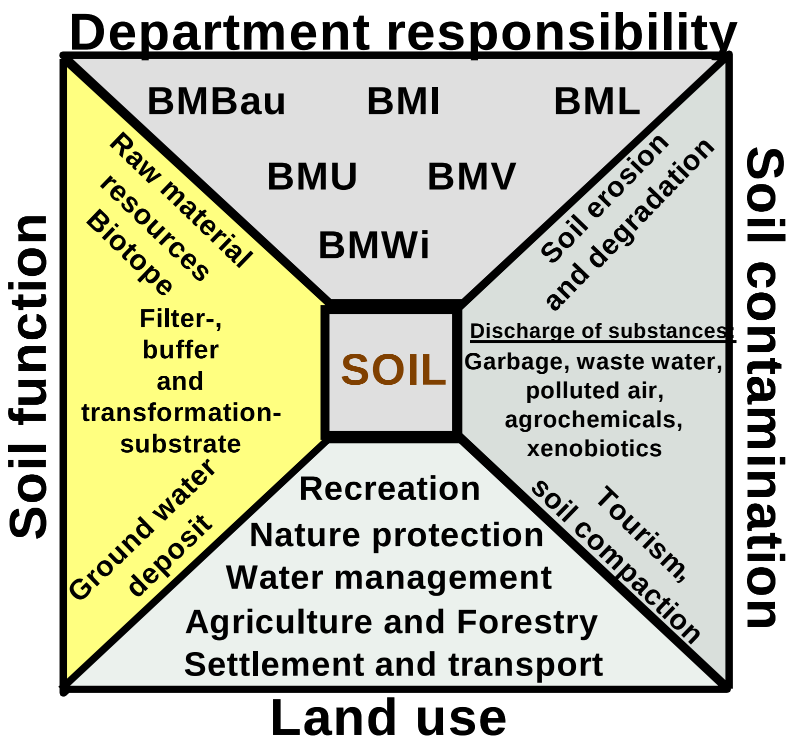


Figure 2: Land use, soil function, soil contamination and department responsibilities connected with the Federal act on soil protection

The soil is being the focus of interest, because all chemicals used by human beings are contaminating the upper soil layer more or less. Figure 2 shows the soil acting as a filter, a buffer and a transformation system in close connection to differing soil contaminations by discharge of substances through garbage, waste water or air pollution and the intensive and concentrated land use, e,g. by agriculture, settlements and recreation. The importance attached to soil is also shown by the manifold political responsibility.

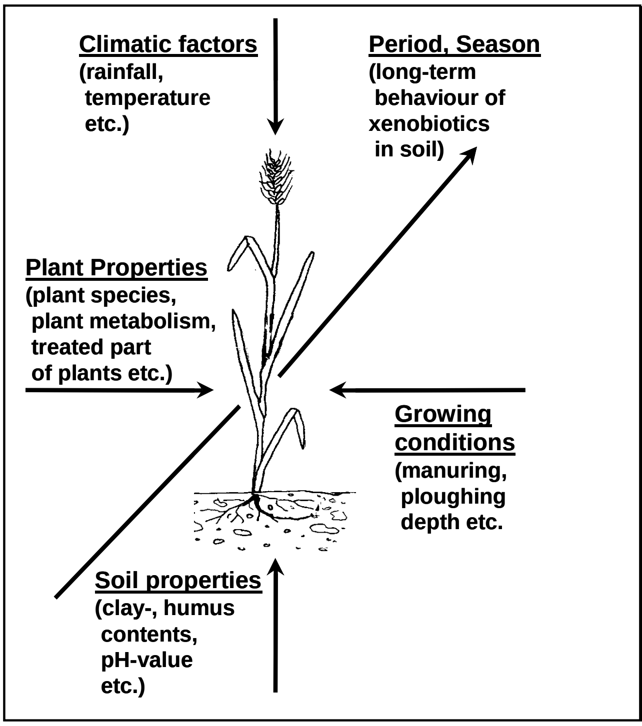
Damages to plants could come from, e.g.:

- Inorganic and organic pollutants, phytotoxic gas and ionized radiation taken up via air
- Inorganic and organic pollutants [e.g. agrochemicals, environmenntal chemicals (xenobiotics), heavy metals] taken up via soil

Hence it appears, that the focal point are xenobiotics, however, organism-specific substances can contaminate plants and food-stuff for example, if a certain dose is exceeded. Every year, hundreds of new chemical substances are created. Because many of these substances differ significantly from natural biochemicals, detailed studies have been designed to discover potential harmful effects. When synthetic compounds are introduced into the environment, their movement through ecosystems is difficult to detect. The qualitative and quantitative assessment of xenobiotic pollution in the different compartments (soil, water, air, plants, animal and humans) is the basis for conducting specific remedial measures. Virtually all treatment measures have side effects that accompany the desired protection of plants. It is up to research to assess and evaluate the benefit-risk-ratio.

Furthermore, diffuse contaminations of crop plants are examined. These contaminations may come from a variety of sources (e.g., industry and motor vehicle emissions, households, horticulture, agriculture and radiation). A prerequisite for obtaining reliable data is the use of modern analytical technology, e.g., gas chromatography with specific detectors and in combination with mass spectrometry, high performance liquid chromatography, atomic absorption and emission spectrometry.

All xenobiotics, like pesticides and environmental chemicals, radioactive substances (naturally occuring and/or after a radioactive fall-out) are dispersed in the natural environment. To estimate the exposure, accumulation and toxicity to organisms the order of magnitude of transfer processes between soil, water and air and the resultuting concentrations in the respective compartments have to be assessed. In Figures 3 and 4 the main factors are shown influencing the soil-plant-transfer of chemicals and the mechanisms of plant contamination by xenobiotics.



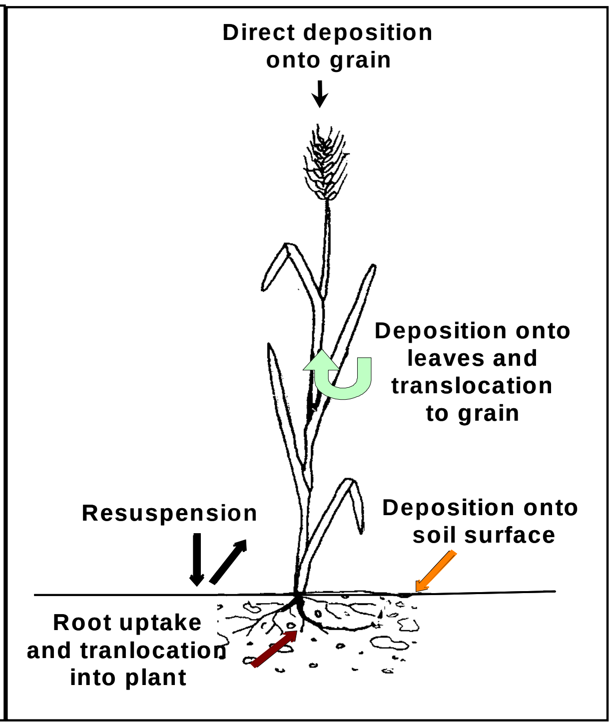


Figure 3: Main factors influencing the soil-plant-transfer of xenobiotics (mod. after PRÖHL, GSF-Neuherberg, pers. com.)

Figure 4: Mechanisms of plant contamination by xenobiotics (mod. after PRÖHL, GSF-Neuherberg pers. com.)

The activity remains detectable for a certain period depending on environmental conditions. To estimate the potential phytotoxicity it is necessary to have sufficient knowledge of the dynamics of the substance in question. Inactivation, distribution and their availibility to plants (uptake) are important processes, which can occur simultaneously and may influence each other. In this connection it is worth mentioning that symptoms of chemical damages are similar to damages caused by frost, heat, nutrient deficiency or excess as shown in Table 3.

Table 3: Damage symptoms of phytotoxic substances

Symptom	Effects caused by:
Chlorosis	Pb; Co; Ni; Zn; deficiency of Mg, N and S; Fe; Cu; Mo; phytotoxins, Lost, radiation; K; SO_2; O_3; NO_2
Necrosis	O_3; Co; Zn; deficiency of N, K, P and S; Mg; Fe; B; phytotoxins; Lost; radiation; frost; Cu; Cr; Zn; Cd; Co; Ni; HF; B; Ni; Cl;
Disturbance of growth	Phytotoxins; frost; radiation
Foliage shed	Ethylene; Al; As
Slight growth	Peroxyacetylnitrate (PAN); Zn; PCB; deficiency of N; phytotoxins

In this connection it is necessary to consider, that plants show only a restrictive reaction pattern. The assignment of damage symptoms are therefore very rarely clear. Furthermore an universally valid statement or a prediction on expected effects is not possible, because combination effects always occur, which lead to unexpected and confusing symptoms. With respect to effects of phytotoxic chemicals it is neccesary to consider dose-response-relationships between plants and phytotoxic compounds as shown schematically in Figure 5. The effects are divided into four activity categories from safe to total damage. Another important fact for risk assessment of chemicals is the availability to plants, which affects not only the activity on plants but als degradation and the potential duration of effects. Additionally, data on degradation rates, adsorption and solubility in water, provided by the basic level investigations, must be take into account.

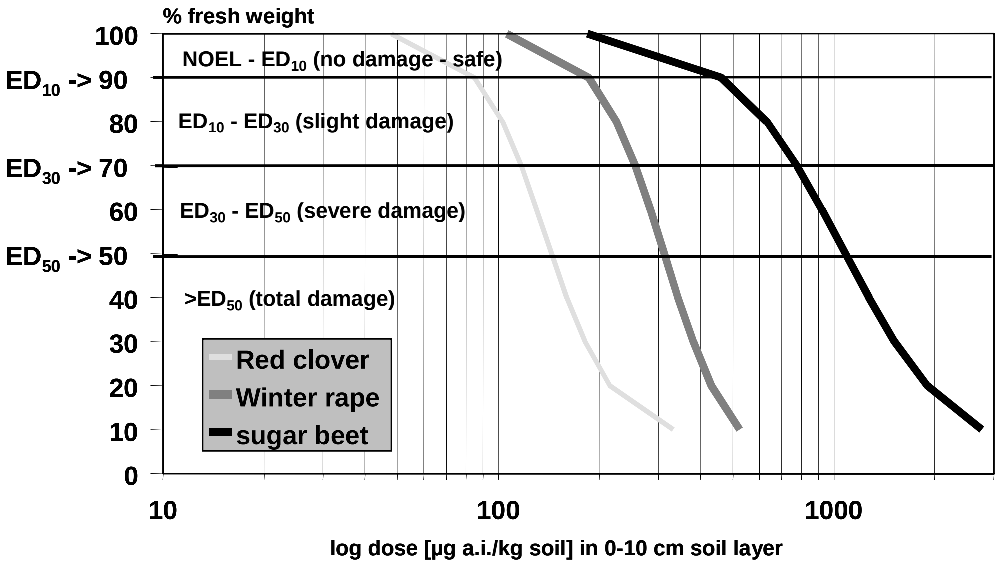


Figure 5: General shape of the dose-response curve between plants and phytotoxic compounds - Comparison of logistic dose-response curves for selected plants (mod. after PESTEMER and GÜNTHER, 1993).

Bioassay results are suitable to compare the effects of different potentially phytotoxic xenobiotics on several plant species or the influence of one compound on several crops as shown in Figure 5. They can be extrapolated to field conditions only in their relation to each other, but can nevertheless often replace expensive field experiments. The simulated "worst case"-conditions in bioassay experiments result in a considerable safety margin, because the optimum uptake conditions of the bioassay are not found in the field under normal conditions. Laboratory bioassay methods have a good reproducibility and can therefore substitute field experiments in many cases as "realistic worst case" scenario (PESTEMER and PUCELIK-GÜNTHER, 1997).

The range of LOEC-values (lowest observed effect concentration) is given in Table 4 for some crops and the heavy metals cadmium and lead as an example for the variability of results obtained in field experiments due to differing pH-values, organic carbon content etc.

Table 4: Phytotoxic levels (LOEC) of cadmium and lead to selected crops (from VERSLUIJS, 1999)

Crop	**Range of LOEC-level [mg/kg]**	
	Cadmium	Lead
Radish	2.5 – 100	500 - 1000
Lettuce	2.5 – 200	1000
Wheat	5 – 113	1000
oats	40 – 97	500
Corn	2.5 – 28	250 - 500

The most important phytotoxic substances in the air are sulphur oxide (SO_x); ozone (O_3); hydrogen fluoride (HF); nitrogen oxide (NO_x); peroxyacetyl nitrate (PAN); ethylen (C_2H_4) and dust exposure. The phytotoxic effects of these chemicals are differentiated into early and late damages as well as primary and secondary symptoms ore in symptoms dependent on civilisation, like cement dust or natural air pollution by dust from soil erosion or desert wind. On the other hand substances like volatilized pesticides; heavy metals; acid aerosols; ammonia (NH_3); aldehyde; hydrochloric acid (HCl); hydrogen sulphide (H_2S); carbon monoxide (CO) and radioactive material occur in the atmosphere. These substances are only in particular cases phytotoxic, because in the atmosphere only traces appear, usually. CO, e.g., is oxidized to CO_2 and play no part as phytotoxin. Some results of effects of selected phytotoxins to a number of crops are given in Figure 6.

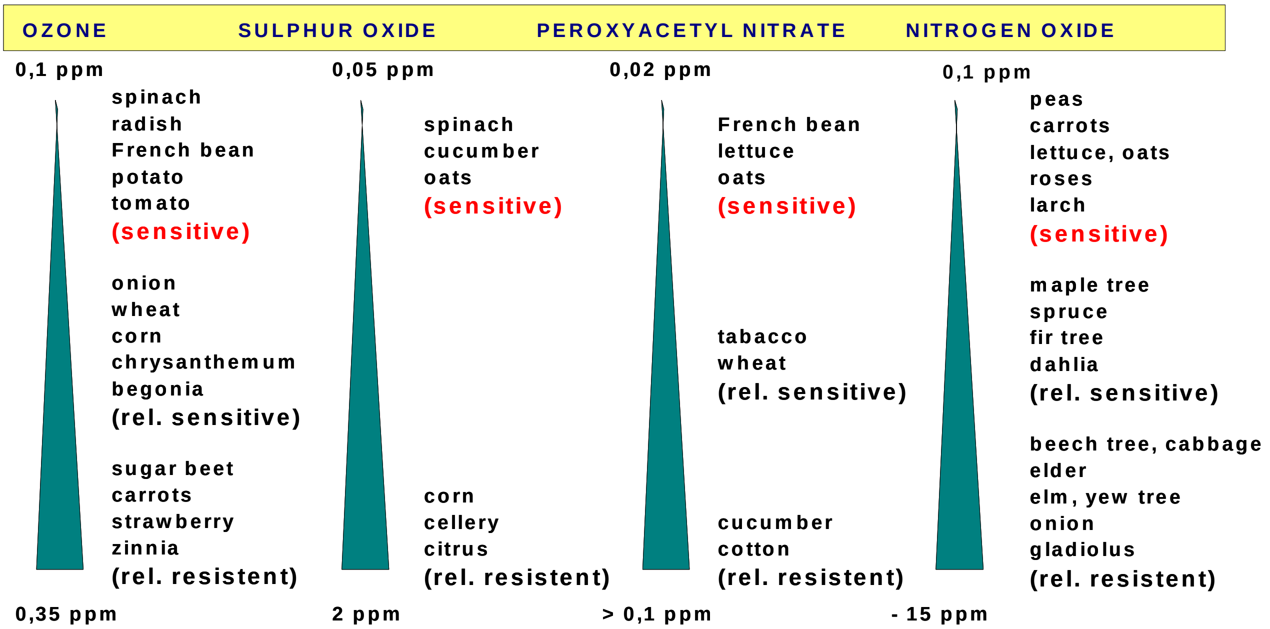


Figure 6: Sensitivity of different crops to selected phytotoxins (mod. after ELSTNER, 1988 in Hock and Elstner)

The origin of gaseous phytotoxins and their interactions are:

Oxidative smog:	NO_x, PAN, O_3 (L.A.-type)
Reductive smog:	SO_x (London-type)
Acids:	HF, H_2SO_3, H_2SO_4, HCl
Dust:	Cement dust and blowed soil
Phytoeffectors:	volatilized pesticides, ethylen

In the environment a manifold contamination of plants by natural substances and also by organisms occurs, e.g.:

- High selenium [Se] uptake from soil solution ⇒ sulphur [S] in amino acids (e.g. cysteine or methionine) are replaced by selenium ⇒ Selenium-amino acids are toxic for human and animals
- Molybdenum [Mo]-deficiency in soil ⇒ nitrate-accumulation in plants + secondary amines ⇒ possible cause for cancer in warm-blooded animals
- Contamination by insects (e.g., grain weevil and grain mite are important stored product pests)
- Contamination by poisonous plants (e.g., *Datura stramonium* and *Atropa belladonna* ⇒ Tropane-alkaloids)
- Contamination by microorganisms and their metabolic products(e.g. Ergot [*Claviceps purpurea*] ⇒ Ergot-alkaloids; mould fungus ⇒ aflatoxines [mycotoxins] - ⇒ possible liver carcinogenity)
- Contamination by bacterial poisons (e.g., *Clostridium botulinum* [Botulinus-toxin]⇒ strongest known natural poison at present)

But most of the pollutants of interest are introduced into the environment by anthropogenic activities. These contaminants are divided into two groups:

1. Intentional contamination ⇒ e.g., with PPP (Plant Protection Products) or fertilizer. Their use is easy to control.
2. Unintentional contamination ⇒ e.g., with PPP out of use corresponding to the plant protection act, by industrial and domestic wastes or with other xenobiotics (environmental pollutants). Their use is difficult to control.

A great number of criteria for assessment of anthropogenic substances exists nationally and internationally, e.g.:

1. Internationally by organizations like:
   - FDA (Food and Drugs Administration, USA)
   - FAO (Food Agriculture Organization)
   - WHO (World Health Organization)
   - OECD (Organization for Economic Cooperation and Development)
   - IUPAC (International Union of Pure and Applied Chemistry)
2. Nationally (Germany) by Federal Boards like:
   - BBA (Federal Biological Research Centre for Agriculture and Forestry)
   - BgVV (Federal Institute for Health Protection of Consumers and Veterinary Medicine)
   - UBA (Federal Environmental Office)

These organizations are responsible for laying down, e.g., orientation-, limit-, tolerance-, MAK(industrial threshold limit value)-values, as well as maximum amounts in food-stuffs etc. .

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Woody plants as airborne lead deposition sites in urban ecosystems

Introduction

Belgrade green spaces have highly complex and exceptionally significant ecological and aesthetic role in the life of its inhabitants. Both of these greenscape roles are important not only because of the fact that Belgrade environment is endangered, but also because it has gone through a period of relatively uncontrolled development, especially in the recent years. During that period urbanistic and other general plans were accepted mostly without serious analyses of the consequences that sudden and chaotic urbanization may bring to the city of around two million inhabitants. That is the main reason why transportation, heating, water supply, institutions of education and culture, recreation facilities, etc., have remained on the level of a smaller and much less ambitious settlement. Hundreds of thousands of vehicles are moving in a traumatic chaos through Belgrade streets marked out in the last century, both in central and peripheral areas. Numerous industrial facilities in the very city mercilessly pollute the environment. Vehicles parked on pavements quite often completely block pedestrian traffic. Urban noise reaches frightening levels at times, while unpleasant scents almost permanently accompany central city's residential areas. Unfortunately, the whole complex of problems is very in efficaciously opposed by outdated and commonly disregarded regulations on environmental protection.

In such circumstances there are relatively few possibilities to make actual steps forward in environmental protection of the capital. Until sound basis for adoption of genuine and professionally conceptualized policy of Belgrade environmental protection is created, Belgrade dwellers are left only with existing, inherited structures and values. Capital's green areas are indisputably among the most significant in this sense.

The efficacy of Belgrade greenscape as a whole depends primarily upon the functionality of composite individual plants. The more accurately chosen and more consciously cared for, the greater and more significant ecological and aesthetic role will these plants have. Even though complex functionality of urban green spaces relies on many architectural and urbanistic components (such as the size, distribution and mutual relations among such urban zones - so-called 'green space system'), their most important and most direct efficacy still depends mostly on specific properties and qualities of individual plants that they are made of [2]. Among various plants species and plant groups, the highest ecological and esthetic weight have the largest and the most durable - trees and shrubs. Their significance originates not only in the actual scope of their physiological activity, but also in their relatively modest maintenance demands (in comparison to flowers or lawns, for instance). With just a simple effort, every tree individual represents exceptionally effective "health factory" in the very source of ecological problems and for a long period of time. That is why it is very important to pay adequate attention not only to the actual existence of urban woody plants, but also to the study of their specific functionality and remarkably positive effect on improving extremely unpleasant conditions in their immediate and broader surroundings, which should be one of the regular issues of related specialists' scientific research [2].

Primary among numerous ecological functions of greenscape trees and shrubs is their so-called 'microclimatic effect' on their immediate surroundings. Not only that trees and shrubs moderate climatic extremes, but also improve the quality of city's air by direct filtering effect, cleansing the atmosphere out of various harmful matter. From ecological point of view, this last is probably the most important function of woody plants in a large city such as Belgrade. It is less important whether plants perform their purifying action by absorption or by deposition. The very fact that plants do reduce certain noxious content from men's immediate surroundings is perhaps of crucial significance [5]. It is especially important when lead is concerned, since it represents one of the most endangering substances in multitude of numerous pollutants that can be detected in Belgrade atmosphere. Since complete abandonment of so-called leaded gasoline represents *condition sine qua non* for serious reduction of airborne lead, and considering difficult financial situation, it may be ascertained that Belgrade and other regions in our country will still be exposed to intensive lead pollution for a considerable time in the future. Thus, other methods and techniques of lowering the airborne lead level in urban air gain on their importance, and they should be treated accordingly. Green spaces and their plants certainly present one of the most significant options in that respect.

Many studies concerning the efficacy of numerous and very diverse woody plants in reduction of atmospheric lead [6] were the basis for the assumption that there could be some difference between native, autochthonous plants and those brought from other climates in their purifying effect. Denied by the research results, however, this assumption transforms into the perception that whenever drastically changed ecological conditions are concerned (so characteristic for highly urbanized and very polluted urban environment), species' origin has little or even no significance. Even though such a statement seams to deny the basic biological and ecological postulates, it is just show how gravely and irreversibly altered the life frame of contemporary urban dwellers is.

Material and Method

Survey aiming to establish eventual differences between autochthonous and allochthonous woody plant species with respect to their airborne lead accumulation capability is being carried out in the central Belgrade region as a part of broad, long-term study of the relationship between air pollutants and ornamental plants in urban green spaces since 1986. Research sites were most endangered city zones by lead - main city streets and access roads to Belgrade. Research objects were represented by healthy and vigorous individuals of most copious ornamental woody plant species in street tree lines and edge parks along the these streets and roads. Chosen individuals of 20 plant species of native and foreign origin were all in the same environmental conditions regrinding lead pollution. They were sampled every year by the end of the season, and then analyzed for total lead deposit by standard procedure using atomic absorption spectroscopy method. Research results refer to total lead deposit, regardless whether the metal was deposited on exposed plant surfaces or (and how much) it penetrated the plant's tissues. During the whole research period there was no visible indications that studied plants suffered any damage that could be ascribed to harmful effect of eventually absorbed lead. Sum results obtained in a ten-year research period (1989-1998) are presented collectively in Table 1.

Results and Discussion

Studied woody plants in street tree lines and green spaces along the city streets and access roads to Belgrade listed in Table 1. belong to the group of common and in domestic landscape architecture preferred domestic or introduced tree and shrub species.

Total "autumn" lead amounts that were established on exposed plant surfaces represent in fact ten-year average. By their absolute values, in comparison to similar studies around the world [4], they indicate the state of not to highly polluted area. And truly, when it is known that during last decades ashes of exposed plants along the highways of Germany contained up to 700 ppm of lead, in cities of France over 200 ppm, in academic center New Haven in USA over 250 ppm, in Hungarian capitol Budapest over 280 ppm, or in Zagreb up to 123 ppm [5], it may be concluded that average total lead amount that may be found on plants along the Belgrade streets (meaning in urban air as well), are not too high. Nevertheless, it should be pointed out that extreme individual values far higher than those presented in Table 1 were established in Belgrade environment [1], indicating that lead as atmospheric pollutant does represents a serious ecological problem in Belgrade environment. It is also clear that constant exposure to this heavy metal (pollutant) may impose various health difficulties to the dwellers of central city area, as well as to those living/residing in the immediate vicinity of heavy traffic access roads to Belgrade. According to numerous and very suggestive studies and reports, this health risk especially concerns children, who were found to be extremely susceptible to airborne lead [1].

The largest average amounts of lead deposit during the ten-year research period were found on individuals of two shrubby species: *Tamarix tetrandra* (89.86 ppm) *and Buddleia variabilis* (87.28 ppm). The fact that the greatest amounts of lead were found on shrub and not on tree individuals (sampling heights 1.2-1.4 m and 2.0-2.5 m respectively) is ecologically significant by itself, since it directly indicates the specific lead behavior in the atmosphere of "street ecosystems" [5]. Most of the lead particles, being heavy, distribute near their source (vehicle exhaust pipes) and do not rise too high except in the case of a strong wind. The second largest average lead deposit was found on trees, but in comparison to the above, it was nearly one quarter smaller in the group of allochthonous species, and over one third in the group of autochthonous plants. Such vertical distribution of lead deposit was to be expected since it is apparent even visually that that lower parts of ornamental plants' crowns along polluted streets are already very excessively covered with a layer of dust, ash and other various particles customary in urban conditions at the very beginning of a summer period. Black or very dark layer of deposited pollutants is generally sticky and extremely favorable for new, additional deposition of microscopic lead particles. The total weight of lead deposit often equals the third of the total leaf weight, and sometimes even the one of the leaf itself. Numerous studies speak of high washing down effect of rain on this deposit [2], ecologically very important phenomenon regardless if particles of lead or other urban air solid pollutants are concerned. It has been shown in Belgrade conditions as well [1] that washing the leaves by simulated rain removes up to 30.5 % of deposit (gentle washing with pure water from no more than 0.2 m distance, without any detergent or mechanical impact). Therefore, it is reasonable to assume that the impact of rain drops from far greater height and in a longer time period should be considerably higher. Of course, there is a question of washed down lead deposit. Careless disposing of polluted plant material on sites where lead can reach ground or drinking waters could cause serious ecological problem.

Table 1: Average lead accumulation on leaves of exposed tree and shrub individuals

INTRODUCED SPECIES	LEAD DEPOSIT (ppm)	DOMESTIC SPECIES	LEAD DEPOSIT (ppm)
Buddleia variabilis	87.28	*Tamarix tetrandra*	89.86
Ailanthus altissima	72.84	*Tilia tomentosa*	68.64
Cotoneaster horizontalis	51.36	*Tilia cordata*	58.25
Acer negundo	48.60	*Aesculus hippocastanum*	56.22
Elaeagnus angustifolia	47.62	*Acer platanoides*	53.96
Acer dasycarpum	42.72	*Hedera helix*	41.42
Gleditsia triacanthos	40.08	*Acer pseudoplatanus*	37.16
Juniperus horizontalis	38.80	*Quercus pedunculata*	35.56
Ligustrum ovalifolium	35.44	*Populus nigra pyramidalis*	34.41
Fraxinus viridis	32.58	*Betula verrucosa*	25.56

The character of lead deposition plant surface also has substantial significance in regard to the behavior of lead in street ecosystems. Lead deposit is easily blown away by wind or washed down by rain from smooth surfaces, while from sticky and coarse ones it is much hard to remove. This has been confirmed in other studies as well [1], and research area of Belgrade is no exception to the rule.

Air filtering or air cleansing efficacy of ornamental plants in general depends on the vitality rate of plant individuals in question. Only plants that fully, intensively and freely perform their basic functions through characteristic physiological processes can be really efficacious in cleansing the atmosphere from certain pollutant [3]. The significance of this well known fact mostly pronounced when absorption of gaseous pollutants is concerned, since they enter the plant through stomata apparatus and transform eventually into substances of less toxic nature. By bonding harmful substances to certain parts of their tissues, plants remove these pollutants more or less permanently from (urban) ecosystem. The vitality of exposed plant individual is also of great importance in the case when plant is mostly physiologically inactive toward specific pollutants, which is regularly the case in relation plant- solid particles. When lead is concerned, deposition of particles on exposed plant surfaces is indisputably more successful, more intensive and ecologically more important if the individuals are healthy, vigorous, with well developed crowns and with large, healthy and long-lasting leaves that stay on the branches during the whole growing season. It is clear that stunted, thinned and diminished crowns of deteriorated or poorly maintained trees, holding just a portion of a usual number and quality of leaves, will not be able to represent the efficacious element of so-called biological environmental protection system.

This fundamental postulate underpins to a certain extent the belief that autochthonous plant species are generally more efficient in such sensitive and important function as the environmental protection is. There is no doubt that there are many indications to the exceptional significance of autochthonous ornamental plant species in mitigating high pollution level, primarily due to their high adaptation to local environmental conditions and comparatively modest demands in respect to otherwise expensive and troublesome maintenance measures. Functionality of domestic plants is also highly regarded when fulfillment of all the specific functions that are not of immediate ecological nature are concerned [1]. These are the main reasons why there is a general rule of systematic use of autochthonous ornamental plants which are well adopted, entail low maintenance cost and present considerable esthetic and psychological value.

However, when lead as a specific pollutant of urban atmosphere is concerned, special advantages of autochthonous species over introduced ones (on the condition that there are no adaptation problems) almost completely disappear. Long-term systematic study of ornamental plants' behavior on streets and roads of Belgrade and Serbia proved that differences in lead deposition that would be the consequence of their different origin in fact do not exist. Lead as a specific and in established concentrations physiologically quite inert matter, uniformly covers all exposed plants surfaces (as well as inert construction material), independent of their origin, adaptation to environmental conditions, health state or some other biologically and ecologically important factor.

This is the explanation of truly high coincidence of lead deposits' average values among exposed autochthonous and allochthonous woody plants in a ten-year research period. It is especially obvious if pairs of morphologically similar species of related categories of woody plants are observed (plants of roughly the same height, crown density and basic form). In that sense instructive are the lead amounts found on specimens of already mentioned *Buddleia variabilis* and *Tamarix tetrandra*, than pairs comprised of *Ailanthus altissima* (72.84 ppm) and *Tilia tomentosa* (68.64 ppm) or *Acer negundo* (48.60 ppm) and *Acer platanoides* (53.96 ppm) plant individuals. This in fact means that the amount of established lead deposit does not vary in relation to the origin of certain species, but exclusively in relation to other already commented plant properties and their position regarding the pollution source.

Nevertheless, when the selection of plants for street green areas and street tree lines is concerned, the criterion that favors the choice of autochthonous plant material, despite of all cited facts, has its significance. Deposition of lead will be equally efficient on both since there are no special advantages in that regard, but domestic plant species have at the same time additional, well known and without doubt advantages that are reason enough for their absolute preference over allochthonous ones. That is the reason why this recommendation is strongly put. This recommendation is also easy to prescribe due to really enormous and practically boundless plant diversity and richness that Belgrade climate offers.

Conclusions

Presented results and their discussion makes the following conclusions possible:

1. Average annual amount of lead deposit on individual tree and shrub species along the roads and streets of Belgrade in the past eight-year period is relatively low (high?), and represents the measure of Belgrade air lead pollution level. The highest accumulation on average have *Buddleia variabilis* (87.28 ppm) and *Ailanthus altissima* (72.84) of allochthonous, and *Tamarix tetrandra* (89.86 ppm) and *Tilia tomentosa* (68.64 ppm) from autochthonous woody species.
2. The differences in relation to deposited lead amounts on leaves, twigs and bark of exposed plants are the consequences of the character of exposed plant tissue surfaces, as well as the elevation of exposed surface in regard to vehicle exhaust pipes.
3. Significant variances in deposited lead amounts on the sampled species of different origin were not established. This fact suggests the conclusion that there are no differences between autochthonous and allochthonous woody species concerning lead deposit capacity. It may be concluded that different ornamental plant species can be used for cleansing the urban air from lead pollution regardless of their origin, providing that they have suitable properties.
4. The use of autochthonous plant species, however, should have priority even when airborne lead deposit is concerned. due to their numerous well known biological, ecological and psychological qualities and values of autohtonous plant species.

Summary

Trees and shrubs of Belgrade green spaces represent very efficacious deposition sites for airborne lead. Despite substantial differences that exist among green spaces' species in their vitality and ecological efficiency, the most important factors that effect lead deposition are the size and character of leaf surface, plant's shape and form, air movement characteristics (wind) and the distance of exposed plant individual from lead emission source (carriageway). Well known advantages that favor the usage of autohtonous plants in urban greenscaping almost disappear when lead deposition is concerned. Differences in lead deposit amounts on different plant parts of native plants and exotics are minimal. Numerical values of average lead deposit found on 20 most common woody species on Belgrade streets during the ten-year research period (1989-1998) confirm this conclusion.

key words: lead pollution, lead deposition, ornamental woody plants

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Oxygen regime of manufactured tree soil under pavements

Introduction

A typical application of tree soil under pavements in the Netherlands may be described as follows. The lateral sides of the tree soil volume are bordered by highly compacted sand. The penetration resistance of this sand is very high, so that the tree roots can penetrate this sand only a few dm. The top of the tree soil is covered by a sand layer with a thickness of about 1 dm, and a pavement which has to carry light traffic and/or to serve as parking places for cars. Large parts of the Netherlands have very shallow groundwater tables. A minimum distance between the bottom of the tree soil and the groundwater table is needed because the water-saturated zone of the sand above the groundwater is not allowed to reach the tree soil. The tree soil should be compacted enough to prevent traffic-induced pavement sinkage and loose enough to allow sufficient growth and functioning of the tree root system. These conflicting requirements can be met by a medium coarse sand that is mixed with 5 % (w/w) organic matter. The soil volume per tree should be very small because of the demands of the road foundation and underground cables and tubes, but large enough to provide sufficient nutrients and water to the tree. This soil volume may be calculated from a water balance and the nutrients demand. In situations with a shallow groundwater table, capillary supply of water to the tree roots is large and the minimum value of tree soil that is needed per tree is determined by the nutrients demand, a typical value being 0.75 m^3 per m^2 tree crown projection. In situations with no capillary groundwater supply the needed tree soil volume is calculated from a water balance that includes the amount of water that is present in the tree soil volume at the beginning of the growing season, the amount of rainfall that penetrates the pavement and reaches the tree soil volume, and the amount of water that is evaporated by the tree during the growing season. Realisation of the growing site of a street tree often starts from a pit with a depth of about 1m. The tree soil is filled in 2 or 3 successive layers. Each layer is compacted by a light-type vibrating tamper until the cone index of the layer equals 1.5 MPa.

A tree needs oxygen, which is taken up by its roots from the soil. The oxygen in the tree soil is supplied by the surroundings, mainly through oxygen diffusion in the gas filled soil pores. In cases with very wide tree soil pits and shallow groundwater tables, this diffusion occurs in a vertical direction from the atmosphere through the paved layer, the sand layer under the pavement, and the tree soil. If the roots cannot take up enough oxygen, the tree shows less growth and may even die. Such problems occur frequently with street trees because of the following reasons. The presence of pavement diminishes the gas exchange possibilities between the atmosphere and the tree soil. Tree pits may be rather deep, so that the tree roots may also be at a large depth. Tree soils often are manufactured from sand and a material with a high content of organic matter. If this organic matter is not stable, it decomposes at a high rate, which is accompanied by a high oxygen consumption of the soil micro-organisms. This oxygen consumption competes with the oxygen need of the tree.

According to Fick's law of gas diffusion:

$$J = D(O_2) \times \frac{\Delta C}{L} = \frac{\Delta C}{R}$$

with

J = oxygen flux density in kg $m^{-2}s^{-1}$ or $m^3m^{-2}s^{-1}$
$D(O_2)$ = (apparent) coefficient of diffusion in m^2s^{-1}
ΔC = concentration difference in kg m^{-3} or m^3m^{-3}
L = distance in m
R = (apparent) resistance in s m^{-1}

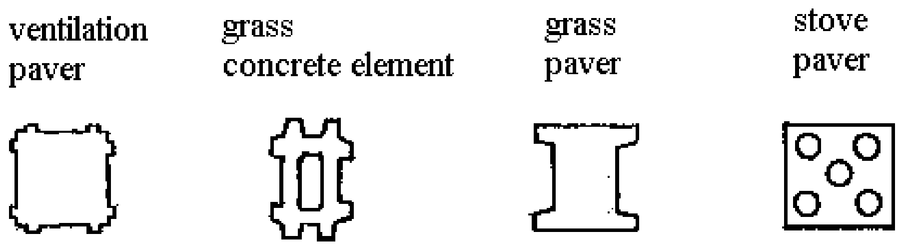

Figure 1: Paver types.

The quantity *R* is meaningful in relation to pavement. Fig. 1 shows a number of paver types. *R* is lower with smaller pavers and wider joints. Table 1 presents, for a number of pavers, dimensions, joint percentage of pavement, and *R* in seconds per cm. Most *R* values in the Table have been calculated from an *R* of the joints fill (clean sand having a $D(O_2) = 10^{-6}$ m^2s^{-1}) by correcting it for the percentage of pavement surface that is occupied by pavers. (NN, 1992). Washing in of dirt lowers *D* in the course of time. *R* for grass pavers has been calculated for joints with sand containing organic matter ($D(O_2)$ of joint fill = 3 x 10^{-7} m^2s^{-1}). The asphalt data were measured.

Table 1: Pavement data.

PAVEMENT TYPE	DIMENSIONS (cm) length x width x height	JOINT %	RESISTANCE R second/cm
warm asphalt	x 10	0	>1 000 000
tiles	60 x 60 x 7	0.5	140 000
		0.6	116 667
tiles	60 x 40 x 7	0.7	100 000
		0.8	87 500
tiles	30 x 30 x 5	1.1	45 455
tiles	30 x 30 x 7	1.1	63 636
bricks	20 x 20 x 10	1.5	66 667
		4.0	25 000
		5.1	19 608
bricks	20 x 5 x 10	7.7	12 987
ventilation pavers	60 x 60 x 7	1.8	38 889
		1.9	36 842
ventilation pavers	30 x 30 x 5	5.6	8 929
stove pavers	30 x 30 x 6	11.9	5 042
grass pavers	20 x 20 x 10	30.0	11 111
Belgian pavers	x 15	6.0	25 000
extremely open asphalt	x 12		700

The oxygen consumption of a tree is not well-known. According to (NN, 1992), the oxygen consumption of a street tree may be estimated as 100 – 200 mg oxygen per hour per m^2 tree crown projection. A maximum value of oxygen consumption by forest trees under optimal conditions is proposed by H. Schack-Kirchner, *Freiburg*, *Germany* (pers. comm.): 1.86 x 10^{-5} cm^3 O_2 per cm^2 soil surface per second. Further quantities that determine the oxygen regime of a street tree growing site are, a. o., the coefficient of oxygen diffusion and specific oxygen consumption rate of the tree soil. The coefficient of diffusion depends on the soil structure, porosity, water content and temperature. The oxygen consumption depends on the amount of decomposable organic matter in the soil, the decomposition rate of the organic matter, the supply of sufficient air (oxygen), the water content, pH, temperature, the relative amount of nitrogen in the organic matter (and further components of the soil). Computer models that can simulate the oxygen regime of growing sites are very helpful in understanding the phenomena involved. Schack-Kirchner made O_2 SIMUL, a one-dimensional model that calculates equilibrium concentrations of O_2 in soil from values for oxygen consumptions and coefficients of oxygen diffusion.

This paper reports the measuring of oxygen consumptions and coefficients of gas diffusion of tree soil mixes, results of computer simulations, and results from tree soil sites.

Material and methods

The components of the mixes that were measured included IJssellake sand and components high in organic matter content: highly decomposed peat that has been frozen, a peat mix, compost made from biowaste, compost made from prunings, heath compost, tree-bark compost. The lower part of the organic layer of high moorland is very old and usually highly decomposed. It is a very useful product if, after it has been separated from the profile, its structure has been upgraded by freezing-thawing cycles during wintertime. The product is very stable and will be referred to as reference peat. The peat mix consisted of reference peat (60%, by volume), heath compost (15%), clay soil (15%), tree-bark (10%). In the Netherlands, the organic fraction of domestic waste is collected separately and composted. This biowaste compost is not very stable, has a very low organic matter content and may contain much salt. Maintainance of urban trees and parks produces a large amount of prunings, which usually is composted (together with other organic waste from urban green areas, like leaves, grass, etc.). This prunings compost has a slightly better quality than biowaste compost. Maintainance of Dutch heathlands includes periodic removal of the sod, which is composted. Tree-bark is a waste material from the wood processing industry. According to Dutch regulations, tree-bark compost should be made from the bark of *Picea* and *Pinus*. The IJssellake sand had a M50 = 0.247 mm and a D60/D10 = 2.2 . Its clay and silt fractions were 3 and 2.7%, respectively. Each of the above 6 materials rich in organic matter were mixed with an appropriate amount of sand in order to obtain 6 different tree soils, each having an organic matter content = 5 % (by weight, on dry basis). In addition, 3 tree soils were collected from experimental locations in a sidewalk of Spakler street in Amsterdam. These locations contained mixes of sand with peat from low fens, sand with biowaste compost, and sand with prunings compost, respectively. These mixes also contained 5% organic matter. The first of these 3 mixes is known as Abo5%, which has been found to be of sufficient quality to serve as tree soil under pavement in Amsterdam.

Samples of 500g (wet weight) were taken from each of the 9 mixes in order to measure their oxygen consumptions in an incubation experiment. Each sample was filled in a 1 liter bottle and compacted with a hand tamper to a penetration resistance of a micro-cone = 1.875 MPa. The micro-cone had a diameter = 2mm and a tip angle = 30^o. From another research it was known that this soil condition has a resistance = 1.5MPa when measured with a cone having a base area = 1 cm^2 and a tip angle = 60^o. The latter cone is used in establishing growing sites for street trees in the Netherlands. The experiment occurred at a temperature = 20^oC. In each bottle with mix a cup with 20 ml of 0.5 molar NaOH was placed, and the bottles were closed. Using a grease between caps and bottles closure was air-tight. CO_2 ,which is produced in the decomposition of organic matter, reacts with NaOH in the cups according to

$$\mathbf{2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O}$$

It is known that one mol CO_2 production by the micro-organisms equals one mol O_2 consumption by the micro-organisms. After 1 – 5 days each cup was taken out of the bottles in order to measure the remaining NaOH. That was done by a titration procedure. First, an excess amount (4ml) of 1.5 molar $BaCl_2$ was added to each cup in order to precipitate HCO_3 :

$$\mathbf{Na_2CO_3 + BaCl_2 \rightarrow BaCO_3\downarrow + 2\,NaCl}$$

The remaining NaOH was measured by titrating with 0.5 molar HCl after addition of 3 drops of phenolphaleinium blue reagens liquid:

$$\mathbf{2NaOH + 2HCl \rightarrow 2NaCl + 2H_2O}$$

The experiments included duplicates, and 2 bottles without soil samples, to find correction values for the CO_2 in the air. After measuring all cups, the cups were filled with fresh NaOH solution, and again placed in the bottles, so that measurements could be done after another 1 – 5 days. This was repeated until the total measuring period was 90 days.

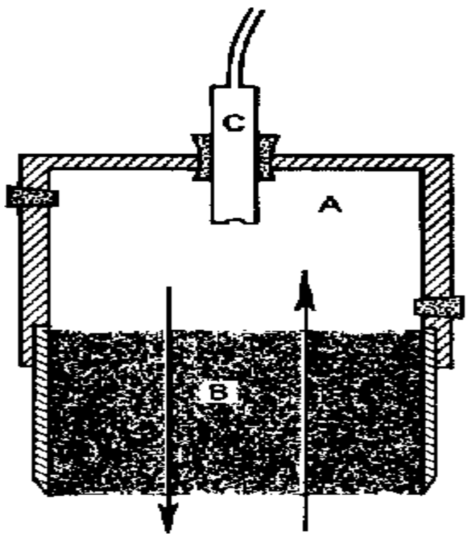

Figure 2: Measuring oxygen diffusion on soil sample B with sensor C in cap A

Gas diffusion was measured on undisturbed core samples that were taken from the tree soils in the experimental sites at Spakler street, Amsterdam. The samples were in metal cylinders with an height = 5 cm and an inner diameter = 5cm. A cap with an oxygen sensor was connected to the top of such a sample. The sample bottom was let free. See Fig. 2 (Bakker et al., 1987). Then, the cap was flushed with nitrogen gas through 2 openings in the cap side until the cap only contained pure nitrogen. Then the cap was closed and recording of the slow increase from zero of the oxygen concentration in the cap was started. The coefficient of oxygen diffusion was determined by plotting time against the logarithm of the difference between the oxygen concentration in the cap and the oxygen concentration in the free atmosphere. Measuring occurred at 20^oC and was continued during a few hours for each sample. In total, 18 tree soil samples were measured. In addition, 2 samples of IJssellake sand were measured.

The oxygen regime of a street tree growing site was simulated by O_2 SIMUL for a mature tree and optimum temperature and soil water content conditions. The object consisted of a 8 cm thick layer of pavement with a joints % = 5, a 10 cm thick layer of sand, and a 82 cm thick layer of tree soil. No gas exchange was allowed at the bottom and lateral boundaries of the tree soil. The area of the growing site was equal to the tree crown projection and the tree roots were assumed to be evenly distributed in the soil volume. The sand layer and the sand in the joints had a diffusion coefficient = 10^{-2} cm^2 s^{-1}. The tree soil had a diffusion coefficient = 0.2 x 10^{-2} cm^2 s^{-1}. The oxygen consumption of the tree roots was 1.86 x 10^{-5} cm s^{-1}. Simulations were done for 3 levels of oxygen consumption by the tree soil: 0.2 x 10^{-6} , 2 x 10^{-6} , and 20 x 10^{-6} mg oxygen per cm^3 soil per second. On volume basis, these are 0.14 x 10^{-6} , 1.4 x 10^{-6} , and 14 x 10^{-6} cm^3 oxygen per cm^3 soil per second, respectively. The model assumed that, for oxygen concentrations lower than 10 %, all consumptions decreased linearly with $[O_2]$ from the consumption input value at $[O_2]$ = 10 % to zero consumption at $[O_2]$ = 0.

Results and Discussion

The results of the oxygen consumption measurements are presented in Fig. 3 for the laboratory made samples and in Fig. 4 for the undisturbed samples from the Spakler street locations. The results of the coefficient of oxygen diffusion measurements on the Spakler street samples from the tree soil Abo5%, tree soil with prunings compost, and tree soil with biowaste compost and on IJssellake sand were 3.7 x 10^{-7} , 6.5 x 10^{-7} , 1.9 x 10^{-6} , and 7.4 x 10^{-7} m^2 s^{-1}, respectively.

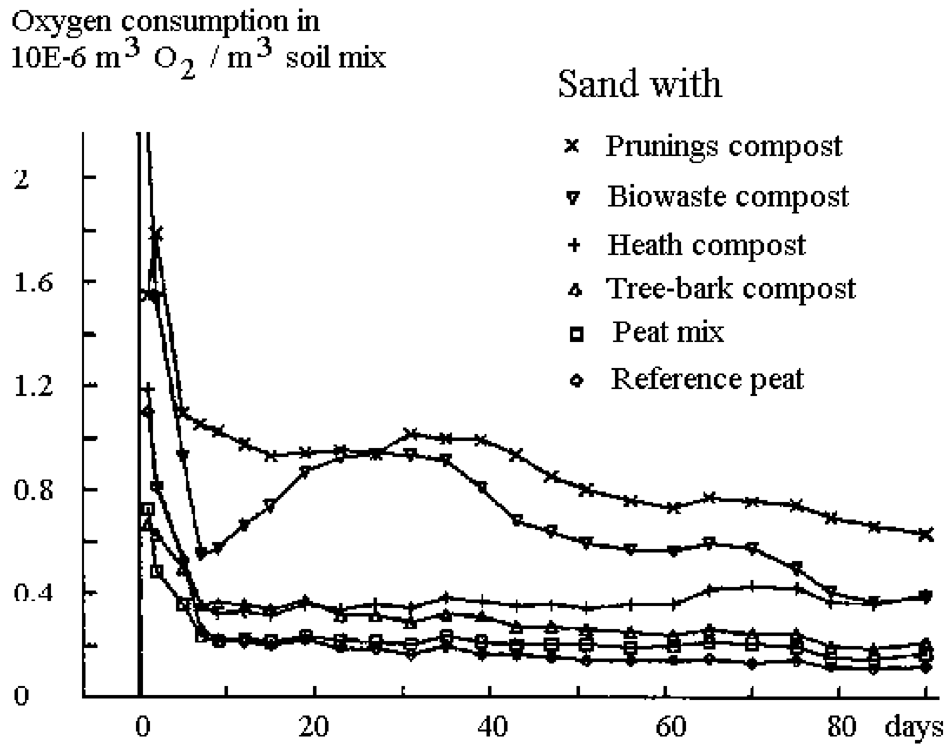

Figure 3: Oxygen consumption of laboratory made tree soils.

Figure 3 presents simulation results: equilibrium concentration of oxygen as a function of depth, at 3 levels of oxygen consumption of the tree soil.

The general shape of the consumption curves in Figure 3 and 4 has a maximum in the first hours, and a decrease with time at a decreasing rate. Product constancy and predictability of product

properties is not always good. Curve shapes are irregular, curves may cross one another, and their order in both Figures differ (See the biowaste and prunings tree soils). Abo5% and the tree soil with reference peat are known as very stable products, which do not cause lack of oxygen problems. This experience from practice is in agreement with the low level of the curves of these mixes. The low level of the curve of the product with peat-mix may be explained by the fact that a major part of the organic material in this mix is refence peat.

The simulation results for a street tree growing site show very low oxygen concentration values (as a rule of thumb, it is often stated that this value should be higher than 10%). Reasons for these low values are: the selected consumption value for the tree is a maximum value; the roots were evenly distributed through the tree soil that reaches to a depth of 1m; oxygen was not allowed to enter through the bottom and lateral sides of the tree pit.

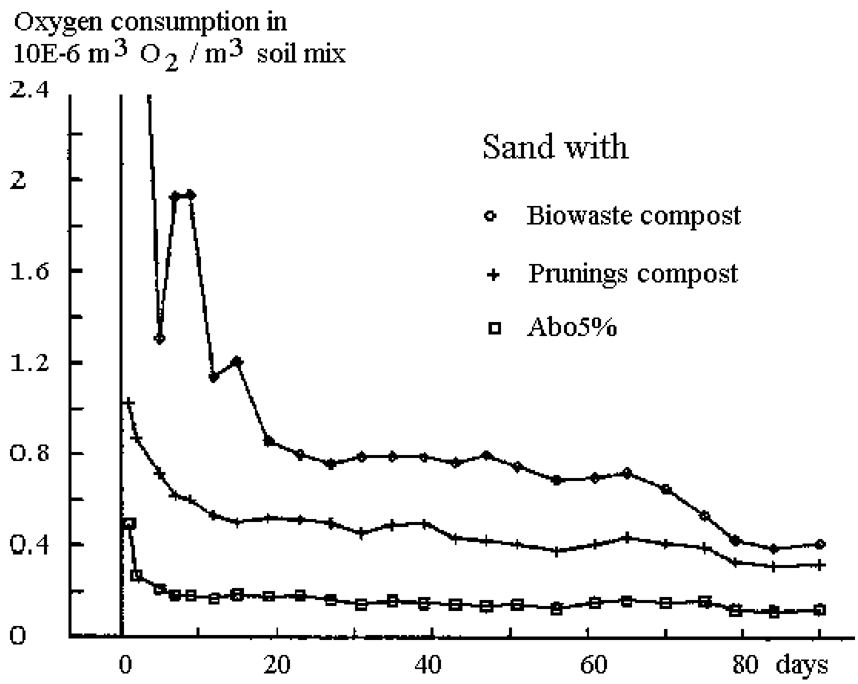

Fig. 4: Oxygen consumption of undisturbed samples of 3 tree soil sites.

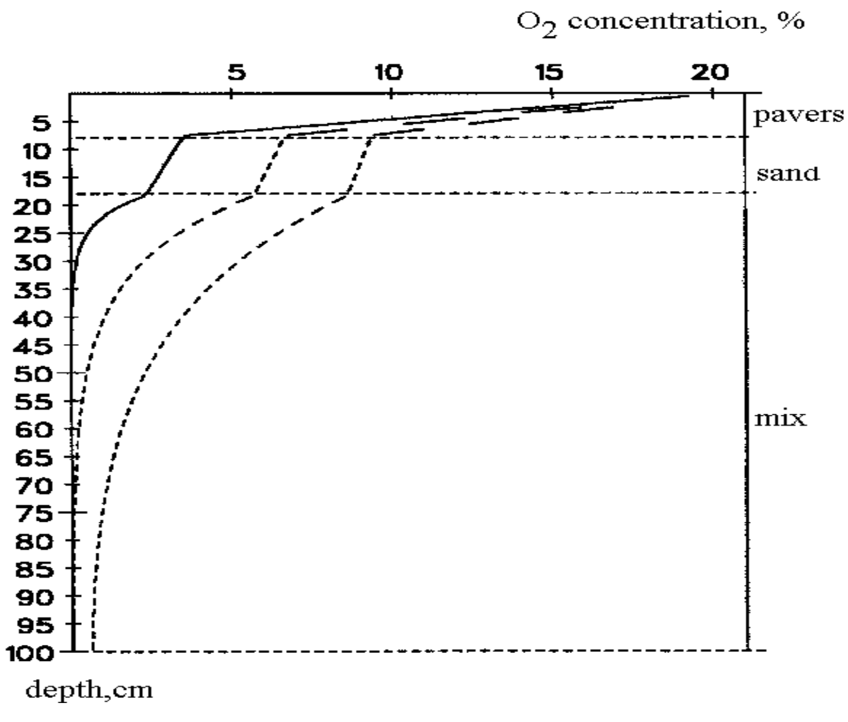

Figure 5: Equilibrium concentrations of oxygen in a tree soil profile at 3 levels of oxygen consumption of the tree soil.

The consumption valus of Figs. 3 and 4 may be interpreted using the results of the Spakler street experiment. In this experiment, the oxygen concentration in the tree soils was measured during a 1 year period after establishing in the beginning of May, 1995. The pits did not contain trees,and were covered by a sand layer and 30 x30 x 5 cm^3 pavers. The 1m wide pits were bordered by an asphalted traffic lane on one side and a bicycle road (30 x30 x 5 cm^3 pavers) on the other side. Each pit had a length of 4.5 m. The tree soils reached to a depth of 65 cm. The groundwatertable was at a depth of 80 cm. The oxygen mearurements showed the following. Abo5%: only on one measuring day (out of 15 measuring days in total) oxygen concentrations slightly lower than 10% were measured, the other measurements showed higher percentages. Sand with biowaste compost: most measurements gave oxygen concentrations near zero. Sand with prunings compost: the measurements gave intermediate values.

The oxygen diffusion in a cross section of the Spakler street and a tree pit was further simulated by a simple 2-dimensional simulation programme. The results showed that for the lower part of the tree soil volume the horizontal oxygen flux into the soil is higher than the vertical flux.

Conclusion

Street trees may suffer from lack of oxygen. Here, roles are played by type of pavement, depth of groundwatertable, oxygen transport possiblities through the tree soil and its surroundings, tree oxygen need, dimensions of the soil volume, tree soil oxygen consumption. A quantitative analysis is possible by measuring oxygen specific consumptions and diffusion coefficients, and by running simulations that should be verified by measurements on tree soil sites.

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Effects of soil physical and chemical properties on tree growth in urban areas

Introduction

The aim of the investigation is to identify the ecological characteristics of urban sites of street trees and to develop a soil substrate for new plantations according to the natural site conditions.

Material and Methods

In the centre of interest is an experimental plantation of *Tilia pallida* (Kaiserlinde), which was installed in 14 German towns during the winter 1987/88 and investigated until 1991. In each town 16 trees ware planted parallel to a street, eight trees were designed for the experimental and eight trees for the practical variant (fig. 1). All the 124 lime trees (height 3.0 – 3.5 m, stem girth 20 – 25 cm) have identical heritage by self-rooted reproduction (tree nursery Lappen / Kaldenkirchen). The select lime tree (*Tilia pallida*) is very common in the towns and its reaction is sufficient sensible on external impacts.

Experimental variant

The lime trees of the experimental variant were planted in pits with a dimension of 2 x 2 m and a depth of 1.5 m (one-layered back fill with an experimental substrate; fig. 1). Founded upon extensive initial investigations of old urban tree sites a catalogue of requirements for soil substrates was defined (fig. 2) and an according one was developed (fig. 3).

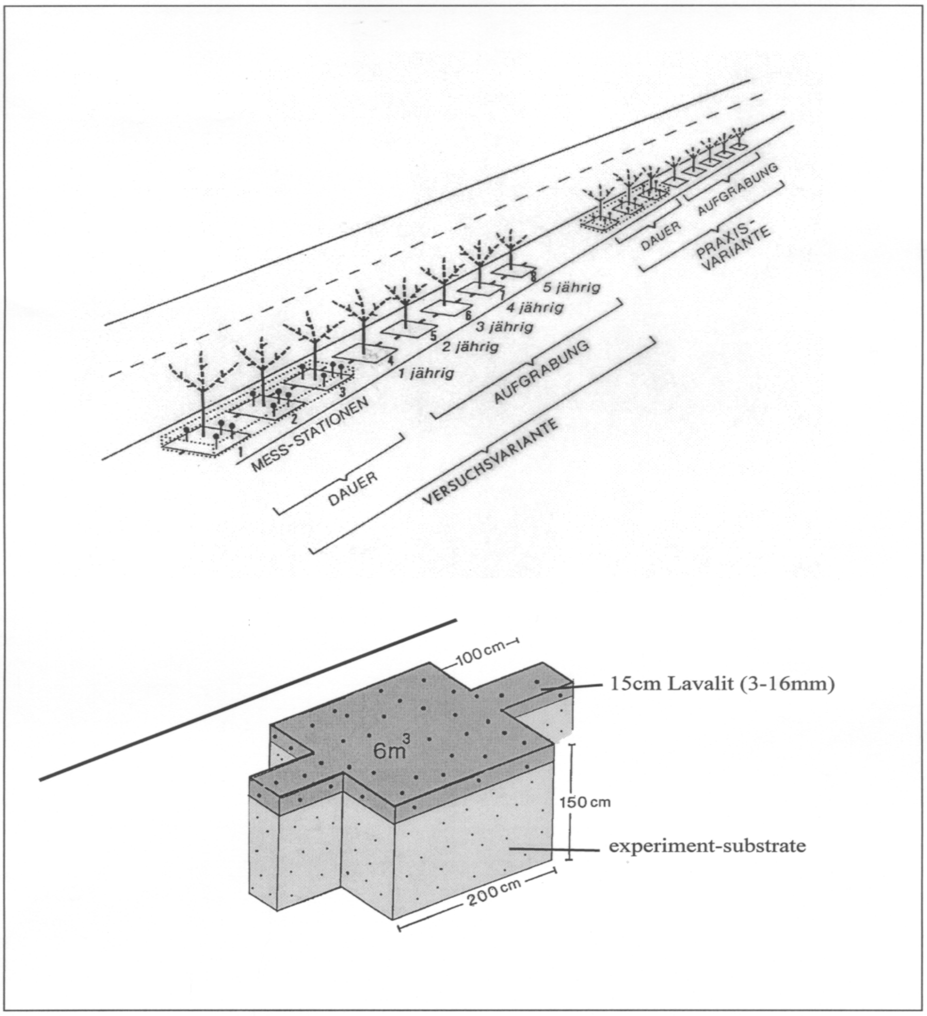

Fig. 1: experiment-arrangement and structure of the planting pits

catalogue of requirements for soil substrates street trees

1. stability in structure and against compaction
   - degree of anisotropy — U — U > 100
   - density of deposit (effective) — Ld — Ld ~ 1,8
     (according to the limit "medium" and "high")*
2. high air capacity
   - part of percentage by volumes of pores > 50µm — LK — LK > 12 Vol-%
     (high: 12 – 18 % by volume)*
3. high hydraulic conductivity
   - permeability (water saturated soil) — kf — kf = 40 – 100 mm
     ("high" = 40 – 100 cm/d)
4. medium available field capacity
   - available field capacity (pF 2,5 – 4,2) — nFk — nFk >140 mm
5. good supply of nutrients
   - classification for urban trees is totally missing
   - availability is much more important than total content
6. corresponding to site and reasonable costs
   - a high percentage of the excavated material is intermixed
     (to avoid the effect of flower pots and to minimise the costs)
   - using cheap admixtures (sand, loess, lava etc.)

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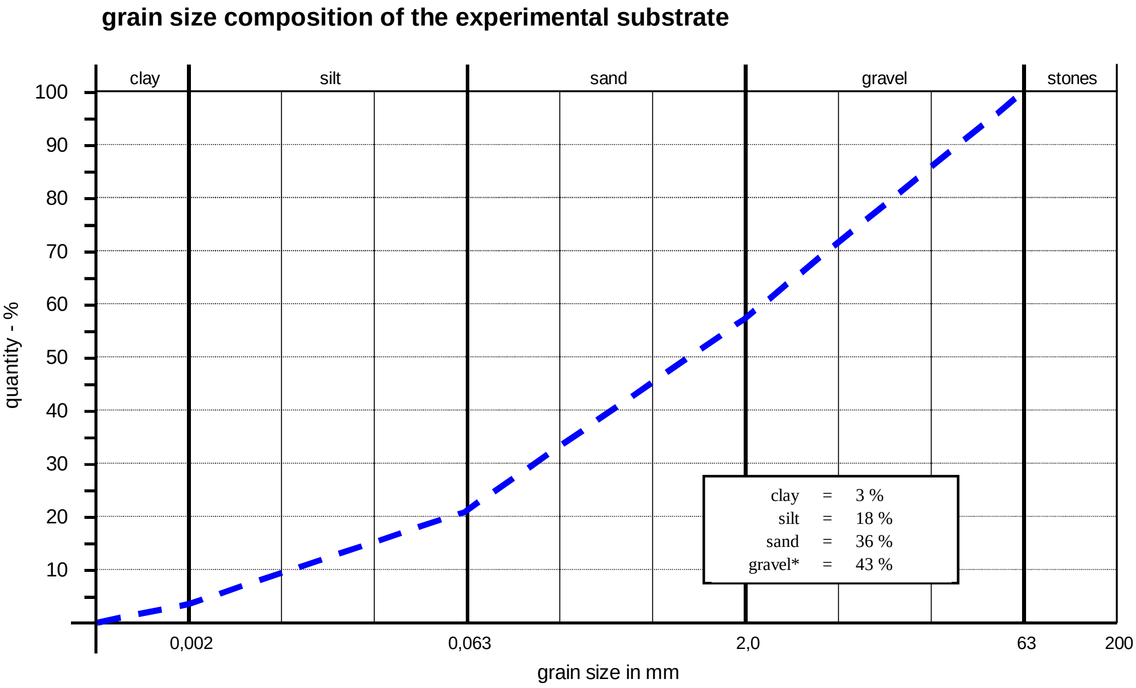
Fig. 2: catalogue of requirements for soil substrates



* admixed with LAVALIT

+ 2 kg TRIABON/m^3 (16 % N, 8 % P_2O_5, 12 % K_2O, 4 % MgO)

Fig. 3: grain size composition of the experimental substrate

The planting substrate has to feature the following qualities:

- a high stability against compaction (by grain to grain support and a small content of clay)
- a permeable system of macropores to ensure a porousness and permeability up to the pit bottom
- a medium available field capacity
- a distribution of macropores which takes in consideration the hydraulic particularity of urban tree sites; that means the capability of quick infiltration of convection respectively intensive rainfall often occurring during the growing period
- the capability of distributing the rain water among a spacious and deep soil volume until the available field capacity is reached
- and resulting from that what is mentioned above the property to guarantee the autarky in water supply as far as possible (watering not necessary).

The experimental substrate was filled in layers while an initial compaction (about d_B 1.7) was obtained by occasionally stamping down the backfill. A gravel respectively lava layer, about 15 cm big and highly permeable, covered the experimental pits as protection against compaction and evaporation.

The planting substrate is made from the particular site material to avoid the effects of plant pots and to minimise the costs. The missing substrates (gravel, sand, silt) are admixed to the excavated soil to gain the required grain size distribution (43 % gravel, 36 % sand, 18 % silt and about 3 % clay). Lavalit serves as an additive to the gravel fraction. It is a volcanic product rich in micropores, which improves the water holding capacity (nFK) besides the support function.

The authors deliberately disclaim organic matter in the admixture. They believe that higher contents of organic matter are typical for forest sites but not for semi-arid and alkaline urban sites. The high water-holding capacity of humic topsoil, the high insolation and the alkaline conditions causes a quick mineralisation in the first years after planting attended with a high release of nitrogen. As a result the roots would mainly be formed in the topsoil and the tree would be dependent on watering in the dry summer months.

The participating offices of horticulture urgently recommended to admix a mineral complete fertilizer to the experimental substrate which probably covers the nutrient requirement not longer than 1 – 2 years (2 kg TRIABON with 16 % N, 8 % P_2O_5, 12 % K_2O and 4 % MgO for 1 m^3 planting soil). The authors, however, believe that a fertilizer is not necessary. According to the initial investigations the absolute nutrient content of soil is not important but the soil physical factors which control the availability of nutrients as well as their uptake by roots.

Practical variant

Eight lime trees in one row represent the practical variant. In some towns they were planted in pits with a two-layered soil – a very humus-rich topsoil, enriched with organic matter and a mineral subsoil. Other towns use a one-layered planting substrate with soil similar to the experimental variant. In some cases organic matter is admixed. The pit dimensions vary from 60 x 80 cm to 350 x 150 cm and even the depths are very different with 60 cm up to 160 cm.

Investigation program

In each variant three tree sites were equipped with permanent measuring instruments (soil water-measuring program; fig. 1). Every year one of the other five planting pits was excavated to examine the root formation and soil development continuously. The program includes biological, soil physical and hydrological as well as chemical investigations (fig. 4).

investigation program :

biological investigations:
- morphology trunk, shoot, leaves
- root distribution
- leaf ingredients

soil physical – hydrological investigations
- soil texture and structure
- air- and field capacity, permeability

chemical investigations
- chemistry of solid soil matrix
- chemistry of perculation water

Fig. 4: investigation program

Results and Discussion

Soil physics and hydrology

Most of the participating towns referred to the requirements of the grain size composition developed for the planting substrate in the experimental variant (fig. 5) though the methods of intermixing were different. The correspondence with the requirements, weighed in different parameters, is „very good" (class 1), „good" (class 2) and „satisfying" (class 3). Class 1 and 2 show a high to very high air capacity and therewith a continuity of macropores > 50 µm in the soil is given from top to bottom of the pit. Just as the available field capacity (pF 1.8 – 2.5) attain medium to high values (about 150 mm) independent of the soil depth.

The example of Frankfurt/Main with its practical variant of a two-layered soil, the 50 cm mighty topsoil contains a little less than 4 % organic matter, turns out the great difference in amount and continuity of macropores in opposite of the one-layered soil of the experiment variant (fig. 6 a, 6 b). The high amount of macropores in the topsoil conditional on the crumb structure abruptly decreases in the boundary of the mineral soil. There it causes a water stagnation and impairs the aeration of the subsoil. This hinders the root penetration in depth and the draught damage in summer respectively the necessity of watering is predetermined.

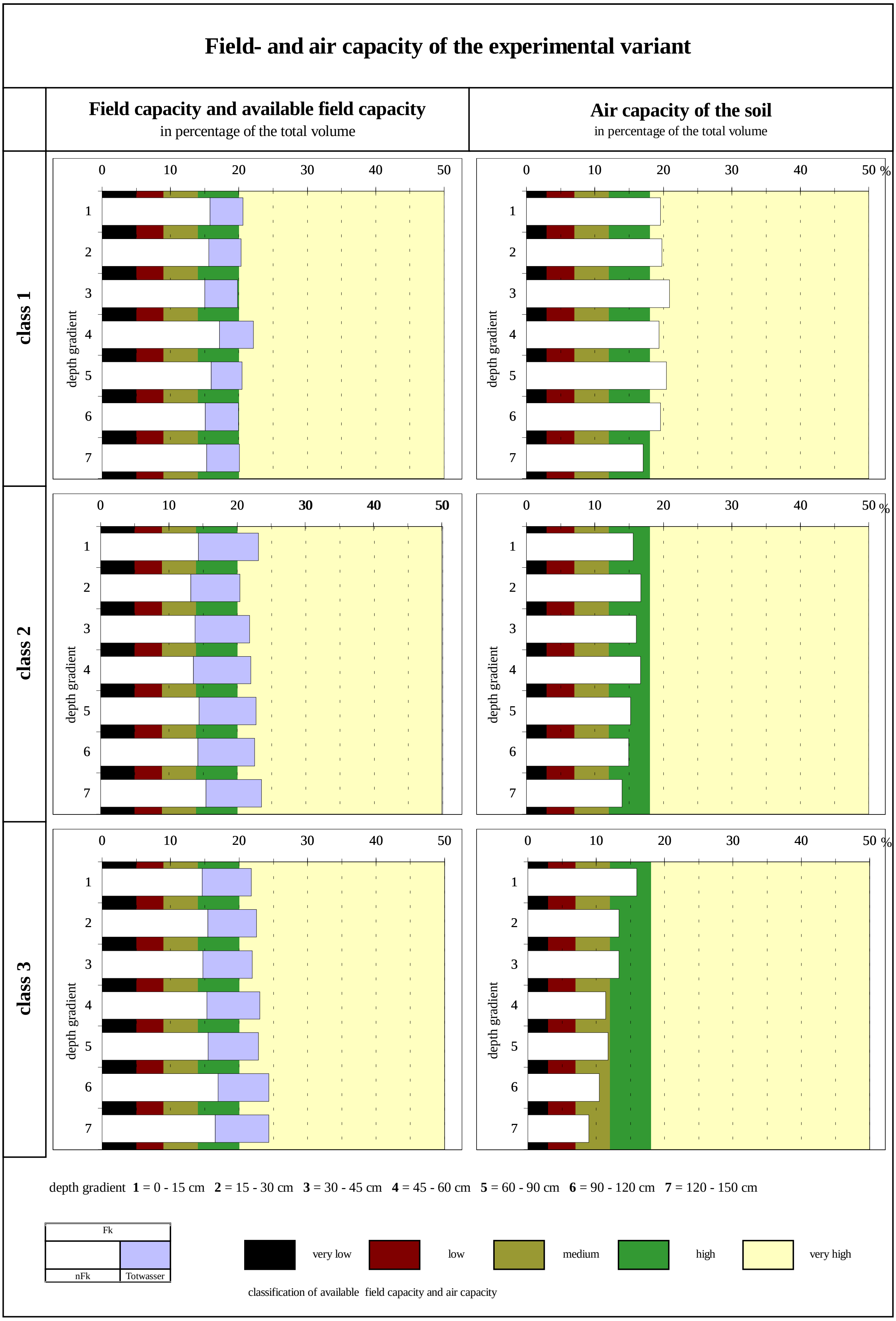


Fig. 5: field- and air capacity of the experimental variant

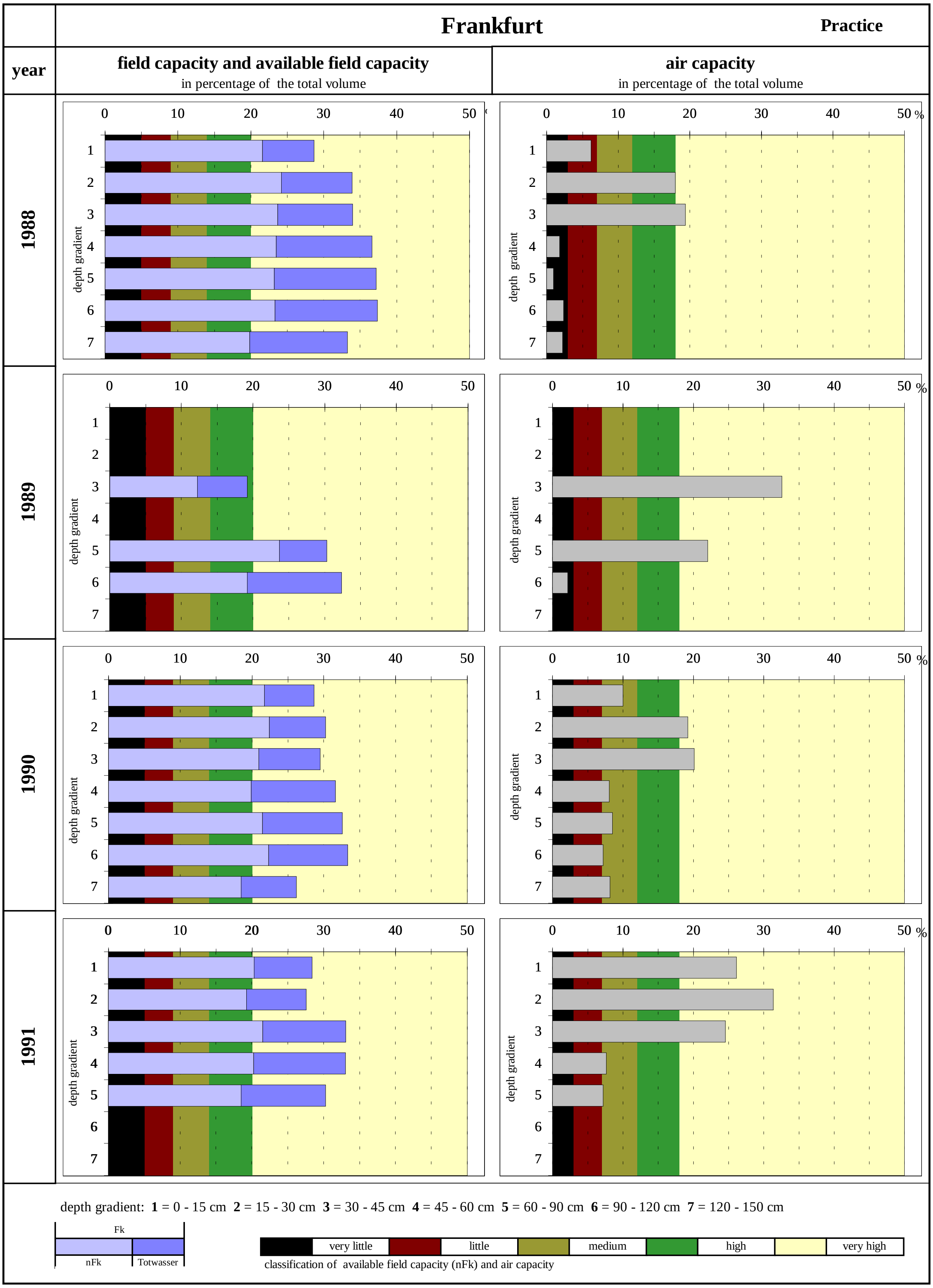


Fig. 6a: field- and air-capacity of the practical variant of frankfurt

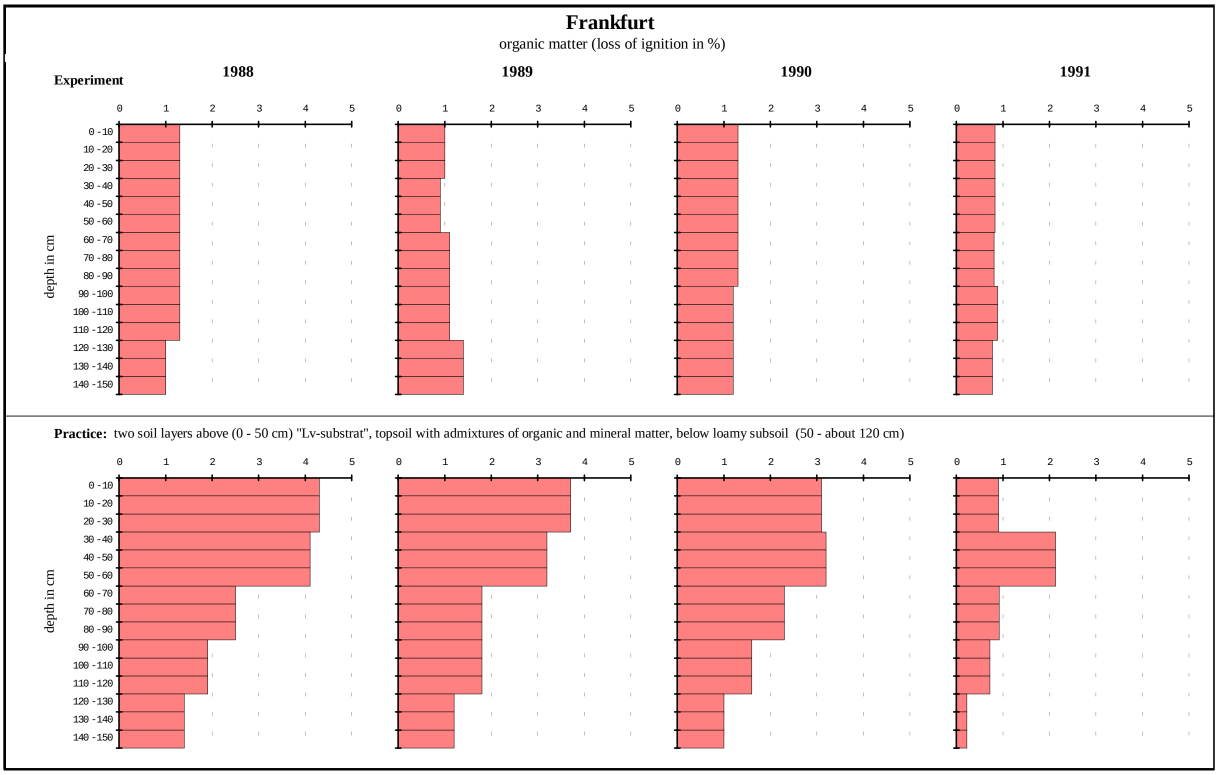


Fig. 6b: organic matter Frankfurt

pH-level

Almost 90 % of the investigated urban soil show alkaline conditions with pH values among 7.0 – 8.5, they move in the calcium carbonate-buffering system. Therefore, the soil chemical conditions obviously differ from the acid soil of forest trees (pH 3.5 – 4.5). The calcium surplus of the urban soil is faced with the calcium deficiency in forest soil with a simultaneous aluminium toxicity. Therefore, it is extremely questionable to pass the characteristics of vitality and damage of forest trees (e.g. forest damage classification) on urban trees.

Organic matter

The content of organic matter is very little (about 1 %) in the one-layered soil of the experimental variant. It results from the humus content of the excavation material. Fig. 7 shows the soil classification of the practical variant in all 14 towns according to their different initial content or organic matter. At the same time the figure represents the loss by decomposition respectively the residue of organic matter at the end of four years after planting (1987 – 1991). In these years the group of the humus-rich soil (4 – 15 % organic matter) already lost 58 – 68 % of their organic matter by mineralisation. The loss by decomposition is obviously less in the medium humic soil (2 – 4 % organic matter) of the practical variant but still amounts to 15 – 41 %. No losses or only very little occurred (0 – 10 %) in the slight humic soil of all experimental and some practical variants. This is due to the existence of stable humus combinations. The use of a larger quantity easier decomposable organic matter on sites of urban street trees is rejected because

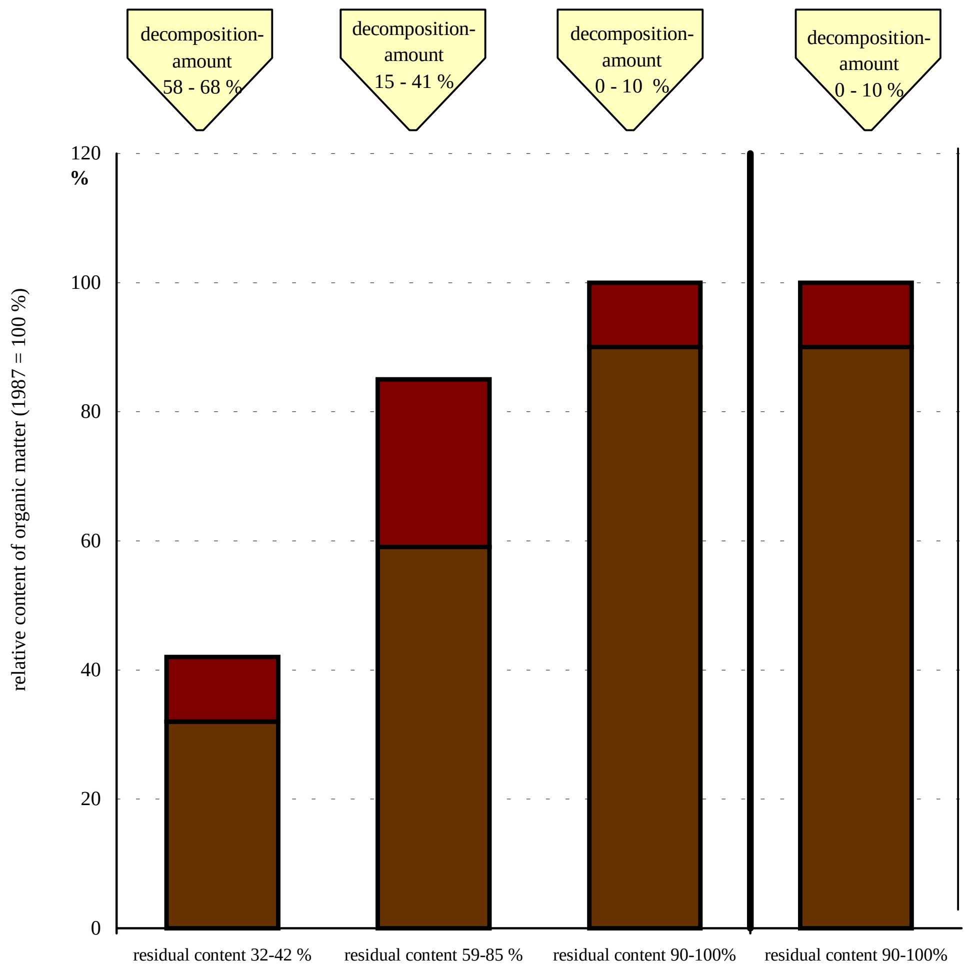
- high nitrogen contents in the soil conditional on intense nitrification results in an unfavourable shoot/root ratio and
- the intense humus decomposition rapidly modifies the characteristics of soil structure for which the formed root system is not prepared.

Nitrogen

A large quantity of easy decomposable organic matter in the topsoil, which causes a rapid mineralisation, cannot be accepted because of site ecological reasons. This intense release of nitrate results in an intensified nitrogen uptake of the trees. High nitrogen contents in the assimilation organs (leaves) correlate clearly positive with an intensified growth of the leaves, side and leading shoots as well as a greater number of buds, altogether with a pronounced crown growth. From the site ecological point of view it is wrong to rate this nitrogen induced crown development for urban street trees as a positive vitality. The additional water requirement cannot be covered with the natural water supply of the urban site, but has to be filled up by extensive watering to avoid drought damages. Not later than now the question arises about a new definition of vitality of urban street trees respectively about parameters of vitality relevant to the site ecology.

Loss of organic matter by decomposition in the year 1987 to 1991 in dependence upon the amount of organic matter in the soil substrate at the time of planting

(content of organic matter in 1987 = 100 %; calculated by median values)



	practice			experiment
org. admixtures compost-cover	yes	yes	no	no
content of org. matter in %	4 - 15 %	2 - 4 %	1 - 2 %	1 - 2 %
classification	"humus rich" to "very humus rich"	"medium humic"	"little humic"	"very little humic"
towns	AB, DA, ES, M	HB, F, KA, MA, WI	DN, ML, MZ, S, WOB	all towns, excepted munich

Fig. 7: Loss of organic matter by decomposition in the year 1987 to 1991

Phosphorus and potassium

Up to now there are no guide values of nutrient requirement and corresponding supply levels of the soil for urban green and trees. The more serious is the conclusion of this investigation that shows the available contents of phosphorus and potassium (CAL) are „high“, „very high“ and even partly „extremely high“ in almost all soil of both variants according to the supply classification for agricultural soil (LuFA Weser Ems). The average content of available potassium is 5 – 15 mg K/100 g soil and of available phosphorus is 10 – 25 mg P_2O_5 / 100g soil. The reference made to the agricultural soil classification ought to show the oversupply (overfertilization) of the urban trees, which nutrient supply is in a multiple less.

Furthermore it is astonishing that against the opinion of the gardeners the high amount of phosphorus and potassium supply did not decline in the four years after the experimental substrate has been intermixed. The alkaline milieu of the soil would already have effected any precipitation and apatitic immobilisation of the phosphorus. Even the mobile potassium was not dislocated respectively leached away. That is an indication to a different soil water budget of the urban street trees than of the forest trees. While forests of humid moderate climate are characterized by a positive soil water budget with descending soil water movements (seepage), towns show a negative water balance with a stagnant and even partly rising soil water movement.

While the available phosphorus and potassium supplies are regularly distributed in the whole soil body of the one-layered experimental variant, there is an extreme difference in the two-layered practical variant between the strongly overfertilized topsoil, additionally enriched with organic matter, and the much lower supply in the subsoil. This dissimilarity results in a favourite root forming in the topsoil.

Shoot development

The evaluation of shoot development referred to the determination of the following parameters during the four years of investigation: increment of stem girth, length increment of the terminal and side shoots, number of buds at the terminal and side shoots as well as the leaf size (in May, June, September). For reasons of statistic all measured parameters were taken in consideration and expressed with the number of shoot increment (**S**pross**Z**uwachs**Z**ahl = SZZ). This number (SZZ) is calculated in the way that the places in the rank order of the years 1988, 1989, 1990 and 1991 are distributed over all towns differentiated from the two variants and than are summed up for all parameters. The sums (= SZZ) are represented in fig. 11 in rising succession. The towns with the highest shoot increments are represented on the left side, those with the fewer increments on the right. Regarding the absolute values there are no significant differences between the crown development of the two variants. This consequence defeats the fear of many experts that only a stunted growth of trees is possible in a very coarse textured experimental substrate. In comparison with the places of the SZZ rank order of the two variants in one town only two exceptions show no congruence. The conclusion is that no external factor (e.g. climate) implies a regional preference or disadvantage but the different soil composition of the two variants rather causes the varying crown development of the trees in one town.

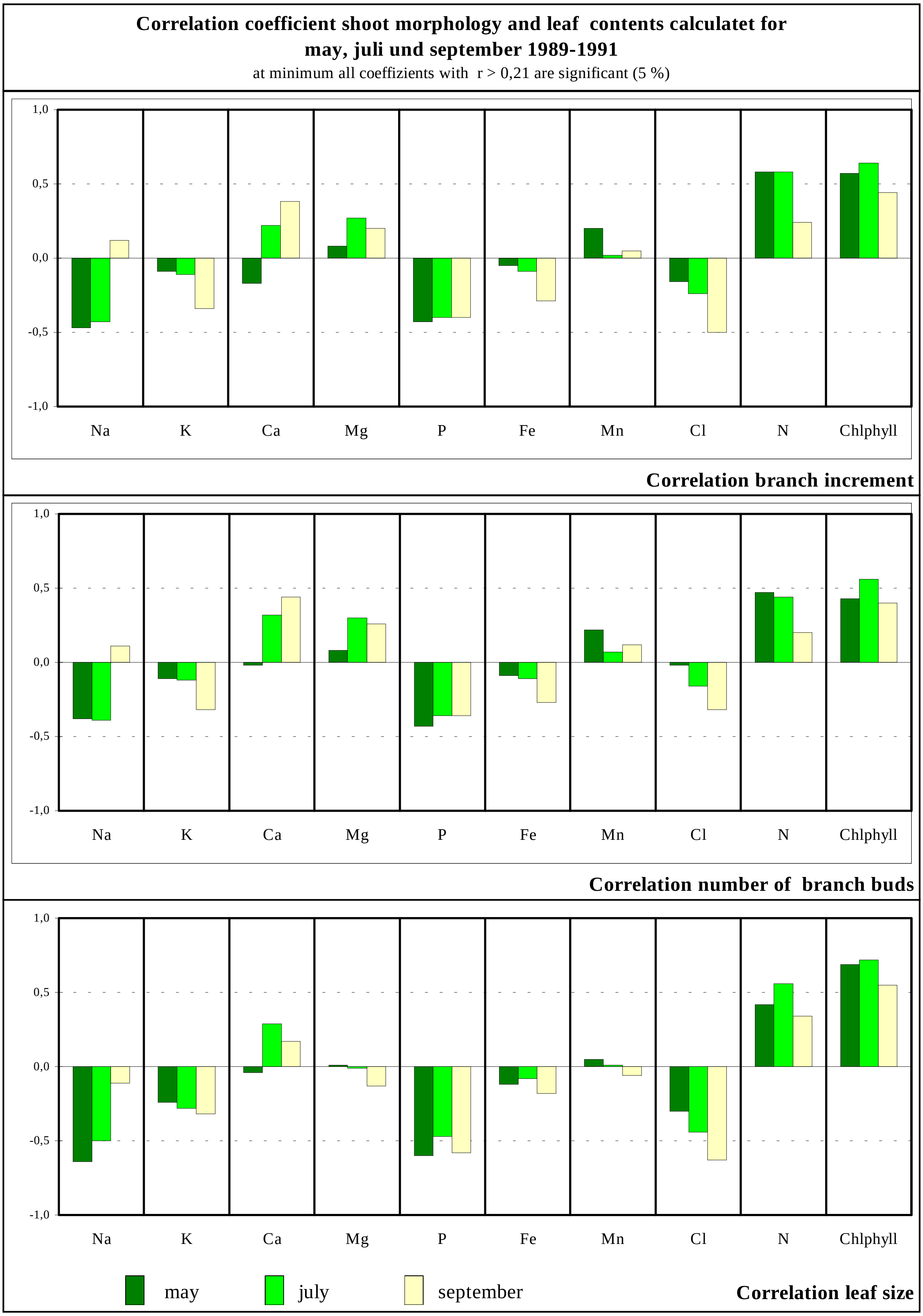


Fig. 8: correlation coefficient shoot morphology and leaf contents

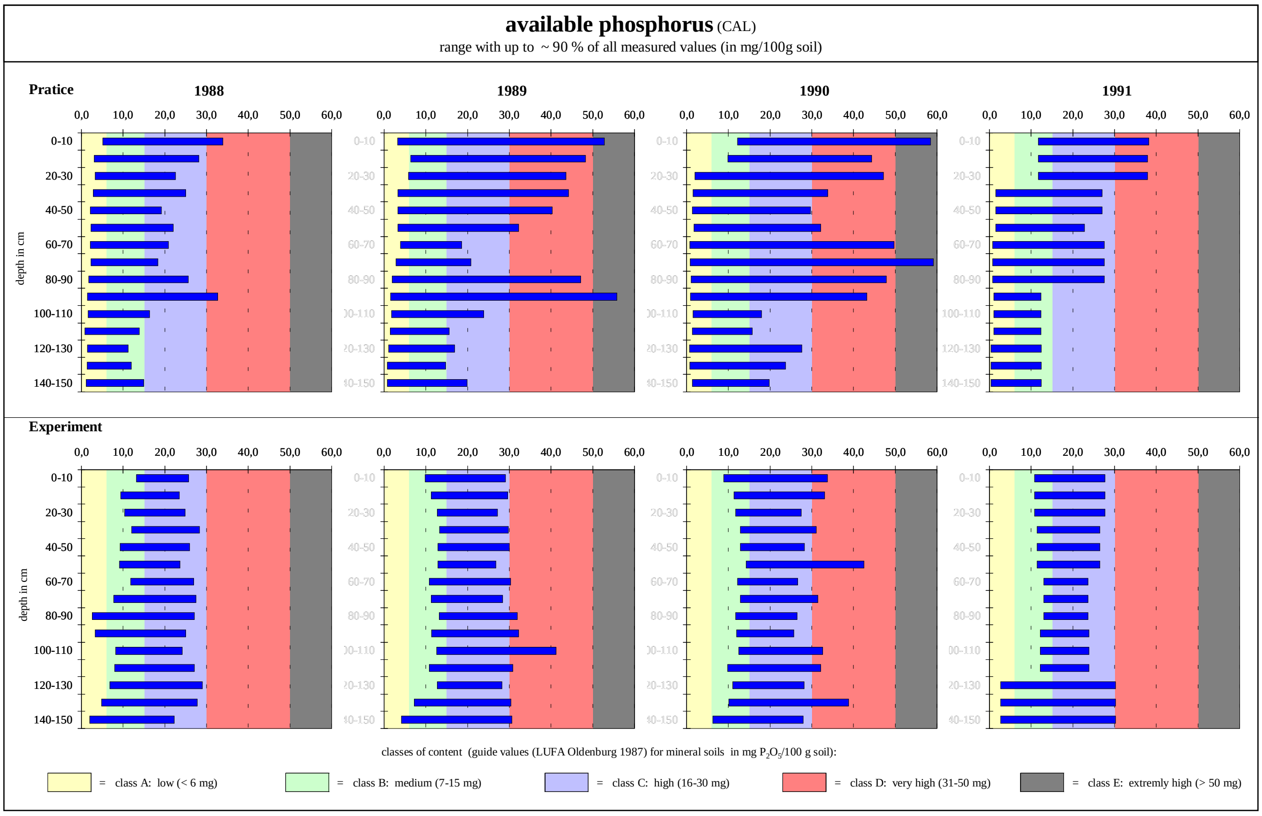


Fig. 9: available phosphorous

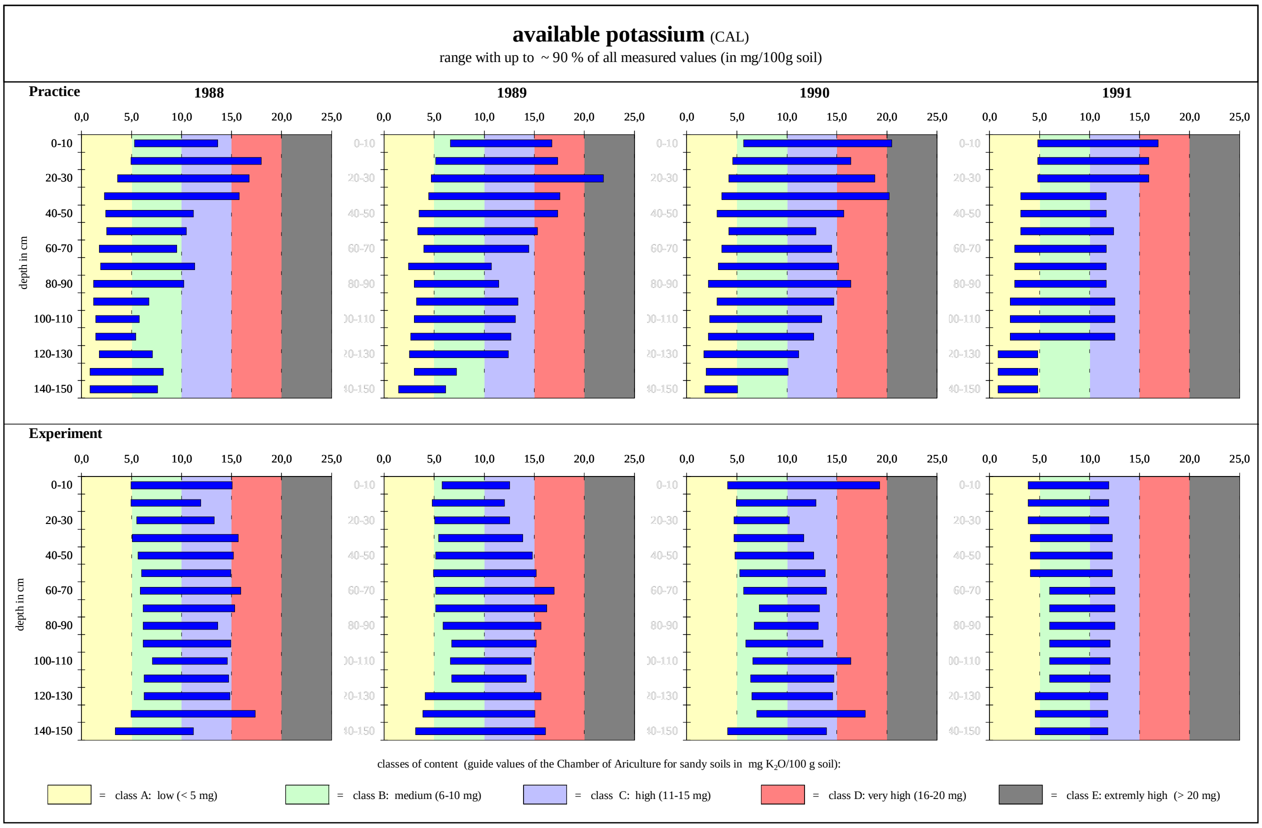


Fig. 10: available potassium

ranking of "shoot increment number" (SZZ - above) in comparison with the "root increment value" (WZZ - below) for the period 1988 - 1991

AB = Aschaffenburg
DA = Darmstadt
DN = Düren
ES = Esslingen
F = Frankfurt
HB = Bremen
KA = Karlsruhe
M = Munich
MA = Mannheim
ML = Marl
MZ = Mainz
S = Stuttgart
WI = Wiesbaden
WOB = Wolfsburg

Fig. 11: rank of the number of shoot increment in comparison with the number of root increment

Figure 12 shows a correlation between the relative amount of growing-season rainfall (April – September) in 1988, 1989 and 1990 and the corresponding shoot increments. In 11 towns of totally 14 it is significant that in the year with the least rainfall the shoot increment was smallest. The other way round in 9 towns the greatest shoot increment was measured in the year with the highest rainfall. This evidence of the importance of precipitation requires a soil composition with a high infiltration capacity, a deep percolation and a good water storage capacity in the subsoil.

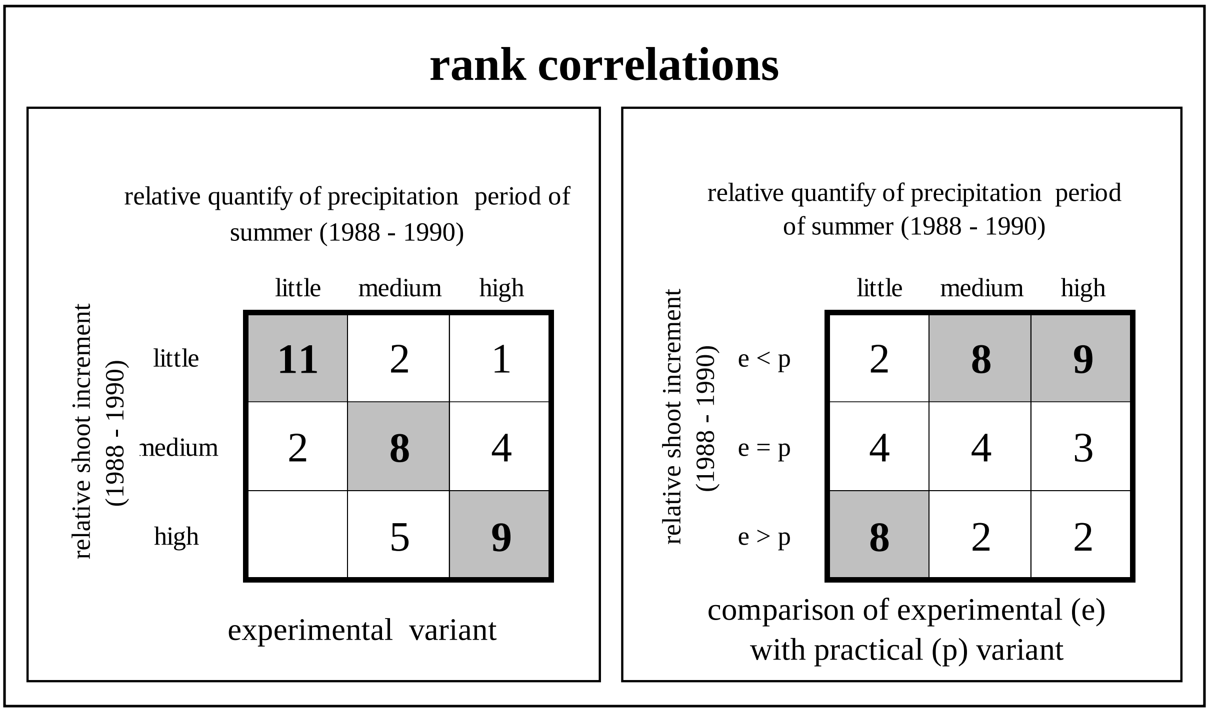


Fig. 12: rank correlations (shoot increment/precipitation)

The comparison of the shoot increment between the two variants shows (fig. 12 below) that the shoot development in the experimental variant is significantly better in years with the least growing-season rainfall than in the practical variant (in 8 of 14 towns).

The highest shoot increments were determined in the practical variant of Munich, Frankfurt, Bremen and Darmstadt, the towns with the highest nitrogen amount in the soil caused by above-average high organic additives.

<u>Root formation</u>

After the planting in winter 1987/88 one tree of each variant was excavated at the end of growing-season to determine the root formation. According to the forest site mapping (1980) the site class determination (fig. 13 a) of the pit walls was carried out in square grids (20 x 20 cm) with the following classes: not rooted, slightly rooted (< 20 fine roots), medium rooted (20 – 40 fine roots) and intensely rooted (> 40 fine roots). The plant pit at least excavated on one side was valued regarding the rooting intensity and presented in a three dimensional diagram. The two sections parallel and perpendicular to the street include the grid system of the rooting intensity classes.

Wolfsburg is selected as a characteristic example to represent the root formation in the two variants four years after planting (fig. 13 b). The lateral root growth reached the pit border not later than two years after planting as in all other 13 towns. In Wolfsburg the planting pits of both variants have a square measure of 200 x 200 cm; often they are much smaller. The question arises about further possibilities of extending the root system respectively about the problem of starting discrepancy between the crown and shoot development. The comparison between the two variants is very impressive. While the 150 cm deep pit of the experimental variant is medium rooted especially in the deeper subsoil, even beyond the pit bottom, the root penetration in the practical variant is confined to the humus enriched soil of the only 70 cm deep pit.

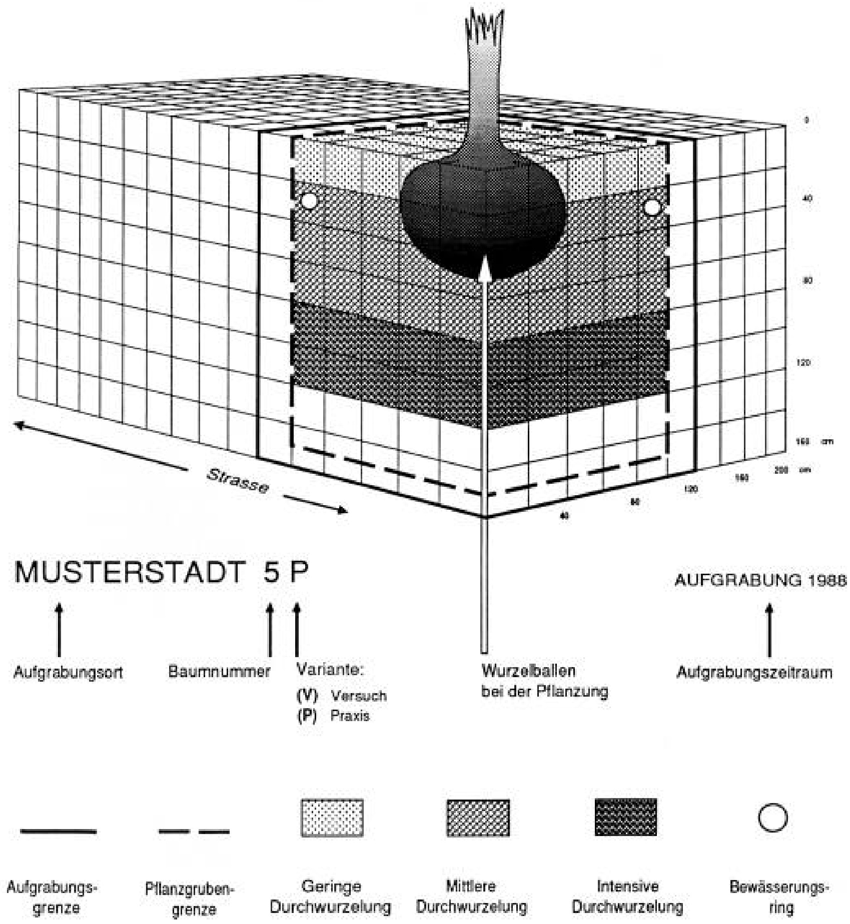


Fig. 13a: legend root diagram

To quantify the root formation a number of root growth was developed (**W**urzel**Z**uwachs**Z**ahl = WZZ). It is the product of the parameters DI (rooting intensity) and DT (weighed depth of rooting): WZZ = DI x DT. The rooting intensity is graded in 3 classes: no or slight rooting = 1, medium rooting = 2 and intense rooting = 3. The depth of rooting is weighing the importance of a deep reaching root system for an urban street tree as follows: root formation in the depth of 0 – 40 cm = 1, 40 – 80 cm = 2 and > 80 cm = 3. In each town all planting pits of both variants assessed in the years 1988 – 1991 were valued grid by grid (20 x 20 cm) by this method and the values of each year were summed up (= WZZ). Fig. 14 makes the different root formations of the two variants obvious. The upper part of the figure shows that the numbers of root increment of the experimental variant (average of all 14 towns) don't exceed the numbers of the practical variant (average of all 14 towns), but the root formation of the last one continuously decreases with advancing years of the trees.

Regarding the practical variants according to their different soil composition it becomes obvious that the root formation in the two-layered substrate (topsoil enriched with organic matter, mineral subsoil) is strongly decreasing already since 1989 while it continuously increases in the accompanying experimental variants. In contrast to the one-layered substrate of both variants the root formation hardly differs from one another. Summing up it may be said that the root formation of urban trees can far better respectively site-related be controlled in a one-layered substrate, which is poor in organic matter with a continuous distribution of macropores up to the pit bottom, than in a two-layered substrate, which topsoil is enriched with organic matter.

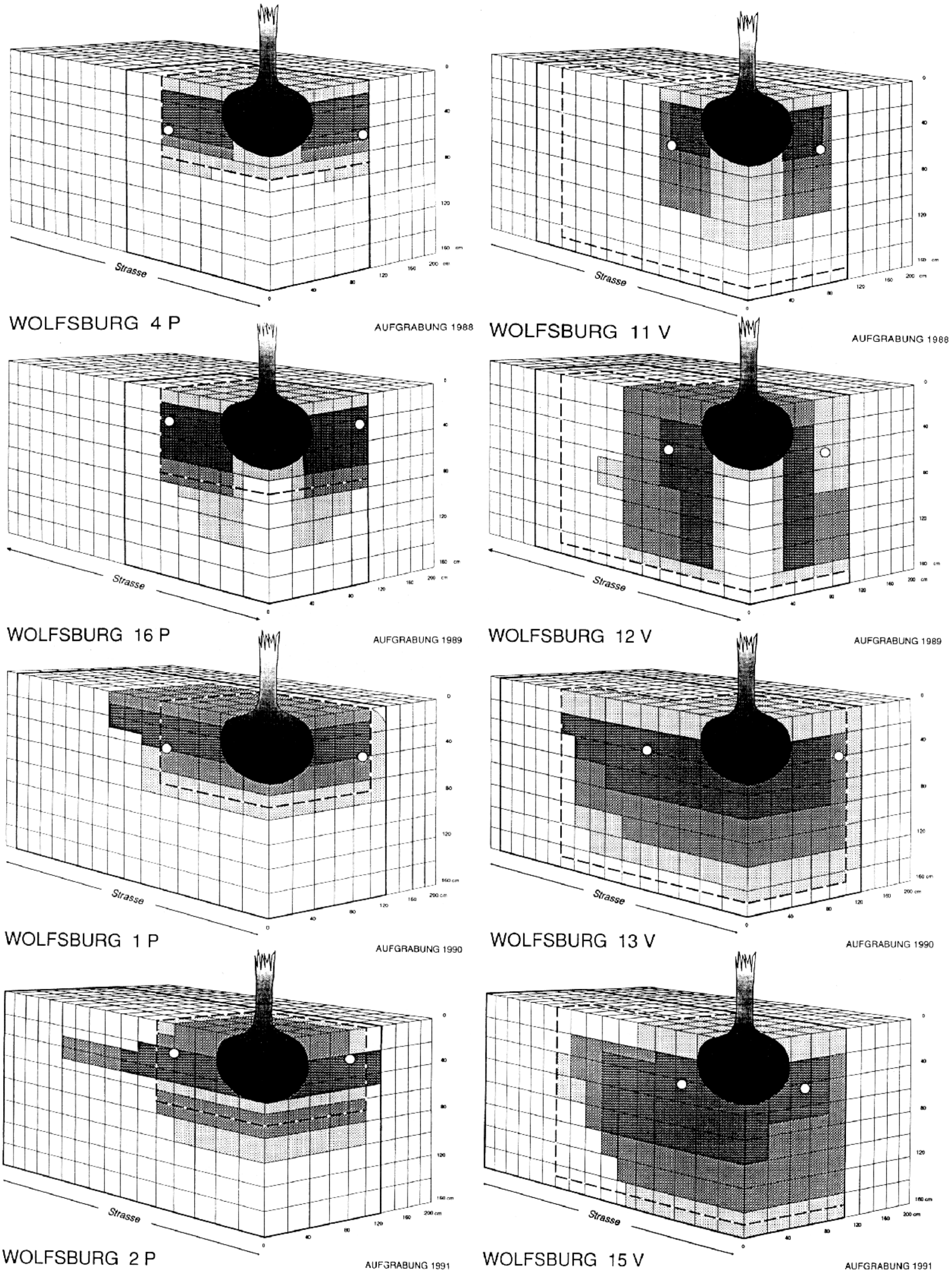


Fig. 13b: The root development in comparison of experiment and practical variant of the city Wolfsburg

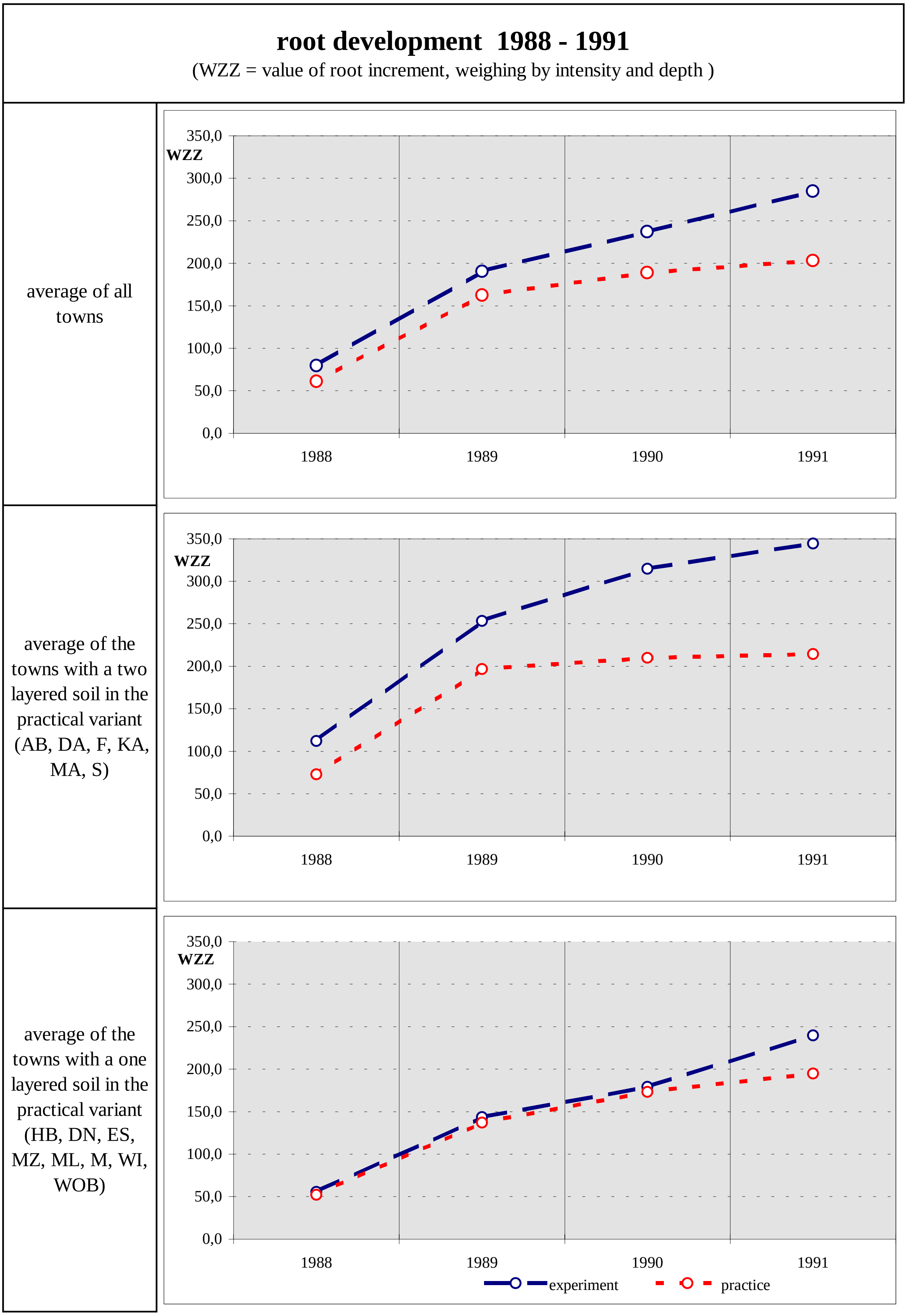


Fig. 14: root development 1988 - 1991 (practice and experiment)

Summary

Within the scope of a planting investigation in the Federal Republic of Germany an experimental planting is laid out along a street in each of the participating 14 towns (Aschaffenburg, Bremen, Darmstadt, Düren, Esslingen, Frankfurt/Main, Karlsruhe, Mainz, Mannheim, Marl, München, Stuttgart, Wiesbaden und Wolfsburg). This planting includes 14 lime trees (*Tilia pallida*) one half of it is planted according to the towns own practice (practical variant), the other half is planted into a scientifically developed substrate (experimental variant). The experimental substrate is composed on the basis of a requirement catalogue, which was specified by extensive initial investigations like excavations of street trees and laboratory tests. Soil physical properities come to the fore in the experimental substrate (e. g. air and water-permeability, stability against compaction) while it is mainly the nutrient content (organic and/or mineral fertilizer) in the practical substrate.

Comparative investigations were continuously carried out on the lime trees and the planting substrate over a period of five years. To express the over-supply of the nutrient requirement of street trees, the supply classification of agriculture soil has been taken and this shows, that the nutrient content of both variants is “high” up to “very high”. There is no significant difference in the shoot development of the two variants though the substrate of the practical one is often enriched with organic matter. The shoot increment of all trees rather correlates with the rainfall conditions of the respective site. The optimised water budget of the experimental variant turns out its positive effect in periods of unfavourable rainfall conditions. The homogeneous soil composition of the planting pit (2 x 2 m) up to 1,5 m depth also results in a regular and deep growing root system, which produce a much greater soil volume in the experimental than in the practical variant. The root formation on the practical variant is mainly confined to the organic enriched topsoil.

Literature

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The predicted effects of climate change on the survival of inner city trees

Introduction

It is predicted that at current rates of carbon dioxide (CO_2) emissions, that the global temperature will rise by a further 3 ^oC by the year 2080 (DETR-Met Office, 1999). Coupled with this there are predicted shifts in weather patterns such that many areas of Central and Southern Europe will receive less rainfall (DETR-Met Office, 1999). The increased pubic and political interest in global warming has lead to many research programmes investigating the consequences for agriculture and the environment. However, the consequences for urban ecosystems have been largely overlooked. Increasing temperatures are likely to increase incidences of inversion smog within cites (Scott *et al*, 1995). This would lead to the imposition of greater stresses on plants from pollution. Higher temperatures would be exacerbated by the urban heat island effect which may increase the evaporative demand on trees.

However, it is likely to be a reduction in precipitation that would have the greatest effect on urban tree health. This would not only mean a reduction in effective rainfall, something that is already restricted by the hard ground coverings, but would also mean a reduction in regional water resources and increased in human consumption (Scott *et al*, 1995). This in turn would reduce the amount of irrigation available for maintaining urban landscapes, since, it is likely that the resources would be prioritised toward maintaining agricultural production and human sanitation.

Urban trees are known to be susceptible to water stress if proper provisions are not made to minimise stresses from other sources (Kozlowski and Davies, 1975). If water availability becomes restricted by climate change, then the stresses imposed on the tree populations of cities will also increase. The result will be an increase in mortality unless trees are properly maintained. Assessing the performance of existing trees will become a necessary part of management to improve care of existing trees but will also improve the choice of trees and landscaping for new planting schemes.

Assessing the likely damage to trees caused by reduced precipitation requires the quantification of the relationship between the physiological health of trees, the amount available water and the rate at which water is used by the tree. The size and number of trees involved in a study of physiological responses means that the total growth or growth rates of tree elements (e.g. lateral extension and increased stem diameter) are often used as indicators of the physiological status of trees. However, data from Bellett-Travers and Ireland (1999) suggested that care must be taken in the interpretation of growth data since growth of laterals is not constant and so the timing of stress may affect the amount of growth reduction. In addition, because the urban environment has a uniquely diverse physical structure, the rate of evapotranspiration may change over a very small distance. Finally predictions of climate change are made on a regional level, therefore, to predict tree response to climate change, the physiological data must be compared to regional climatic data. Hence, the prediction from growth data of the effects of reduced precipitation due to climate change requires: an analysis of changes in growth rate in response to changes in available moisture to show that the two parameters are significantly correlated; and a simple method that compares changes in growth to changes in regional climate.

The research presented in this paper is combined from two projects, one, a at field studies of the soil moisture requirements of trees, the other, a study of the growth of trees in different years in the same location in Chelmsford, UK. The paper investigates the response of lateral extension to water stress within a replicated field experiment. This is compared to the response of stem diameter increases which are known to be particularly sensitive to changes in water availability (Glock, 1955). The lateral extension of street trees within an urban area were compared differences in lateral growth to differences in precipitation and evapotranspiration between years. It was anticipated that differences in lateral extension between years could be used to indicate trees that would be at risk of damage if the climate becomes drier as a result of climate change.

Materials and Methods

Experimental design

Measurements of lateral extension (to the nearest 0.5 cm) and stem diameters (to the nearest 0.01 mm) were made to the every 2-3 weeks during 1993 and 1994 on established trees *Betula pendula*. Roth and *Platanus x hispanica*. Meunchh in a field trial previously described in Bellett-Travers and Ireland (1999). The trees were subjected to 4 irrigation treatments: a control, and 3 treatments of increasing soil moisture deficit (SMD) (Bellett-Travers and Ireland, 1999). For this paper only data from three treatments were used, the controls, the treatment that received no irrigation, and the treatment that received no irrigation plus rain diverted away from the trees with plastic shelters.

Measurements of soil moisture deficit

The SMD was calculated at the beginning of each month between April and September from gravimetric measurements of soil moisture content using the method of Klute (1964). Weekly changes in SMD were calculated using the IMS model (Silsoe College, Beds, Uk and W S Atkins Agricultue, Cambridge) which were corrected with the monthly gravimetric measurements.

Calculation of relative growth rate ratios

To compare the effects of increasing SMD on growth, the relative growth rate (Blackman, 1919), of lateral extension and stem diameter were calculated for each treatment the values for the non-irrigated treatments were expressed as fractions of the relative growth rates of the controls (Burgess and Carr, 1997). These could then be compared to the corresponding values of SMD. To calculate relative growth rates, Gompertz growth curves (Smith *et al*,1990; Equation 3) were fitted to each set of mean growth data (lateral extension and increases in stem diameter) with time (R^2 values between 0.985 and 0.998).

$$\mathbf{i} = \mathbf{M}e^{-e^{-b(t-m)}} \qquad \text{(Equation 1)}$$

Where,

i = the incresed size (length or diameter),
M = the maximum total increase at the end of the growing season,
m = the number of days to maximal growth rate,
t = time
b = coefficient (the shape parameter).

From these curves the equation of relative growth rate (RGR) with time could be calculated since:

$$\mathbf{RGR} = \frac{1}{i}\frac{\partial i}{\partial t} \qquad \text{(Equation 2)}$$

Where,

i = the incresed size (length or diameter),
t = time

and therefore:

$$\mathbf{RGR} = \mathbf{b}e^{-b(t-m)} \qquad \text{(Equation 3)}$$

Where,

i = the incresed size (length or diameter),
m = the number of days to maximal growth rate,
t = time
b = the shape parameter.

Tree survey case study

Trees within a 0.5 km x 0.5 km area of north Chelmsford, UK previously described in Bellett-Travers et al (1999) were used as a case study. The extension of ten laterals, to the nearest 0.5 cm, were measured at the end of the 1997 (Bellett-Travers et al, 1999) and 1999 growing seasons. To take into account evapotranspiration as well as rainfall, comparison of the standard SMD to the average standard SMD from 30 year average weather data (Bellett-Travers et al, 1999) were used to show a year was 'wetter' or 'dryer' than average. Comparison showed that 1997 was a drier than average year (Bellett-Travers et al, 1999) and that 1999 was a wetter than average year (Writtle College, 1999). Using equation 4, lateral extension during the dry year (1997) was compared to lateral extension in the wet year (1999).

difference in lat. exten. = total lat. exten. 1999 - total lat. exten. 1997 (Equation 4)

In addition, to take into account the fact that overall growth may be reduced by stress the mean of lateral extension in 1997 and 1999 combined was calculated.

Results and Discussion

The RGR fractions were calculated for corresponding weekly values of SMD between upper and lower limits of measurable change in growth for each parameter. For example, lateral extension was measured to the nearest 0.5 cm, therefore, of the limits of RGR were taken to be 1 and 0.5 over the total extension, in cm, at the end of the growing season. The relationship between the change in relative growth rate fraction and SMD was significant ($p < 0.01$) for established *P. x hispanica* and accounted for around 50 % of the variance (Figure 1). This indicates that changes in SMD bring about proportional changes in the RGR of laterals. However, the relationship between the change in relative growth rate fraction and SMD was not significant ($p < 0.01$) for established *B. pendula* (Figure 1). This may be due to the low number of observations used in the model (n=6) and the moderate nature of the stress applied during growth (only up to -40 mm) Never the less, the low value of R^2 highlights the problems of interpreting changes in lateral extension from species that have flushes of growth early in the growing season.

The relationship between changes in the RGR of stem diameters and SMD were significant for both species ($p < 0.01$; Figure 2) but the level of significance was no greater than that of the relationship between RGR of laterals of *P. x hispanica* and SMD and the proportion of variance accounted for by the relationships were less. Therefore, lateral extension may be as good as or better than increases in stem diameter as an indicator of changes in physiological health of certain species. Since only two species have been used in this study, further research to investigate the growth responses of laterals of different species is necessary to confirm these findings.

Using lateral extension as the indicator of physiological health, the response of 66 trees to a wet year (1999) were compared to responses of the same trees to a dry year (1997) (Table 1). The Ordinance Survey Grid Reference and *Genus* of each tree is also stated to indicate relationships due to the spatial distribution or type of tree used.

Trees of the *Genus Tilia* and *Betula* were largely unaffected by differences in the climate between years shown by the high values of mean extension and the low differences in extension between years (Table 1). As already discussed, the lateral extension of *B. pendula* may not be a good indicator of the physiological status of this species. The *Tilia* sp. were all located in the same are an the local environment may encourage good growth even in dryer years. Trees within the grid references TL 705.4-706.1, 092.0-092.9, showed very low values of mean extension (below 5 cm). Within the same area, trees 16 and 21 had a reduction in lateral extension of over 30 cm and trees 15 and 19 died between 1997 and 1999. This indicates that trees within this area may be prone to water stress.

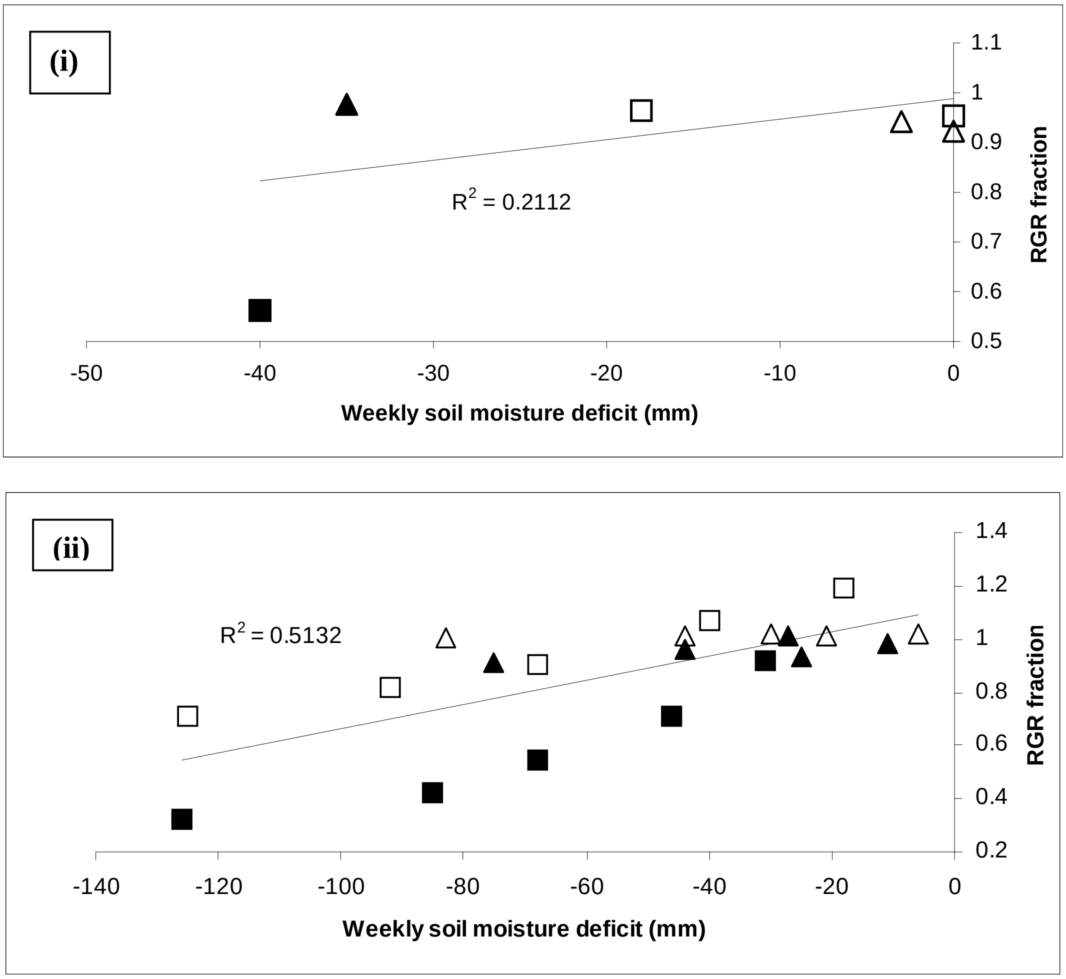

Figure 1: Relationship between the mean relative growth rate (RGR) fraction (RGR of treatment/RGR of control) of laterals and the weekly soil moisture deficit for established *B. pendula* (i) and *P. x hispanica* (ii) subjected to a no irrigation treatment △ and a no irrigation and reduced rainfall treatment □, during 1993 (open symbols) and 1994 (closed symbols). Lines represent fitted linear models n = 6 for established *B. pendula* and n = 20 for established *P. hispanica*.

Also of interest are those trees with large positive responses to drier years, i.e. negative differences in extension between 1999 and 1997. With some *Genus* such as *Betula* sp. (Tree No. 54) the response may be due to early growth before water stress is a significant factor in which case higher light intensities and warmer temperatures may encourage growth in 'drier' years (Larcher, 1995). With other trees this may be an indicator of severe stress caused by another factor as was the case with trees 10, 52 and 43, all of which had received considerable damage to the trunk.

The case study was set up in a relatively small area of Chelmsford (less than ** of the total area). Therefore, the area cannot be seen as a representative sample of the town as a whole. However, it was possible to identify trees that were adversely affected by drier years. In addition, it was apparent that *Genus* and landscaping were factors in the performance of the trees. Before measurements were taken in 1999, it was anticipated that the growth of the trees would be generally better than in 1997. This was not always the case. The mean total lateral extension of the trees was less than 10 cm in over 50 % of the trees. In comparison to results from larger studies (Hodge, 1991) this would be considered to be poor performance. While the case study would appear to show that the methods used indicated the tree's responses to differences in water availability, the study needs to be repeated and expanded to validate the methods used. The poor performance of the trees is of concern and indicates the danger they will be in if the climate becomes drier.

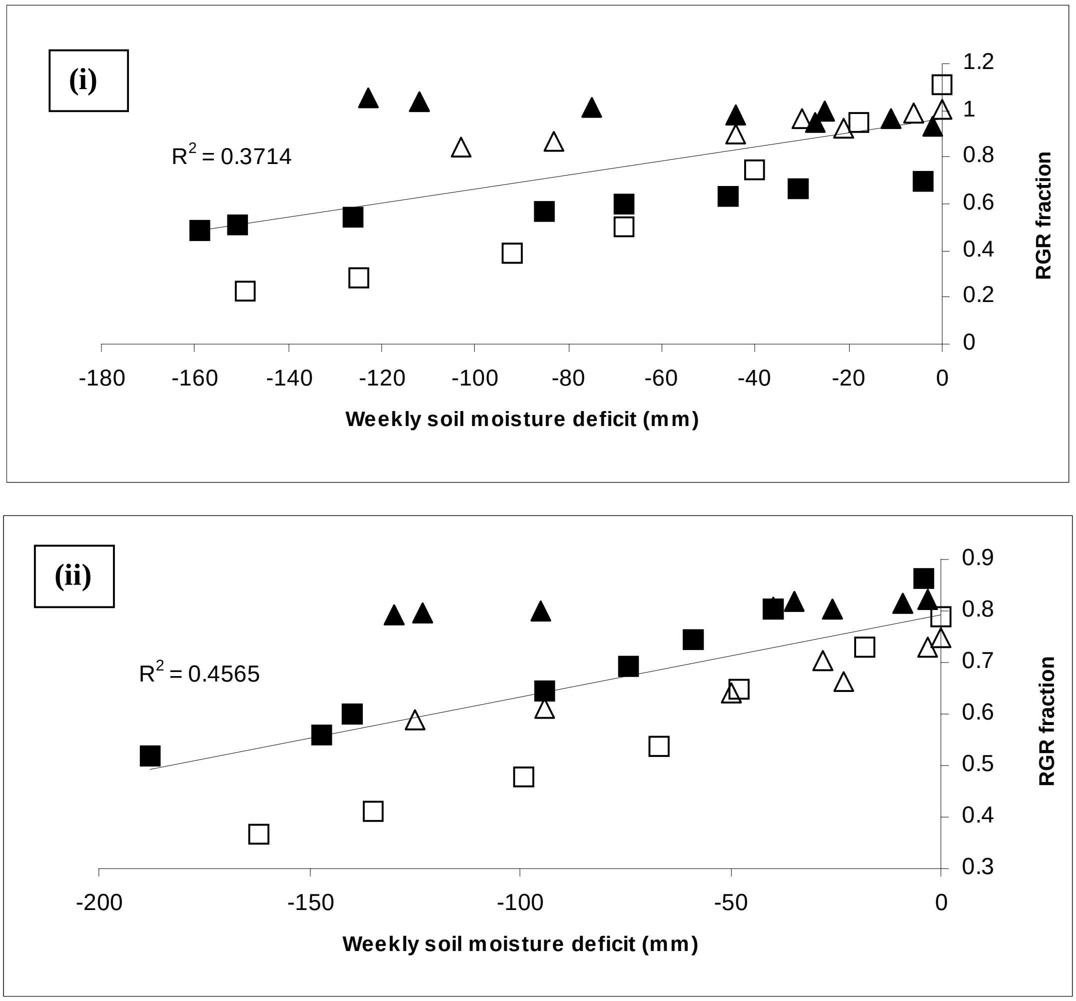

Figure 2: Relationship between the mean relative growth rate (RGR) fraction (RGR of treatment/RGR of control) of stems and the weekly soil moisture deficit for established *B. pendula* (i) and *P. x hispanica* (ii) subjected to a no irrigation treantment and a no irrigation and reduced rainfall treatment, during 1993 (open symbols) and 1994 (closed symbols). Lines represent fitted linear models n = 30.

Table 1: The extension fraction (mean total lateral extension in 1999-mean total lateral extension in 1997) and mean extension (mean of extension in 1997 and 1999). For 66 trees within a 0.5 km x 0.5 km square of Chelmsford in South East England.

Genus	Tree No	Grid ref.	Extension difference	Mean extension
Acer sp.	43	TL 705.19, 091.49	-21.0	11.5
Acer sp.	50	TL 705.36, 092.36	-5.0	19.5
Acer sp.	65	TL 704.63, 093.63	-5.5	10.8
Betula sp.	1	TL 706.03, 092.39	4.0	8.0
Betula sp.	53	TL 705.56, 092.99	-2.0	21.0
Betula sp.	54	TL 705.58, 093.13	-17.0	21.5
Betula sp.	55	TL 705.64, 093.44	1.5	18.3
Caprinus sp.	25	TL 705.53, 091.33	6.0	5.0
Caprinus sp.	26	TL 705.89, 091.21	9.5	9.3
Caprinus sp.	30	TL 707.26, 091.25	0.5	8.8
Caprinus sp.	41	TL 705.07, 090.73	5.0	8.5
Crataegus sp.	6	TL 705.79, 092.05	9.0	-1.5
Crataegus sp.	7	TL 705.62, 092.07	3.0	0.5

Genus	Tree No	Grid ref.	Extension difference	Mean extension
Crataegus sp.	8	TL 704.49, 092.32	12.0	4.0
Crataegus sp.	9	TL 705.47, 092.21	4.0	2.0
Crataegus sp.	10	TL 705.57, 092.17	-11.0	7.5
Crataegus sp.	11	TL 705.70, 092.15	14.0	2.0
Crataegus sp.	12	TL 705.95, 092.70	3.0	1.5
Crataegus sp.	13	TL 705.80, 092.72	4.5	-0.3
Crataegus sp.	14	TL 705.71, 092.74	3.0	0.5
Crataegus sp.	15	TL 705.64, 092.74	dead	dead
Crataegus sp.	17	TL 705.62, 092.85	9.0	-0.5
Crataegus sp.	18	TL 705.75, 092.82	8.5	-0.3
Crataegus sp.	19	TL 705.91, 092.80	dead	dead
Crateagus sp.	29	TL 706.70, 091.30	14.0	9.0
Crataegus sp.	57	TL 705.36, 093.18	1.5	8.3
Crataegus sp.	64	TL 704.67, 093.53	4.0	0.0
Fraxinus sp.	23	TL 705.53, 092.36	7.0	7.5
Laburnum sp.	21	TL 705.48, 092.41	33.0	10.5
Laburnum sp.	24	TL 705.46, 092.29	5.0	2.5
Malus sp.	27	TL 706.15, 091.31	26.0	5.0
Malus sp.	52	TL 705.47, 093.01	-16.0	12.0
Prunus sp.	2	TL 706.05, 092.46	6.0	17.0
Prunus sp.	3	TL 706.07, 092.54	-2.5	16.3
Prunus sp.	4	TL 706.00, 092.10	1.5	-0.3
Prunus sp.	5	TL 705.99, 092.00	12.0	5.0
Prunus sp.	16	TL 705.57, 092.76	30.5	11.8
Prunus sp.	20	TL 705.57, 092.58	8.5	21.8
Prunus sp.	22	TL 705.72, 092.56	-11.0	9.5
Prunus sp.	42	TL 705.22, 091.09	-7.5	4.8
Prunus sp.	44	TL 705.16, 092.24	3.0	7.5
Prunus sp.	45	TL 704.98, 092.27	-0.5	2.3
Prunus sp.	46	TL 704.86, 092.31	dead	dead
Prunus sp.	47	TL 704.60, 092.37	-3.0	3.5
Prunus sp.	48	TL 704.49, 092.32	-1.0	4.5
Prunus sp.	51	TL 705.41, 092.66	19.0	15.5
Prunus sp.	56	TL 705.38, 093.26	-1.5	13.8
Prunus sp.	59	TL 705.08, 093.37	-10.5	17.3
Prunus sp.	62	TL 704.77, 093.47	1.0	13.5
Prunus sp.	63	TL 704.77, 093.55	2.5	5.8
Pyrus sp.	28	TL 706.48, 091.35	-2.0	3.0
Sorbus sp.	58	TL 705.22, 093.31	28.0	-16.0
Sorbus sp.	60	TL 704.93, 093.38	-12.5	21.3
Sorbus sp.	61	TL 704.91, 093.46	7.0	-2.5
Tilia sp.	31	TL 707.99, 091.50	-7.0	11.5
Tilia sp.	32	TL 708.04, 091.71	0.0	12.0
Tilia sp.	33	TL 708.04, 091.75	2.0	14.0
Tilia sp.	34	TL 708.04, 091.79	-4.0	12.0
Tilia sp.	35	TL 708.05, 091.82	-6.0	12.0
Tilia sp.	36	TL 708.05, 091.85	-1.0	11.5
Tilia sp.	37	TL 708.05, 091.88	-4.0	10.0
Tilia sp.	38	TL 708.06, 091.90	-9.0	10.5
Tilia sp.	39	TL 708.06, 091.93	-2.0	11.0
Tilia sp.	40	TL 708.07, 091.95	-5.0	12.5
Tilia sp.	66	TL 708.31, 091.84	-2.0	16.0
Tilia sp.	67	TL 708.25, 091.92	3.0	19.5

Summary

Data is presented from a fully replicated field trial in which the lateral extension and increases in stem diameter of *B. pendula* Roth. and *P. x hispanica* Meunchh were compared to increasing soil moisture deficit. The relative growth rate (RGR) of laterals and stem diameters were calculated from Gompertz models of growth. When the RGR of treatments were expressed as a ratio of the RGR of controls it was shown that the regression of ratio to a fall in soil moisture deficit (SMD) was significant (p , 0.01) for the stems of both species and the laterals of *P.x hispanica*. The relationship was not significant for the regression of RGR ratio of laterals of *B. pendula* against SMD. Trees within a 0.5 km x 0.5 km square of Chelmsford, UK were used as a case study to investigate the effects of a drier climate on lateral extension. It was possible to identify trees that were adversely affected by drier years. It was also apparent that *Genus* and landscaping were factors in the performance of the trees. Of the 66 trees studied, 3 had died since 1997, and the mean total lateral extension of the trees was less than 10 cm in over 50 % of the trees. The case study indicated the tree's responses to differences in water availability could be measured with the methods used but the study needs to be repeated and expanded to validate it. The poor performance of the trees points to an increase in the amount of damage if the climate becomes drier.

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Structural analysis of long-term abiotic stresses in urban trees

Abstract

Damages to the root systems restrict shoot growth in the canopy by way of several interconnected stress-sensitive markers of branching in a typical and predictable manner. So start and succession of devitalisation can be reconstructed.

Problem

Urban trees have to adapt to heterogeneous and compound soils. Trees in urban areas steadily suffer from multiple destructive actions to their root growth. Their roots are exposed to permanent or brief soil compaction or construction work. Investigations in urban cultural engineering show that the 'soil airspace ratio' is the decisive limiting factor of root and tree growth (LIESECKE, 1997). On the assumption that root and branch growth are closely correlated (root-shoot-balance, cf. ROLOFF, 1989: 191 ff.), reduced branch and wood formation indicates deteriorated root growth. The paper is to detail the effect of these stresses on shoot growth in terms of structural analysis. Above ground shoot growth of trees results in a distinctive branching pattern ('phanerophytes'). Because all green shoots lignify for a certain period, one is able to trace the tree's growth history in analysing and comparing pattern formation of unharmed and stressed trees. Stress-modified branch formation is a perpetual 'window' for both actual and antecedent growth (i.e. 8-35 seasons in a particular species). The paper gives a short overview about fundamental characteristics of tree structure and its rules, and details on those criteria decisive for stress reaction by two species.

Material and methods

Research is based upon material of urban areas of the town Aachen as well as of near-by forest plantations. Samples were pre-selected from trees of same age group (mid adult) showing a different level of vitality by binoculars from ground level. Samples originated from the canopy where the optimum shoot formation is found without competition to neighbour trees. Material was collected with the help of an elevator truck or by climbing the tree using the double rope technique. The samples of a species were classified into four levels of vitality, i.e. growth activity, in accordance with the levels dealing with vitality by crown transparency: vit. 0 - unharmed, vit.1 - light, vit. 2 - medium and vit. 3 - severe growth depression (cf. ROLOFF, 1989, 1991). The basis of comparison is the unharmed pattern. 104 samples of 10 species were analysed: *Acer pseudoplatanus*, *Aesculus hippocastanum*, *Betula pendula*, *Carpinus betulus*, *Fagus sylvatica*, *Platanus x hybrida*, *Quercus robur*, *Q. petraea*, *Tilia cordata*, *T. platyphyllos*. In the present paper, the problem is shown by Linden and Beech, which also stand for a different model how to react on stress of the same kind (cf. GLEISSNER, 1998a for other examples).

ABC and basic grammars of structural analysis in woody plants

A first consistent concept of shoot growth and its effect on branch and crown formation was suggested by TROLL (1935) and RAUH (1939), also in visualising their ideas by profiles. HALLE et al. (1978) evaluated the influence of reproduction on the tree architecture, in addition. ROLOFF (1988, 1989) focussed on the effect of ageing on the crown formation and proposed branching structure as a tool of bio-indication as an alternative to 'crown transparency' assessment, which is suggested not to provide significant results due to a long-term study (SANASILVA-Bericht, 1997).

Plant structural analysis does not mean a mere listing of descriptive feature and measurements as axis length, leaf shape or size, bud form etc. This may be sufficient for systematic purposes. The profiles ought to be read rather as an algorithm or programme code than a drawing (cf. KURTH, 1999). Structural analysis records interconnected relations and gradients of morphological characteristics, which are, in addition, transform spatially and in time during crown development. So, structural analysis also deals with developmental dynamics.

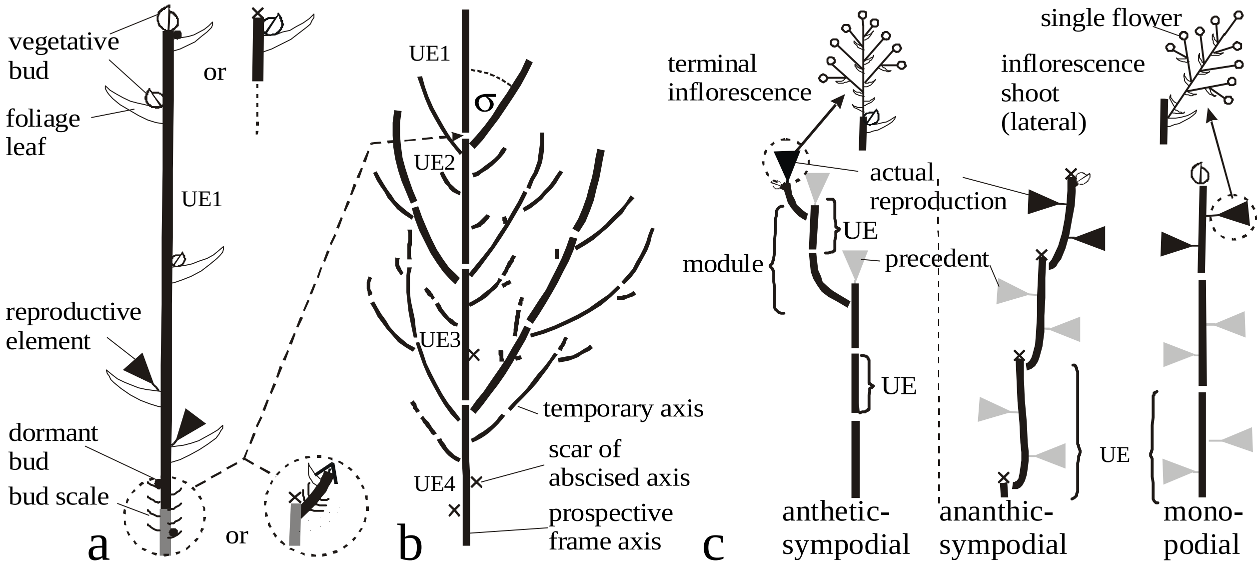

Fig. 1: Legend and basic shoot elements
a: unit of extension (UE) with a complex of seven characteristics (see Table 1A)
b: branch constructed by subsequent UEs; thin-lined temporary axis: extension and longevity depend on the origin on the mother unit; σ - serial branching angle
c: shoot chain models due to the position of both reproductive elements and vegetative buds

Basic expressions and interactions of shoot growth are viewed and analysed by three categories according to the trialectic concept (FROEBE and CLASSEN-BOCKHOFF, 1994): (A) organisational construction ('Bauplan'), i.e. the serial and lateral sequence of axes; (B) spatial arrangement, i.e. shoot orientation and strength within the three-dimensional crown, (C) growth dynamics, i.e. innately triggered differentiation in time or metamorphosis. Outer stresses can modify the inner arrangement and dynamics but not the organisational construction, which is stress-insensitive. The latter can be looked at different system levels: meristems, phyton (nodal - internodal), unit of extension, branch and crown. A short overview of structural criteria is given here (Table 1, see GLEISSNER, 1998a: 20 ff. for details). It is the basis for those facts decisive for growth shifts under the influence of abiotic stresses.

The 'unit of extension' (UE) is suggested to be the decisive increment of branch and crown formation. The UE covers an arrangement of seven gradients fixed to the same distinct shoot section (see Table 1A a. Fig. 1a for details; cf. HALLÉ et al., 1978: 30 f.). The annual shoot in younger trees often consists of 2 or 3 UEs, there is only one UE per season later on.

The branch is compound of subsequent units on the basis of distinct rules. An important one is the shoot chain: It determines in which position vegetative buds and reproductive elements as flowers or inflorescences are placed (Fig. 1c). Another important factor is the control of length extension within a UE and branch, called serial precedence. In the case of acrotony, distal shoots at the UE extend more in length than proximal ones. This fixation also decides on the further differentiation of a branchlet, simply depending on its origin along the UE of an upright leader axis (Fig. 1b, 2a, 3a). Also parameters of spatial formation and dynamics are involved in the determination of shoot length extension and reproductive ratio (cf. Table 1 B-C). Those which are sensitive for abiotic stresses are detailed now also explaining how to detect the start of the stress reaction.

Table 1: Structural, functional and dynamic categories and attributes of woody shoots.
● - new, ♦ - modified characteristics.

system level			parameter	manifestation
meristem differentiation			position primary:	apical / lateral (proventitious); intercalary / procambial
			secondary:	adventitious: phellem-born / cambium-born
			quality	vegetative / reproductive
			duration of intercalary activity	continuous to rhythmic unfolding [8]
			♦ interval between finished preformation and intercalary activity	none up to long interval according to ● preformation type P0, P1, P2, P3 [PHF table 13]
A Organisational construction	phyton nodal / internodal	lateral	leaf number per node	single / two or many
			leaf position	disperse (1/2, 2/5, 3/8 ...) / decussate or whorled [9]
			prophyll arrangement [10]	addorsed / transversal
			internodal extension	none / normal / extreme / infra-nodal
		serial	leaf formation	scale leaf (bud scale) / foliage leaf / bract
			● quantitative bud potential	none /dormant bud [5] / fully developed bud with catalepsy [6] / lateral shoot with syllepsy [7] / terminal bud; accessory bud /prophyll bud
			qualitative bud potential	vegetative / reproductive (flower /inflorescence)
	♦ unit of extension (Fig. 1)		curve of internodes	sinusoid / sigmoid
			heterophylly	transition mode between scale leaf - foliage leaf
			● serial gradient of lateral bud activity	conjunct / disjunct / long-shoot-short-shoot-dimorphism
			♦ serial precedence	acrotonic / mesotonic / basitonic; ● subacrotonic / ● pattern interference
			pattern of qualitative differentiation	position of reproduction: terminal / lateral (distal / medial / proximal)
			pattern of branch abscission (see D)	positively correlated to precedence
			pattern of reiteration	negatively correlated to precedence
	association of units 'branch'		● qualitative shoot differentiation	homonomy / vegetative shoot + ♦ inflorescence shoot (Fig. 1)
			♦ shoot chain (Fig. 1c)	monopodial / ● ananthic-sympodial / ● anthetic-sympodial
			number of renewing shoots	monochasial /dichasial /pleiochasial [11]
			● reproductive element arrangement [3]	competition for the apex /'mixed' type 1-3 /occupying vacant positions /competition with repeating shoots /double /respectively multiple use of axils by accessory and prophyll shoots /alternation of reproductive and non-reproductive units / insertion of an additional reproductive section
B Spatial arrangement	serial symmetry [PHF fig. 6]		♦ serial branching angle σ (Fig. 1b)	UE gradient / light reaction / leader competition
			shoot bending during unfolding	straight / concave / convex / zigzag-formed
			shoot bending by reaction wood [2]	item
			shoot orientation to the vertical	orthotropic / plagiotropic / hanging
	lateral symmetry [PHF fig. 7], [12]		● lateral branching angle λ	adjustment to gravity / light
			● spatial orientation of orthostichies	adjustment to gravity
			● bud shift out of the leaf median line	adjustment to gravity / light
			internodal torsion by torsion angle ε [13]	primary: during preformation [1] / during unfolding
			local torsion	secondary: torsion wood [4] at the UE base or top
			spatial-dependent leaf formation [14]	anisophylly
			lateral precedence (anisoclady)	hypotonic / epitonic / amphitonic / 'clinotonic' [15]
			♦ spatial-sensitive flower formation	sensitive / non-sensitive
	trunk formation		leader shoot formation	monoaxial / polyaxial
			orientation of leader shoots	orthotropic / plagiotropic
C Growth dynamics	♦ ageing trends in leader shoots [PHF fig. 44]		multiple UE unfolding	lamma shoot / ● UE repetition / syllepsy
			● interference of unfolding patterns	syllepsy [7] / catalepsy [6] / opsigony [5]
			decrease of length extension	● decrease of internode length / ● decrease of foliaged leaf number
			● decrease of serial precedence	● decreasing bud inhibition / ● decreasing number of foliage leaf node / ● displacement by inflorescence shoots
			branch abscission	intervening tissues / mechanical / ● excessive reproduction
			reiterative capacity	tentative up to strong; ● R_{ZERO} / R_{PER} / R_{TRUNK} / R_{BAS} [PHF fig. 47]
			mode of reiteration	traumatic (cp. Fig. 2) / ● senescent
	● subor-dinate shoots		internode length reduction	
			♦ decrease of serial precedence	
			♦ shortened longevity	
			internodal thickening	increase / decrease comparing a leader shoot

Annotations: [PHF fig...] relates to figures in GLEISSNER, 1998a; [1] BELL, 1991; [2] FISHER and STEVENSON, 1981; LYR and CASPERSON, 1992: 387 ff.; MATTHECK et al., 1994; [3] GLEISSNER, 1999: fig. 5; [4] MATTHECK et al., 1994; [5] with 'opsigony' sensu MÜLLER-DOBLIES et al., 1984: 146; [6] l.c. 133; [7] l.c. 128; [8] 'indeterminate' and 'determinate' growth, ROLOFF, 1989: 22; *Populus* and *Quercus* type: LYR & HOFFMAN, 1992: 398 ff.; [9] TROLL, 1935: 97 ff.; [10] l.c. 333; [11] l.c. 617 ff.; [12] l.c. 16 f.; [13] l.c. 219, 387; [14] l.c. 387 ff.; [15] l.c. 17, 306 alternately one side is strengthened

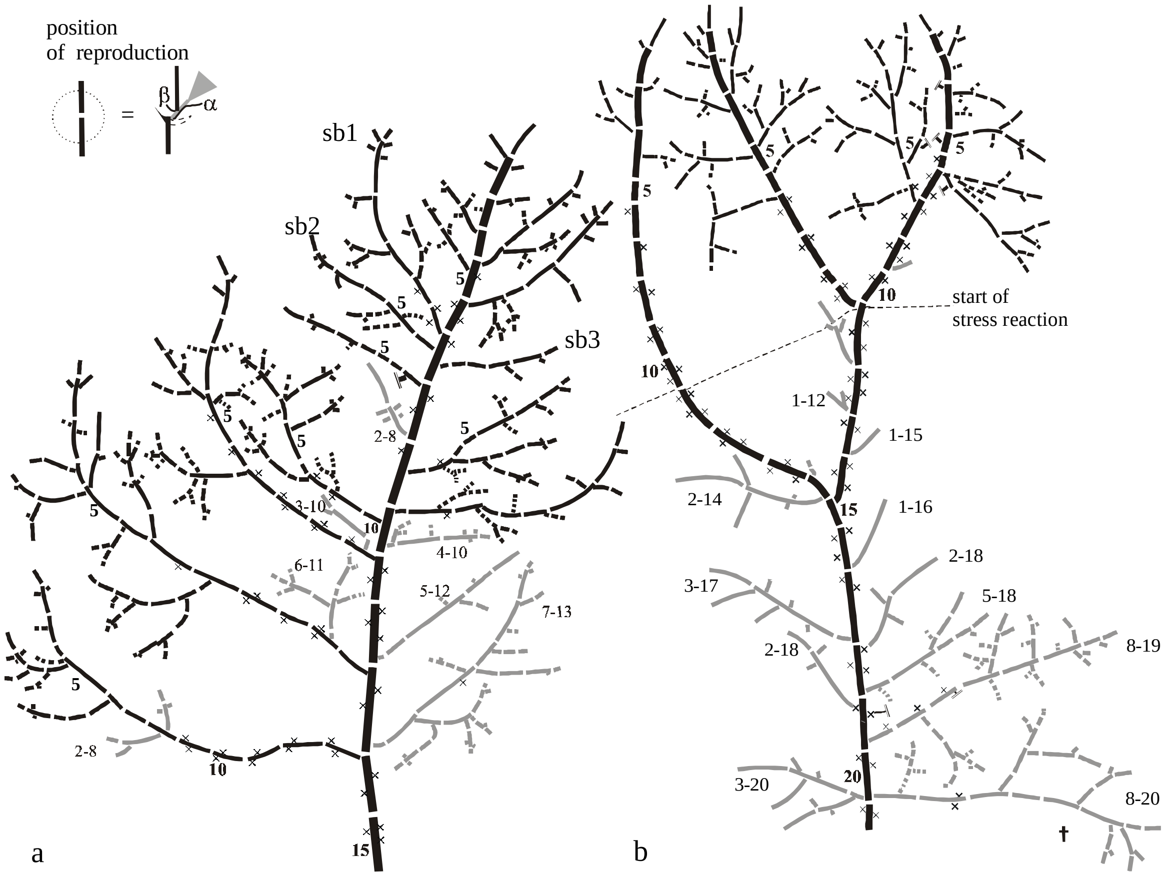

Fig. 2: Great-leaved Linden. Comparison of unstressed pattern and light stress reaction. Orthotropic canopy leaders (80 y.) depicted to same scale
a: vit. 0: monoaxial frame branches with 'acrotony' and intersected reproduction (see detail); orthotropic reiterations develop from older branch sections; sb1-3 - multi-seasonal differentiation of 1st-order branchlets due to their position on the leader UE.
b: vit. 1: premature abscission of 1st-order branches; stress-induced reiterations develop with plagiotropic orientation; e.g. 8-20 stands for its origin at UE20 8 seasons ago

Examples of different stress reaction

Great-leaved Linden (*Tilia platyphyllos* Scop.)

Orthotropic as well as plagiotropic frame branches have a planar arrangement of its 1st-order axes. This is due to both the distichy and position of the inflorescences. The leader shoots are mostly monoaxial although the shoot chain is sympodial. The 1st-order axes diverge at the branching angle of 70-90° and shed step by step from 3 to 14 seasons due to separation tissues (BÖHLMANN, 1971). Shoot longevity correlates with acrotony (Fig. 2a). Shedding is finished after 14-15 seasons, and this gives a marked transition zone between fine-twigged peripheral layers and the inner crown framework. Few but vigorous orthotropic shoots can arise here from dormant buds and fill up small gaps in the hemline. Because they re-capitulate the pattern of vegetative phase they are called reiteration shoots. When the crown is fully extended in size at the age of 120-140 y. and start collapsing, these reiterations will be decisive for the secondary crown formation, and prolong the longevity of the Linden.

In the case of damage to the roots the reiterations are a very good marker of growth depression. Then a manifold of them evolve from older frame branches having plagiotropic orientation. But why they are so many? The primary peripheral layer is 'thinned out' as its older 1st-order axes shed prematurely. This loss of branchlets also reduces the optimum assimilation area. It is no loss of leaves as the term 'transparency' could suggest, the leaves never have been produced. Many reiterations together establish a secondary mono-layer hemline below the primary one. In the shade of the latter, the reiterations have to grow plagiotropically. They started 8 seasons ago, this is detected by the total age of the oldest reiterations (8-20 in Fig. 2b). Nearly all of them arose from shoot sections grown before damaging happened. Also the length extension of leader shoots is affected from UE 10. So the stress reaction started about 10 seasons ago here. Then compensatory shoots in form of reiteration started two seasons later. Length reduction in Linden is not so marked with vit. 1. Its effect is more important with vit. 2 and vit.3. Then even the distal branches are shed prematurely, leader shoots bend concavely, and also reiterations are retardant. In the given example roots sustain lasting damage by soil compaction about 11 seasons ago.

European Beech *(Fagus sylvatica L.)*

As in Linden, its branches are of planar construction as the leaf arrangement is distichous. The leaders are built monoaxial because a prominent vegetative bud provides the terminal continuation. It is the same for the typical short-shoots arising from the distal UE section (cf. UE 3-4 in Fig. 3a). As already explained by Fig. 1b, the acrotonic precedence and the meristem position is decisive for whether a long-shoot or a short-shoot is developed in subsequent seasons. The acyclic emergence of reproduction is another reason for reducing the UE extension in adult state. Being in non-reproductive state next season, the UE again is prolonged and has a higher branching ratio. In the case of reproduction the vegetative buds have to compete with lateral reproductive elements. This is expressed in mid adult 1st-order shoots and in the senescent leader shoot (Fig. 1a a. d; ageing trends cp. GLEISSNER, 1999b; LÜSCHER, 1990). As a brief conclusion, subordinate shoot sections in mid adult age anticipate the branching of leader shoots in senescent age. Reiteration is very rare in unharmed trees.

As to the effect of stresses on shoot growth in Beech, the principal syndrome has already been investigated in particular by ROLOFF (1988, 1991): In addition, the present paper focuses on how to detect the start of stress reaction and on the difference to intact senescent trees.

With vit. 1, lateral shoots develop as short shoots. They do not shed prematurely as it is in Linden but reduce their extension. The start of stress reaction is detected by the change of precedence (Fig. 3b). The leaders, however, do not suffer essentially from the length reduction. With vit. 2, even the leaders grow reduced by length and lateral branching, and bend downwards (Fig. 3c). Claw-shaped short-shoots (also S-shaped with vit. 3) remember the short shoots suffering from extreme shade at the lowest crown sections of an unharmed tree. However, in the canopy there is no lack of light. Stress-induced reiteration is missing. Instead of it few short shoots in upward position can re-differentiate to a long shoot; if they increase in number that could be a marker of regeneration. Within a particular canopy branch, the growth collapse of distal branch sections is evident in comparison with the still non-stressed proximal section (UE 9-10 in Fig. 3 b a. c).

A senescent tree (Fig. 3d) not exposed to outer stresses has a high ratio of reproduction, its UE length varies with reproductive state. So it is not with devitalised trees of younger age. A growth depression by outer stresses does not only slow down the length extension but also reproduction at the same time. The last statement is still based on a qualitative analysis of a few samples (cp. Table 2). It is a general trend in temperate species to increase the reproductive ratio during ageing. The vegetative growth rate of senescent canopies is very low in favour of strong flowering (GLEISSNER, 1998a, 1998b, 1999b). This successful senescent phase is to differ from the latest period of decay, when the crown as a whole starts to collapse (SMIRNOVA et al., in print).

Table 2: *Fagus sylvatica*. Particular specimen data showing the length reduction and numbers of working buds. L_{10} – average UE length of the latest 10 seasons, $repB_n$ – number of buds in reproductive state during the latest n seasons, $vegB_n$ – number of buds in vegetative state.

	early adult phase 45 J.	senescent phase 240 J	vit. 1	vit. 2	vit. 3
L_{10} (cm)	33.5	10-12	7.7	3.1-3.4	<2
$vegB_5$ ($vegB_{10}$)	42	0 (16)	8-28 (42)	3 ($vegB_8$: 6-8)	1 (2-7)
$repB_5$ ($vegB_{10}$)	210	11 (95)	5-22 (27)	0 ($vegB_8$: 1-2)	0 (0)
ΣB_5 (ΣB_{10})	252	11 (111)	11-40 (69)	3 ($vegB_8$:7-10)	1 (2-7)

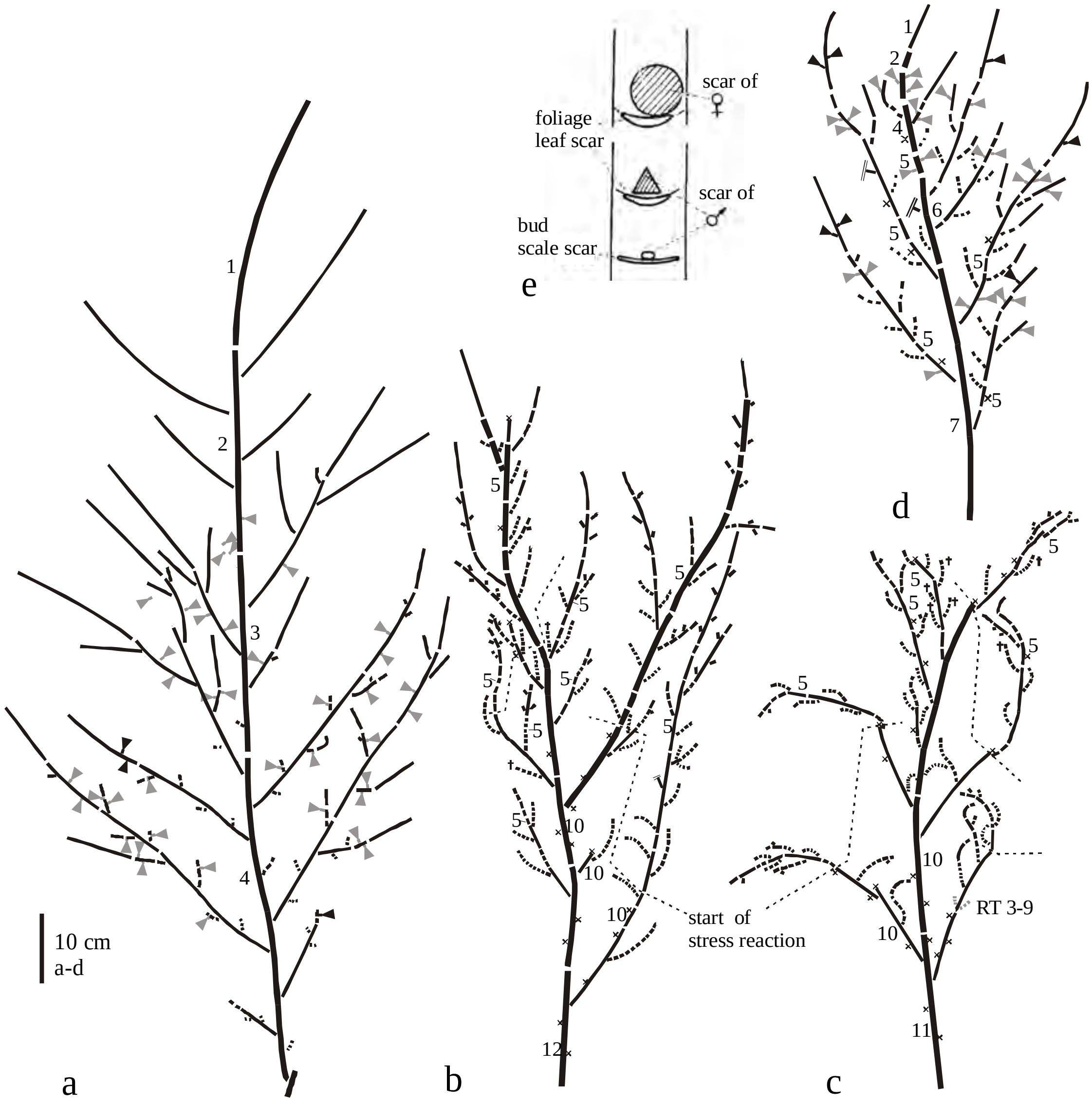

Fig. 3: European Beech. Comparison of unstressed pattern and light and medium stress reaction. Canopy leaders depicted to same scale. Alternation of reproductive (female) and a non-reproductive seasons shown in (a) a. (d).
a: vit. 0 (90 y.): mid adult phase
b: vit. 1 (150 y.): all lateral shoots develop as short shoots after start of stress reaction
c: vit. 2 (100 y.): the leaders also show a distinct reduction in length and lateral branching and bend downwards; claw-shaped short-shoots
d: vit. 0 (240 y.): senescent phase with high reproductive ratio and varying UE length
e: scars of male and female inflorescence shoots help to reconstruct the reproductive ratio

Conclusion

The base of comparison is the shoot increment 'unit of extension'. It enables to explain the modifications of shoot characteristics or gradients by abiotic stresses as follows:

- UE length (ROLOFF, 1989, 1991) by variation of the internode length and number of foliage leaf nodes; the current number of foliage leaves and the related total leaf surface per UE depend on that. A persistent length decrease nearly always indicates the start of stress reaction.
- number and ratio of vegetative, reproductive and dormant buds per UE (including flowering ratio = ΣvegB / ΣrepB)
- number of vegetative buds per 5- or 10-seasoned branch section (vegB5, vegB10)

- serial precedence (mode of lateral branching per UE)
- plagiotropic concave bending of the leader shoots
- emergence of reiteration shoots (unfolding from dormant buds at bud scale sections): Their current age, strength and branching ratio and their upright orientation enable to trace to the start of the stress reaction; when growing more vigorous again, they can indicate regeneration
- branch abscission ratio
- shoot unfolding dynamics: lack of lamma shoots or sylleptic unfolding depending on the developmental phase

This list presents a maximum of stress markers. Normally a selection of them occur in a particular species, which can be seen at best in light state of stress. This is why, four models of stress reaction are differentiated beyond the investigated species (Fig. 4). With severe stress other markers can occur in addition.

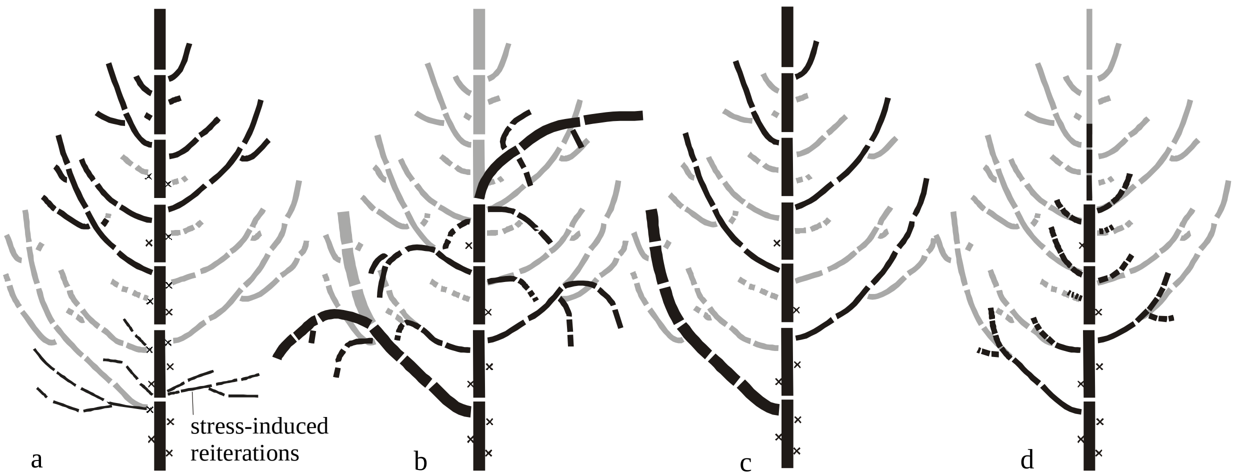

Fig. 4: Different mode of stress reaction detectable at light state of vitality
Schematised pattern, potential branching depicted as grey lines
a: *Tilia* type: premature branch abscission and reiterations compensate for it (*Acer pseudoplatanus*, *Platanus* x *hybrida*, *Quercus petraea*, *Q. robur*, *Tilia* spp.)
b: *Betula* type: dysfunction of reaction wood, reduced leader shoot formation due to the plagiotropic orientation (also Carpinus betulus)
c: *Aesculus* type: less branching from the very beginning due to a selective bud inhibition

<u>Applications and perspectives</u>

Resulting applications and recommendations for urban forestry and silviculture are:

- practical tool of tree control from the ground and quick assessment in using binoculars (GLEISSNER, 1995, 1999a; ROLOFF, 1989, 1991)
- reconstruction of the growth history in detail in analysing canopy samples for the purposes of forest dieback control or research and reports on particular trees: from 8 seasons in *Platanus* up to 35 seasons in *Acer*, *Aesculus* or *Fagus* (GLEISSNER, 1998a; ROLOFF, 1988)
- sensitisation for damaging treatments at the tree location and their effect on root and shoot growth
- preventive: modification of the planning taking particularly the tree location into account or modification of not avoidable construction work
- assessment of amelioration treatments in urban forestry

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Session 4 – Procedures for diagnosis and monitoring

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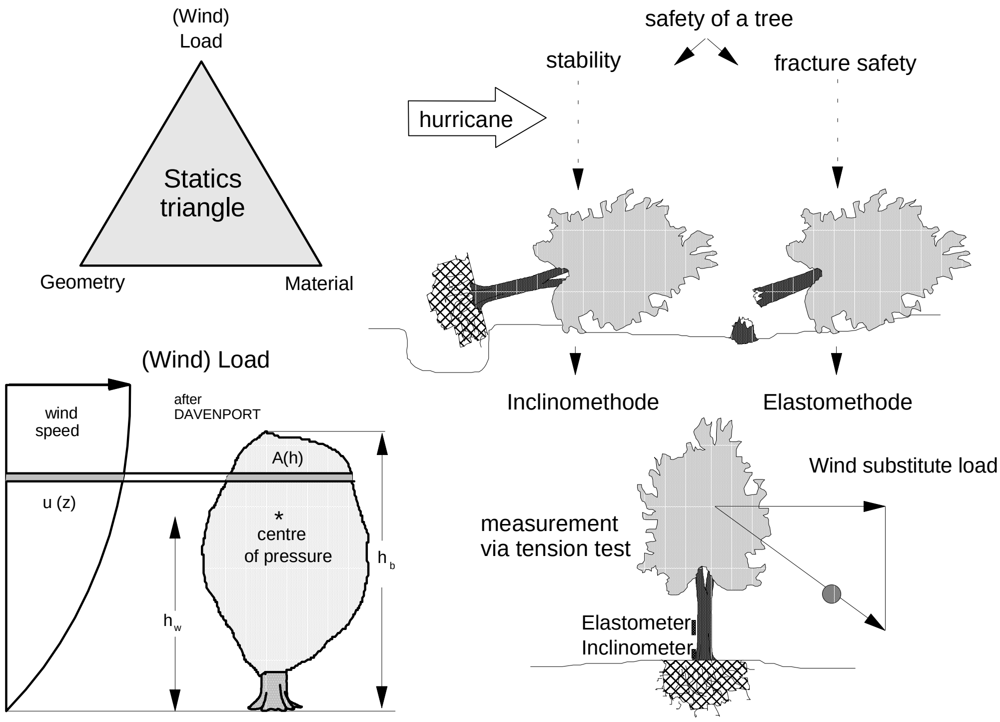
State-of-the-art examination methods for the stability of trees

A variety of the equipment to examine the stability of trees is restricted to consider but selective information. Using these data, it is very difficult to obtain analyzable of even quantitative results about a tree's safety. Therefore, I want to focus on statics-integrated methods. These examination methods were developed in Germany and comprise, until now, the experience of over 4,000 static reports.

Two different kinds of tree failures are basically distinguished: a tree may break or the whole tree may be thrown over. Failures occur when either the load is too heavy for a certain structure or the structure fails under a certain load. Such a setting of a task would normally be solved by engineers, so why not also use a similar method when dealing with natural constructions like trees.



Thus, it is a logical conclusion to apply commonly used international methods of statics and dynamics for assessing trees and their safety: this means that the load capability of the individual structure (tree) consisting of its specific material and its stressed cross-sections is to be established. By this the relationship of balance is determined using the so-called triangle of statics.

Working out this mathematical relationship, the aspect is quite helpful that a tree is as unilaterally stressed bending carrier a statistically simple structure in all its parts. Another advantage which simplifies the analysis of the fracture safety is that with bent structures the most stressed part is located on the surface. Here the representative outer fibers are found whether there are cavities caused by fungi or not. Therefore, the bending of these outer fibers is measured by exposing the top of the tree to a substituting load (simulation of wind). When the maximum elastic bending capability for green wood of a tree species is known The weakest cross-section can be found by measurements with a low load level harmless to the tree. Using the weakest cross-section, the critical load (when the tree will break) can be predicted. The developed measuring instrument is called "Elastometer". Its two metal points are pushed into the bark and measure the bending of the woodfibers underneath it. Is the "breaking load" now known the maximum load a tree can endure during a hurricane can be determined.

For this, we follow the rules to assess loads on buildings caused by wind currents close to the ground. In Germany, these rules are described in DIN 1055 and DIN 1056. For our purpose, we have further developed these approaches by taking the dynamic of a tree into account. Moreover, we have even carried out wind measurements in order to establish the air resistance coefficient of different green trees.

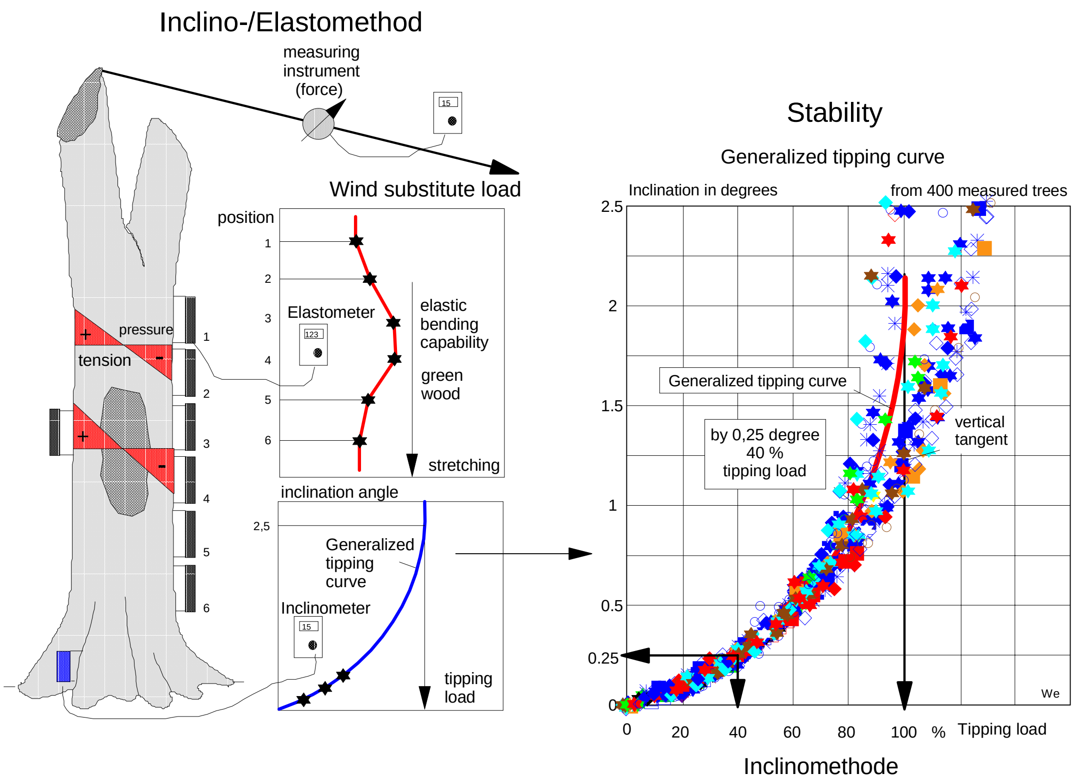
Meanwhile, we have drawn up more than 4,000 static reports and all of them have proved to be correct without exception. That applies to the trees certified safe as well as for those we found to be not safe anymore.

The devastating hurricane "Lothar" on December 26, 1999 subjected all our assessed trees to a real hard examination. And this practical test confirmed our work. All our "safe" trees are still standing, and the 10 trees which failed during the hurricane were all certified unsafe and have neither been supported nor cut down so far.

Easy access to a tree's stem enabled the development of this measuring method to assess the fracture safety. This does not apply to the roots. A known fact is that a weak anchoring can be determined by a higher pliability. Thus, we fixed a so-called "Inclinometer" on the stem just above the ground to determine the angle of inclination when a tree is exposed to a pulling load. With trees collapsed in experiments, the pulling load was found to be increased only by an inclination angle of 2-3 degrees independent of species or ground conditions. Thereafter the load remains constant and then decreases again until the total failure occurs. The comparison of the collapsing curves of hundreds of trees showed a strong similarity. This enabled us to establish a "general tipping curve" to predict the maximum collapsing load. By this we can determine the collapsing load at low inclinations below 0.25 degrees without harming the trees.

By comparison of the artificial pulling loads with the loads prevailing during a hurricane the stability (coefficient of the standing safety) can be established in an analyzable and quantitative way within the same process as the breaking safety. We have called this method the "Inclinomethode".

The combination of both methods, "Elastomethode" and "Inclinomethode" is superior to all other methods so far.



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Standing tree quality assessments using Acousto Ultrasonic

Introduction

Wood as a natural raw material is becoming more and more important in our society, facing both environmental constraints issued from the use of fossil energy and new needs of raw material linked to the present demographic evolution. Wood is produced by trees, which are organic vegetal elements forming an important link in the carbon turn-over cycle. In the forest, they are part of the eco-system; in the cities, they take single roles in ecological and decorative functions.

The maintenance of the cultivated forest in the developed countries, or the protection of the forests in developing countries need a financial support obtained by the valorization of the forest products through an industry of wood transformation. To help in this general scheme, quality assessments of standing trees may be considered to have two different targets: biological internal quality related to wood degradability and elastic quality of the heart-wood regarding the industrial valorization of the wood products, especially in timber construction.

Wood quality measurements using NDE applied to standing trees are related in this paper, where the NDT method chosen is the ultrasonic stress wave method, already used as a grading method for sawn timber [1].

Physical singularity detection on standing trees

A tree, as an organic vegetal system, is always in competition with wood destroying fungi, which are active in the tree in function of both its age and vitality. The first stage of the parasite's development is often a coloration of the grain, giving successively decay, cavity and failure of the tree, with a pathogen systematic adapted to each species. In this paper, NDE have been focused on spruce soft rot decay, beech red heart, and on several ornamental specie internal singularities.

Until recently, there were only few reports about NDE of physical statements of standing trees. The only investigation method was the bore method, allowing a direct optical diagnosis of the internal wood quality. But this method is definitely not non-destructive. Decays correlated to moisture content have been a first approach with the works of Shigo [2], extended by Kucera [3], and at the origin of the Vitamat device. The principle of this technique is to measure the electric resistivity of wood by using two needles as electrodes, set up progressively through the tree diameter in order to record the conductivity profile. Decayed wood containing high moisture content will show high conductivity in comparison with undamaged wood.

Another method deduced from the initial boring system is the resistograph technique [4, 5]. This method, based on density, measures the drill resistance of a small drilling needle (from 1.5 mm to 3 mm in diameter, and an average length of 400 mm). The resistance is measured, stored and graphically displayed. The recorded variable is very well correlated with wood density. Then, by visual or computing drilling profile analysis, the internal statement of the tree can be postulated. Even though the method requires the piercing of the material, it was accepted as a NDT, given the extreme fineness of the needle.

Both conductivity and density based methods are very efficient, but quite time consuming to perform the diagnosis. Because foresters and wood industrials need techniques to get more information about the wood quality in standing trees on large scales, the ultrasonic method has been regarded for applications in radial axis measurements - to detect internal singularities - and in longitudinal axis measurements - to give data about wood fiber quality.

Ultrasonic method applied to standing trees

In a first feasibility study on singularity detection on standing trees using ultrasound [6], important decays have been observed on a sample of spruce trees. In fact, based on eq. [1], where the speed of ultrasound, V, is expressed in function of the modulus of elasticity of the radial axis, E_R, and the density, ρ, it can be assumed that the ratio E_R/ρ is roughly constant for healthy wood.

$$V^2 = E_R/\rho \qquad [1]$$

Actually, the variability of E_R is very low with reference to the variability of E_L (longitudinal modulus of elasticity). Furthermore, it dependents more on the density than E_L does. This way, at constant temperature and moisture content, the speed of ultrasound, V, can be regarded as constant for a healthy species.

Because biological degradation resulting from wood-destroying fungi action is associated to the reduction of elastic properties, damaged wood will affect the ultrasound propagation speed, and, in extreme cases, will force the wave to find another way, like it is shown on figure 1.

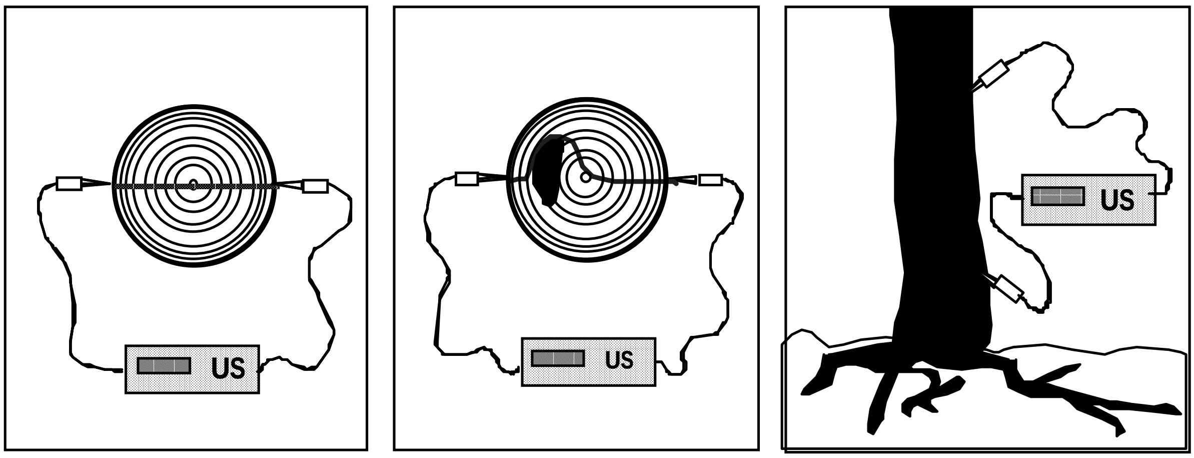

Figure 1.a Figure 1.b Figure 1.c

Figure 1: Scheme of ultrasonic wave propagation on the radial axis of a) healthy tree and b) damaged tree; c) longitudinal measurements

From a NDE point of view, the decay propagation can be expressed using eq. [2]

$$T_x = \frac{V_r - V_m}{V_r} 100 \ [\%] \qquad [2]$$

T_x : degradation ratio [%]
V_r : referential speed calibrated for the species [m/s]
V_m : measured speed [m/s]

Concerning wood quality grading on standing trees, visual inspection is the common rule. The implications are numerous, specially in terms of valorization of the forest products, because final grading and quality identification are done at the last transformation step. Initial grading at the first step (i.e. in the forest) as quality index attributed to forest places could be very helpful for the forest management.

Ultrasonic grading applied to logs has shown very interesting results [7], and figure 2 shows the relationship between the speed of ultrasound measured on logs and MoR, the modulus of rupture in bending of sawn timber coming from the logs. Based on the efficiency of the NDE applied to logs, it was postulated that NDE, in view of first step grading, could be applied to standing trees. The longitudinal ultrasonic test applied to standing trees is shown in figure 1, c.

Ultrasonic measurements and tree sampling

The sample of trees was collected in several geographic areas of Switzerland, and at different altitudes, from 400 m to 1300 m. Spruce as softwood representing, and both oak and beech, as hardwood specimen, were sampled.

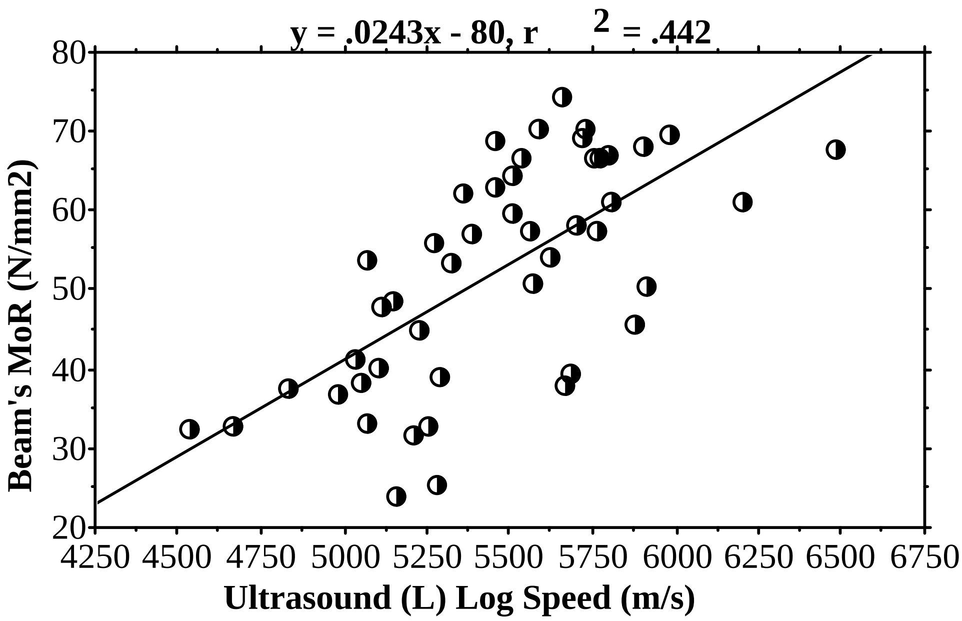

Figure 2: Relationship between ultrasonic speed recorded on logs versus MoR (modulus of rupture) of sawn beams cut in spruce log

Radial ultrasonic measurements were performed using Sylvatest®, a new ultrasonic grading instrument, on each tree, at 30 cm over the soil. Two orthogonal axis of measurement were selected in relation to topographic soil characteristics. Tree diameters have been measured accurately, using a millimeter compass, and the degradation ratio observed after cutting down the tree was quantified on both measured axes.

The numerical characteristics of the sample were:

Spruce	n = 180	20 < ø < 140 cm	400 < Altitude < 1300 m
Oak	n = 50	32 < ø < 102 cm	400 < Altitude < 700 m
Beech	n = 80	32 < ø < 96 cm	400 < Altitude < 800 m

Longitudinal ultrasonic measurements have been done on 12 spruce trees. After harvest, ultrasonic measurements were done on logs, in the sawmill. Sawn timber beams were sampled, and tested in the laboratory in four-point bending, at constant and standard conditions of temperature and moisture content. Ultrasound data were collected on the beams before the destructive static tests.

<u>Longitudinal measurements</u>

The ultrasonic longitudinal research applied to standing trees is quite difficult to support, regarding the needed collaboration with both foresters and sawmillers. In this feasibility study, only one forest area was considered for the sampling, and only 12 trees were followed from forest to sawn products. Therefore, the results can be translated only as a tendency, which should be extended when based on a sample of several forest origins and taking into account the different growth condition effects.

These first results combining ultrasonic data measures on living trees and both mechanical and physical properties of timber beams sawed in the trees, show significant relationship, allowing to postulate an NDE quality concept. An example of correlation is given in figure 3, showing the relationship between the speed of ultrasound measured on the tree and the density of the sampled beam.

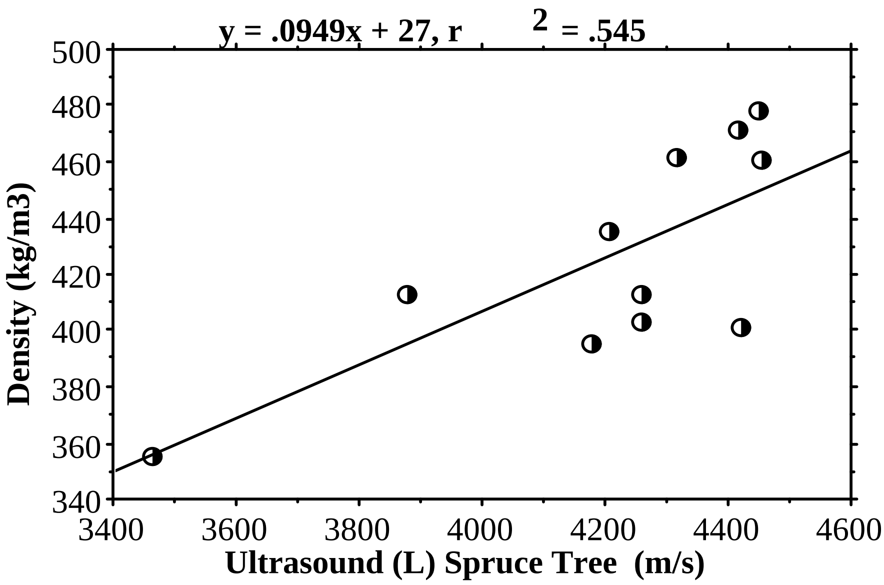

Figure 3: Speed of ultrasound measured on spruce standing trees and average density of the contained wood products

Decay detection on standing spruce trees

Using the two ultrasonic radial measurements as NDE parameters to estimate the ratio of decay, computed as mentioned in eq. [2], the correlation coefficient between evaluated decay and observed decay is r = 0.755.

After controlling some dispersed points, it appeared that some trees with red coloration (heart) have been declared visually decayed, but were not degraded in terms of density. Then, it has been considered to filter the data in order to purge both visual appreciation error and ultrasonic acquisition incertitudes on data. Taking out the 10% of the more dispersed points, the correlation coefficient is climbing to r = 82, as it can be observed on figure 4. It can be mentioned that a sample based on more degraded wood will increase significantly the correlation level. Actually, the analyzed sample was representing production forest wood. The result is biased because of a large part of healthy wood.

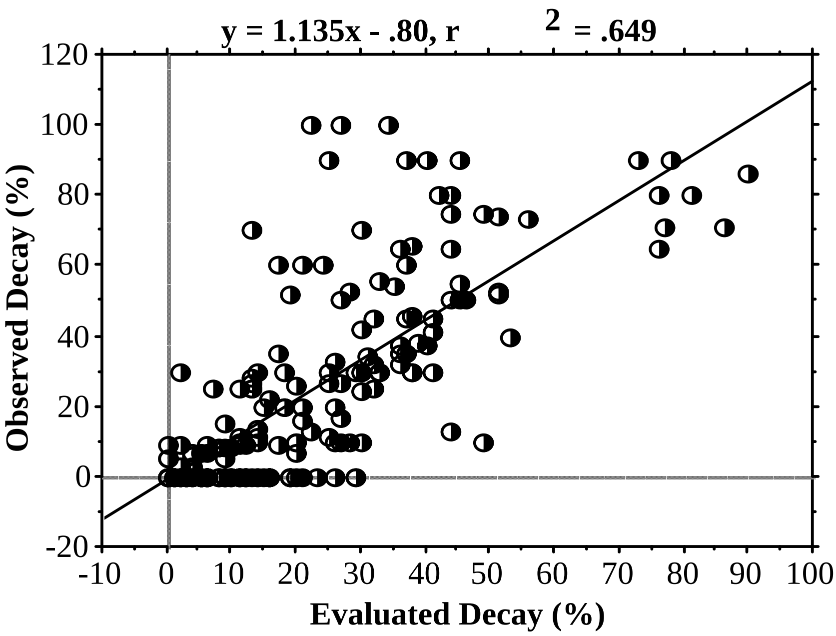

Figure 4: Relationship between decay NDE, using radial US data and the ratio of observed wood decay or wood coloration on spruce trees

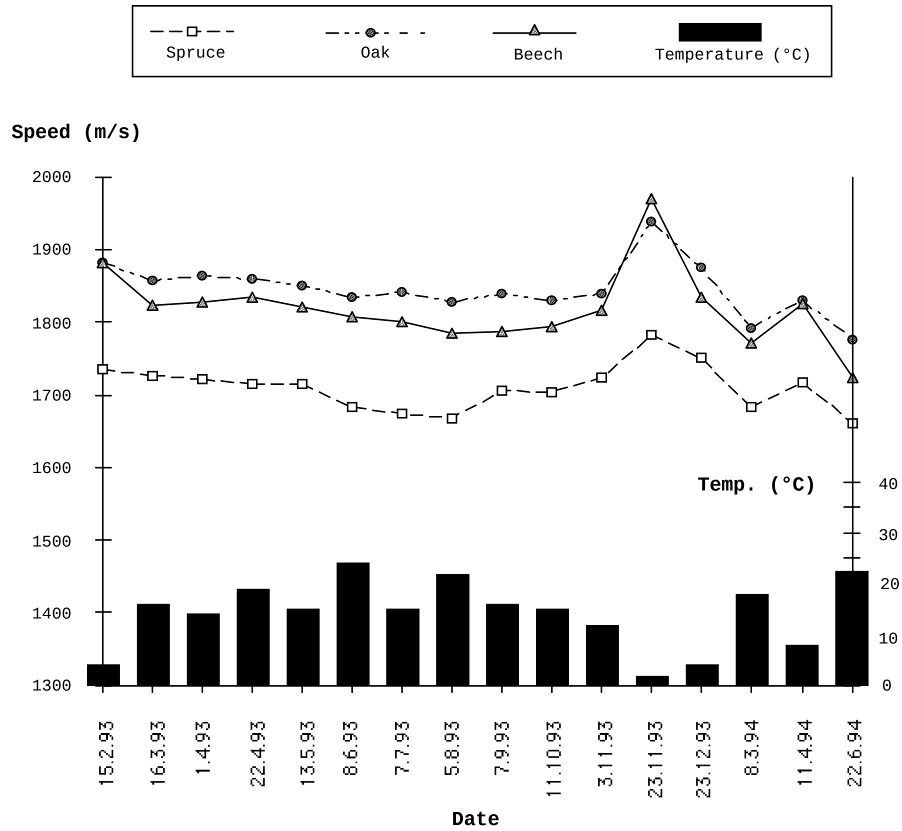

Figure 5: Season effect on the radial ultrasonic measurements recorded on standing trees

<u>Season effect</u>

Because ultrasonic properties in wood are very sensitive to moisture content and temperature [7], it has been postulated that radial measurements applied to standing trees could be affected by seasons. Thus, a sample of trees has been selected and measured each month, in order to quantify this physical effect.

The results obtained with more than 50 trees - spruce, oak, and beech - are shown in figure 5. It can be observed that season effect on ultrasound properties can be considered in a range of 5%, where lower speeds are associated to growing time, while higher speeds occur in winter time when the tree is empty of sap and the environmental temperature is much lower. Consequently, the referential speed of healthy species has to be calibrated, taking into account a season effect.

<u>Coloration detection on standing beech trees</u>

The same ultrasonic radial measurement as for decay detection in spruce trees has been applied to beech trees, in order to evaluate internal red coloration. There are few studies about beech red heart coloration. Some results show that the coloration can be associated with pathological actions or with soil and age variables [8, 9]. It appears very difficult to associate degradation of wood and coloration in the special case of beech. Therefore, it has been especially uncertain to quantify the coloration of our sample. However, extended studies allowing to precise the origin of the coloration have been judged too expensive. The results described in this paper are based on visual observations only. The correlation coefficient between ultrasonic radial measurements and the ratio of coloration is shown in figure 6.

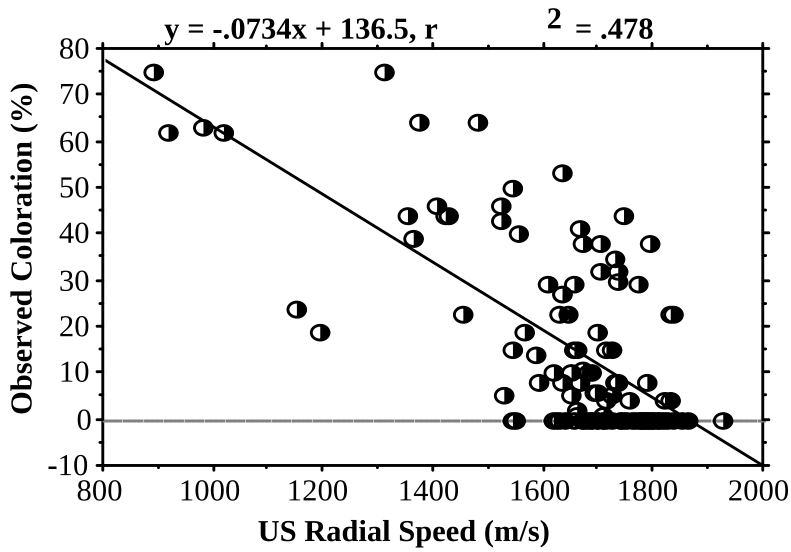

Figure 6: Relationship between the ultrasonic radial measurement and the observed red heart coloration of beech trees

The quality of the result shown in figure 6 is very encouraging. Improvement of the accuracy of the coloration variable could be helpful for a better calibration of the method. Analysis of separate data grouping red coloration without degradation and pathological red coloration should improve NDE results.

<u>Degradation detection on standing oak trees</u>

From a NDE point of view, oak can be associated to beech. In fact, calibrations and results of ultrasonics tests are quite similar for both species. However, two differences have been noticed. On the first hand, contrary to beech, oak trees develop nearly no coloration. Then, biological oak degradations are evaluated with more accuracy. On the second hand, studies show that oak is the species which is the most concerned by frost-cracks problems [10]. Oak measurements show that ultrasonic wave propagations is sensible to cracks, radial shakes and ring shakes. Nevertheless, the sensitivity is limited. Then, cracks and shakes are difficult to detect using ultrasound, in the actual state of the art.

<u>Urban trees</u>

Measurements on urban trees give the same quality of evaluation as seen before. As an example, figure 7 shows different levels of degradation and sensitivity of decay detection. Based on the measurements on two axis, the degradation can be localized on the diameter. Cavities of very large spots of fungi can be accurately evaluated as well.

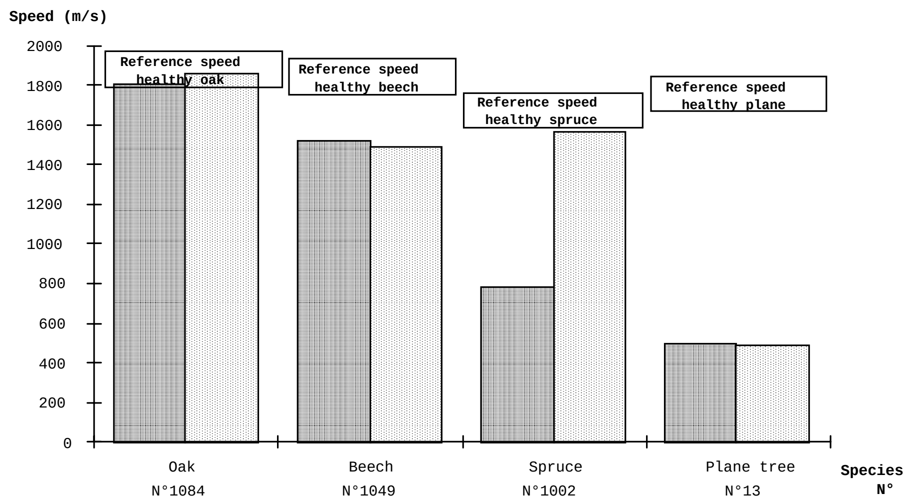

Figure 7: Position of the radial speed measured on two axis compared with the expected references

Figure 7b.1

Figure 7b.2

Figure 7b.3

Figure 7b.4

Figure 7b: Visualization of the decay for several trees at different levels of degradation:
7b.1 - Oak sample no.1084, healthy;
7b.2 - Beech sample no.1049, centered pathology;
7b.3 - Spruce sample no.1002, lateral decay;
7b.4 - Plane sample no.13, internal cavity.

In case of important degradation, the ultrasonic method appears to be very efficient. In fact, the accuracy of the method is improved for trees which are widely damaged. This result is quite important in view of applications for the security control of urban trees.

Conclusions

The ultrasonic technique as NDE method can be applied to standing trees in different way. Based on longitudinal data obtained in the sapwood of spruce, at the soil level, wood properties like density or modulus of elasticity can be estimated. Using radial measurements, internal singularities like decay or pathological coloration can be detected. With an accuracy of more or less 15%, softwood decay in spruce can be non destructively evaluated by ultrasound. In the case of beech red heart, the sensibility of the ultrasonic technique is lower, but biggest coloration proportion can be measured. In order to increase the efficiency of the detection method, a season effect has to be taken into account in the calibration of the referential speed.

Summary

Trees are organic vegetal materials forming an important link in the carbon turn-over cycle. In the forest, they are associated together in the eco-system. In the cities, they act singly in ecological and decorative functions.

Quality assessments of standing trees may be considered to have two separate targets: biological internal quality related to wood degradability and elastic quality of the heartwood regarding the industrial valuation of the wood products.

Biological internal quality of standing trees can be non-destructively evaluated using ultrasound. The speed of a low frequency wave propagated on the radial axis of the tree is measured. Compared to a referential speed for each species, deviation of the speed is considered to be indicative of degraded wood. Diameter and seasoning effects must be taken into account for better accuracy of the diagnostics.

Elastic quality of the wood contained in the tree can be evaluated by ultrasound. In this application, speed of sound is measured on the longitudinal axis in the sapwood area. Dispersion of the results in terms of speed is the basic information allowing a first step in grading the internal wood material.

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DNA heteroduplex mobility assay as a highly sensitive diagnostic technique for phytoplasma diseases of different origins

Introduction

Accurate identification and classification of phytoplasmas will provide valuable information for the studies on epidemiology and control of phytoplasma diseases important in agriculture, horticulture, and forestry. Since the introduction of polymerase chain reaction (PCR) to phytoplasma studies (Deng and Hiruki 1990), restriction fragment length polymorphism (RFLP) analyses of PCR-amplified highly conserved genes have been extensively used to identify and classify phytoplasmas worldwide (Gundersen and Lee 1996; Gundersen *et al.*, 1994; Kuske and Kirkpatrick 1992; Lee *et al.*, 1993; Namba *et al.*, 1993; Seemüller *et al.*, 1994). Phylogeny and taxonomy of phytoplasmas have been established on the basis of analyses of RFLP and sequence data of 16S rRNA gene, 16/23S spacer gene and 16S ribosomal protein genes. Heteroduplex mobility assay (HMA) is based on a principle that DNA heteroduplexes formed between related sequences reduce their mobilities in polyacrylamide gels and the degree of their delay is proportional to the extent of specific divergence (Delwart, *et al.*, 1993). The sensitivity of HMA for detecting DNA mutation is higher than any other technique currently available except for exhaustive DNA sequencing studies (Delwart *et al.*, 1993, 1994). HMA has recently been applied to the studies on identification and classification of phytoplasmas. Previous studies have indicated that HMA is a reliable, simple, rapid, and accurate method to detect and estimate the genetic divergence of phytoplasmas (Zhong and Hiruki, 1994; Ceranic-Zagorac and Hiruki, 1996; Cousin *et al.*, 1998; Wang and Hiruki, 1999, 2000).

In this study, the genetic diversity of phytoplasmas was investigated by HMA using field samples collected from different origins in Alberta.

Materials and Methods

Sources of phytoplasmas: Phytoplasma isolates from North America, Asia, and Europe were used in this study. Aster yellows (AY27), clover proliferation (CP-0) and potato witches'-broom (PWB-0), originally collected from field plants in Alberta, were maintained in periwinkle (*Catharanthus roseus* (L.) G. Don) in greenhouse and used as references. The field samples of CP, PWB and alfalfa witches'-broom (AWB) were also collected in northern Alberta and maintained in greenhouse over several years. Aster yellows phytoplasma from apricot (AYA, formerly ACLR) was kindly provided by Dr. E. Seemüller, Institut für Pflanzenschutz im Obstbau, Dossenheim, Germany. The following phytoplasmas were isolated from diseased plants in the fields in Edmonton, Alberta in 1999: China aster (*Callistephus chinensis* (L.) Nees) yellows (ChAY), French marigold (*Tegetes patula* L.) yellows (FMY), cosmos (*Cosmos bipinnatus* Cav. cv. Dazzler) yellows (CoY), clarkia (*Clarkia unguiculata* Lindl. cv. Passion for Purple) yellows (ClY), California poppy (*Eschscholzia californica* Cham. cv. Tai Silk) yellows (CPY), queen anne's lace (*Ammi majus* L.) yellows (QALY), scabiosa (*Scabiosa atropurpurea* L. cv. Giant Imperial) yellows (ScY), pot marigold (*Calendula officinalis* L.) yellows (PMY), swan river daisy (*Brachycome multifida* (DC.) G.L. Davis. cv. Misty Pink) yellows (SRDY), purple coneflower (*Echinacea purpurea* Moench.) yellows (PCY), and monarda (*Monarda fistulosa* L.) yellows (MY). Paulownia (*Paulownia tomentosa* (Thunb.) Steud) witches'-broom (PaWB) sample was collected in Zhenzhou, P.R. China.

DNA extraction and PCR amplification: Total nucleic acids were extracted from about 1g of freshly cut midrib tissues of diseased samples as described previously (Wang *et al.*, 1998). The universal primers P1 (Deng, and Hiruki 1991) and P7 (Smart *et al.*, 1996) were used in PCR assays for detection of various phytoplasmas.

PCR amplifications were performed as described elsewhere (Wang *et al.*, 1998). Five microliters of the PCR products was analyzed by electrophoresis in a 1% agarose gel, and DNA bands were stained in ethidium bromide and visualized with a UV transilluminator.

Nested PCR: To increase the sensitivity of PCR and to detect potential mixed infections, nested PCR was employed using primers P3/P7 (Smart *et al.*, 1996) designed to amplify 16/23S spacer genes and R16F2n/R2 (Lee *et al.*, 1993; Gundersen and Lee 1996) designed to amplify the partial 16S rDNA. PCR products amplified by primers P1/P7 were diluted 0 to 100 times in sterile deionized water on the basis of the concentrations of amplified target DNA fragments and were used as templates for a subsequent series of 35 PCR cycles. PCR parameters for primers R16F2n/R2 were the same as above. The following parameters were used for primers P3/P7: denaturation at 94°C for 40s, annealing at 55°C for 45s, and extension at 72°C for 50s.

RFLP analysis of 16S rDNA sequences: RFLP analysis of known phytoplasma strains CP, PWB, and AWB was employed to compare the sensitivity of HMA with RFLP in differentiation of closely related phytoplasmas. The partial 16S rDNA sequences (1.2 kb) amplified by nested PCR using primers R16F2n/R2 were analyzed by restriction endonuclease digestion. Five microliters of each PCR product were digested with the following restriction endonucleases according to the instructions of manufacturer: *Alu*I, *Hha*I, *Hpa*II, *Mse*I, *Rsa*I, and *Sau*3AI (GIBCO/BRL, Gaithersburg, MD). The restriction products were resolved on a vertical 5% polyacrylamide gel followed by staining in ethidium bromide. The DNA bands were then visualized using a UV transilluminator.

HMA of 16/23S rRNA genes: To detect the potential mixed infection of phytoplasmas, the 16/23S spacer gene and 16S rRNA gene amplified by nested PCR were analyzed by HMA. An aliquot of 4.5 µl of the PCR products amplified from phytoplasma reference was combined with each 4.5 µl of PCR products amplified from various phytoplasma isolates and then 1 µl of 10× annealing buffer (100 mM Tris-HCl, pH 8.0, 10 mM EDTA, pH 8.0, 1 M NaCl) was added. One drop of mineral oil was overlaid on the reaction mixture. After denaturing at 98°C for 4 min, the DNAs were hybridized on ice. The hybridization products were separated by electrophoresis in a 5% polyacrylamide gel in 1× TBE buffer (0.088 M tris-borate, 0.089 M boric acid, 0.002 M EDTA) at 200V for 3 h at room temperature in PROTEAN II (Bio-Rad, Hercules, CA). DNA bands were stained in ethidium bromide and visualized as above.

Results

Detection of phytoplasmas in the diseased plants: The direct PCR and nested PCR were employed to detect phytoplasmas in fourteen field samples of ornamental plants collected in Alberta in 1999. For the directed PCR with primers P1/P7, the approximately 1.8 kb DNA fragments were amplified only from diseased queen anne's lace, California poppy, China aster, swan river daisy, pot marigold, purple coneflower, and monarda (data not shown). All other field samples and healthy samples were negative. Following primary amplification, the PCR products were subjected to nested PCR amplification using primers P3/P7. The DNA fragments approximately 300 bp were amplified from all diseased samples (Fig. 1). The similar DNA fragments were consistently amplified from all other phytoplasma samples used as references in this study by both direct PCR and nested PCR using primers P3/P7. However, 16/23S spacer genes of CP, AWB and PWB were smaller than those of AY 27 and test samples (Fig. 1).

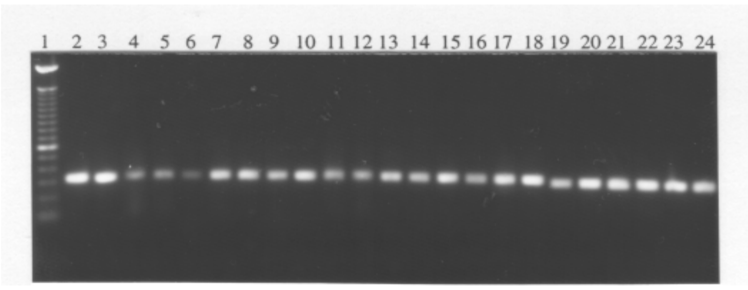

Figure 1: 16/23S spacer gene of phytoplasmas amplified by nested PCR from various phytoplasma isolates using primer pair P3/P7 and separated by electrophoresis in a 1 % agarose gel. Lane 1, 100 bp DNA ladder; lanes 2 - 24, AY27, AYA, ChAY1 ChAY2, FMY1, FMY2, CoY, ClY, CPY, QALY, ScY, PMY1, PMY2, SRDY, PCY, MY, PaWB, AWB1, AWB92, CP1, CP4, PWB1, PWB3.

Sensitivity of HMA in detecting DNA mutation of phytoplasmas: To detect DNA mutation of phytoplasma isolates collected from field, spacer gene and 16S rRNA gene were amplified from field samples and standard phytoplasma isolates CP-0, AWB-0, and PWB-0. When AY27 was used as a reference, DNA heteroduplex bands in addition to the homoduplex bands were observed in polyacrylamide gels for both genes. The differences in heteroduplex mobilities were clearly discerned among CP, PWB, and AWB phytoplasma isolates when 16S rDNA fragments and 16/23S spacer region sequences were analyzed by HMA

(Fig. 2a, 2b). Two types of phytoplasma isolates of AWB, CP and PWB were differentiated by HMA. The first group (type I) includes 17 phytoplasma isolates such as AWB-0, AWB 1-7, 90, CP-0, CP 1, 2, 16, 19, 20, PWB 3, and 5. The heteroduplex mobilities of AWB 92, CP 4, PWB-0, PWB1, 2, and 4 isolates were identical among themselves, but were different from type I for both genes when AY 27 was used as a reference and thus formed type II. Since the spacer genes of AY 27 and CP, PWB, AWB are different in length, two homoduplex bands were observed for the spacer genes. The upper band of homoduplexes represented the spacer gene of AY 27 while the lower one represented those of CP, PWB, and AWB respectively.

The same PCR products (1.2 kb) amplified from CP, PWB and AWB field samples and standard isolates were subjected to RFLP analysis with endonucleases *Alu*I, *Hpa*II, *Hha*I, *Kpn*I, *Sau*3AI, and *Rsa*I. The results showed that all field samples and standard isolates of CP, PWB and AWB shared the identical RFLP profiles with all restriction enzymes tested (Fig. 3).

Identification and classification of phytoplasmas: Heteroduplexes were formed by combination of spacer gene amplified from AY27 and each of the remaining phytoplasma isolates (Fig.4). Two major groups were clearly discerned on the basis of the heteroduplex mobilities: CP group including CP, PWB and AWB phytoplamsa isolates; and AY group including all other phytoplasma isolates tested in this study. In CP group, two or three isolates of each AWB, CP and PWB were chosen to compare with the test samples. For phytoplasma isolates in AY group, three subgroups were identified by HMA. When spacer gene of AY27 was combined with those of ChAY, FMY, ClY, CPY, and MY, the heteroduplexes and homoduplexes comigrated together, indicating that they shared very high level of homogeneous sequences and were classified in subgroup 16Sr I-A (Fig. 4). The heteroduplexes were separated from homoduplexes for AYA, GALY, ScY, PMY, SRDY, and PCY phytoplasma isolates and showed the similar mobilities. Thus they were classified as the second subgroup representing 16Sr I-B subgroup (Fig. 4). PaWB phytoplasma produced unique heteroduplex mobility and was classified as the third subgroup corresponding to 16Sr I-C subgroup (Fig. 4).

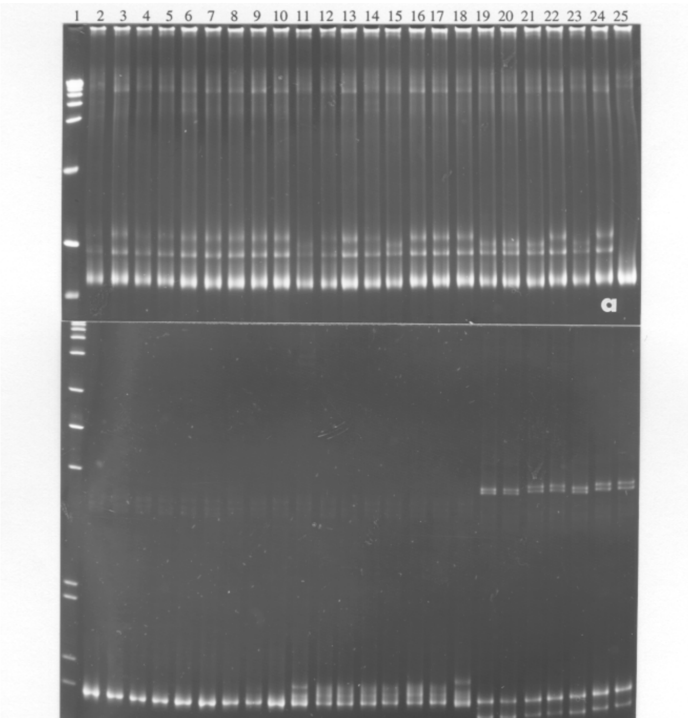

Figure 2: z. HMA of nested PCR-amplified 16S rRNA gene (a) and 16/23S spacer gene (b) from CP, PWB and AWB phytoplasma isolates. Heteroduplexes and homoduplexes were separated by electrophoresis in 5% polyacrylamide gels. AY27 was used as a reference. Lane 1, 1 kb DNA marker; lane 2, AWB phytoplasma isolate as standard; lanes 3 to 11, field samples AWBI, AWB2, AWB3, AWB4, AWB5, AWB6 AWB7, AWB90, AWB92; lane 12 CP phytoplasma isolate as standard; lanes 13 to 18, field samples CP1, CP2, CP4, CP16, CP19, CP20; lane 19, PWB phytoplasma isolate as standard; lanes 20 to 24, field samples PWB1, PWB2, PWB3, PWB4, PWB5; Lane 25, AY27

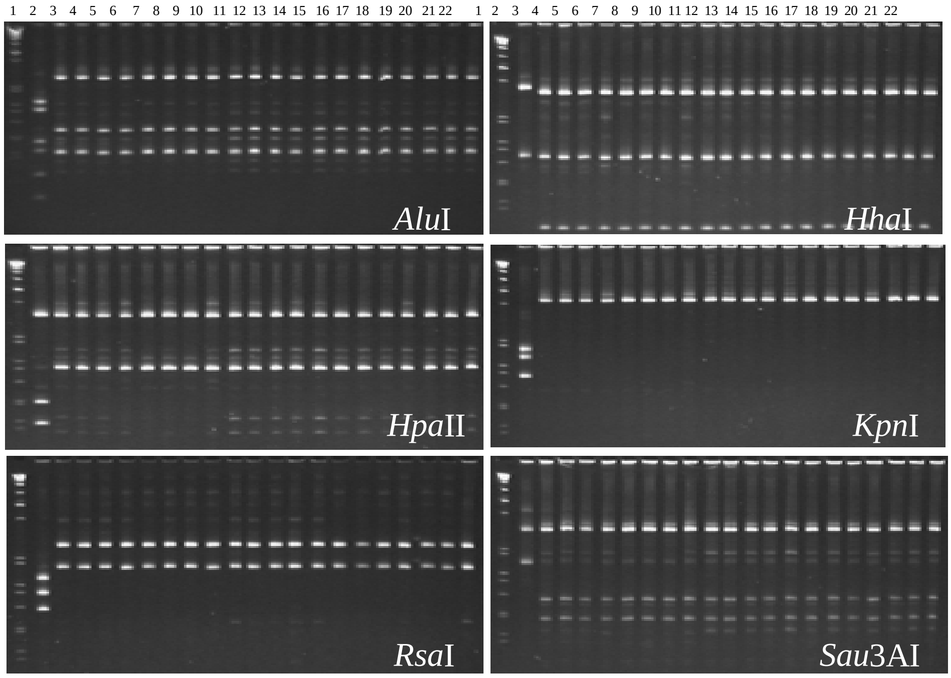

Figure 3: RFLP analysis of PCR-amplified 16S rDNA fragments from various CP, PWB and AWB phytoplasma isolates. Lane 1, 1 kb DNA marker; lane 2, AY27; lane3, AWB phytoplasma isolate as standard; lanes 4 to 9, field samples AWB1, AWB2, AWB3, AWB4, AWB90, AWB92; lane 10, CP phytoplasma isolate as standard; lanes 11 to 16, field samples CP1, CP2, CP4, CP16, CP19, CP20; lane 17, PWB phytoplasma isolate as standard; lanes 18 to 22, field samples PWB1, PWB2, PWB3, PWB4, PWB5.

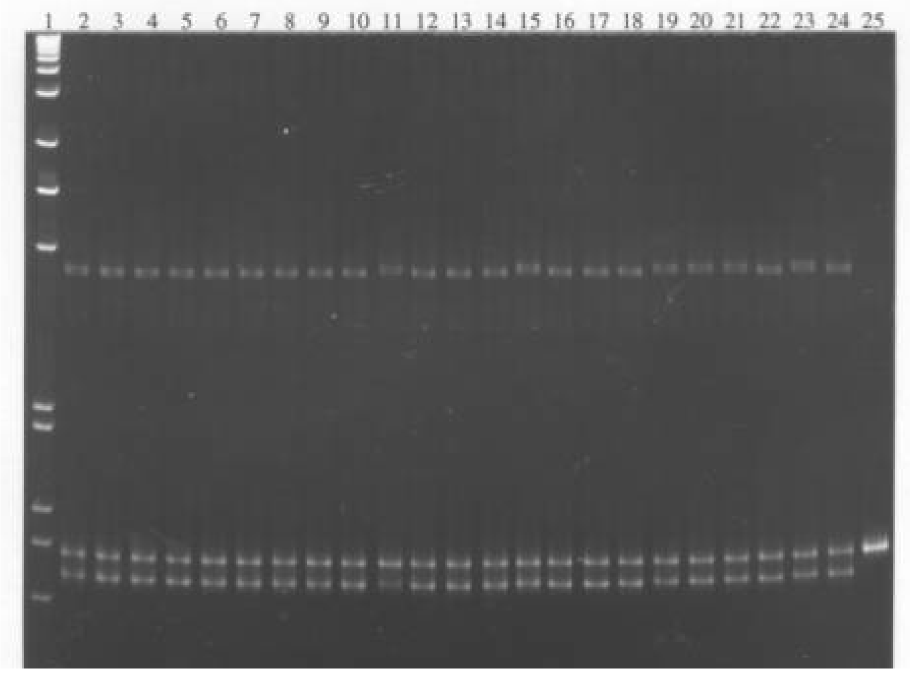

Figure 4: HMA analysis of nested PCR-amplified 16/23S spacer gene from various phytoplasma isolates. Heteroduplexes and homoduplexes were separated by electrophoresis in a 5% polyacrylamide gel. AY27 was used as a reference. Lane 1, 100 bp DNA ladder; lane 2 to 25, AY27, ChAY1 ChAY2, FMY1, FMY2, CoY, ClY CPY, MY, AYA, QALY, ScY, PMY1, PMY2, SRDY, PCY, PaWB, CP1, CP2, CP4, PWB1, PWB3, AWB1, AWB92.

Discussion

In this study, we demonstrated that HMA is a highly sensitive diagnostic technique for differentiation and identification of phytoplasmas. CP, PWB and AWB phytoplasmas which have been identified in the same group based on their identical RFLP profiles in previous studies (Lee *et al.*, 1991, 1993; Gundersen *et al.*, 1994; Khadhair and Hiruki, 1995). In this study, twenty isolates of CP, PWB and AWB were subjected to RFLP analysis. All isolates showed identical RFLP profiles with all endonucleases used in this study, indicating that RFLP failed to detect genetic differences among CP, PWB and AWB. However, after subjecting the same phytoplasma isolates to HMA, the genetic differences were clearly discerned in both 16S rRNA gene and 16/23S spacer gene. The results provided the valid evidence that HMA is much more sensitive than RFLP analysis in differentiating the closely related phytoplasma isolates. The high sensitivity of HMA in detecting DNA mutations of phytoplasmas was also demonstrated in previous studies in which a single base pair insertion/deletion or two base pair substitutions in 500 bp DNA fragment were easily detected by HMA (Wang and Hiruki, 1999, 2000).

HMA is more accurate than RFLP analysis for classification of phytoplasmas. While RFLP analyses of highly conserved genes have made it possible to construct a phylogenetic tree of phytoplasmas, RFLP analysis is based on the presence or absence of restriction sites in a DNA fragment and many restriction enzymes must be used (Lee *et al.*, 1993; Gundersen *et al.*, 1994, 1996). The results of RFLP analyses may incorrectly increase or decrease the genetic distance between phytoplasmas. DNA sequence analyses of more than 20 phytoplasma isolates in previous studies have indicated that RFLP-based classification of phytoplasmas in certain groups do not fully coincide with the phylogenetic relationships of the organisms (Seemüller *et al.*, 1994; Kuske and Kirkpatrick, 1992). For example, stone fruit strain AYA (formerly ACLR) and an typical aster yellows strain share the sequence homology at the level of as high as 99% (Seemüller *et al.*, 1994). However, AYA and the aster yellows strains were classified into two different major groups since they are different at one *Alu*I site and one *Rsa*I site (Schneider *et al.*, 1993). Our results of HMA have showed that AYA and AY27 belong to the same major group but different subgroups.

Use of different standard phytoplasma strains as references can increase the sensitivity in detecting the minor differences between phytoplasma isolates. In this study, the heteroduplex mobility of AYA was very similar to those of QALY, ScY, PMY, SRDY, and PCY when AY 27 was used as a reference. However, the differences between AYA and others were clearly observed by HMA when CP was used as a reference (data not shown). This suggested that two or more references should be used when one tries to differentiate phytoplasmas in the same group or to detect the minor mutations of phytoplasmas.

HMA provides an efficient method for identification of phytoplasmas especially for the survey of a large number of field samples and quarantine projects. HMA is highly capable of determining genetic distances between the test samples and the standard phytoplasmas. It is less expensive than RFLP analysis that requires many expensive endonucleases. In this study, fourteen phytoplasma isolates were classified into three subgroups by HMA. The results fully agree with the results reported in the previous studies (Lee *et al.*, 1993, Seemüller *et al.*, 1994; Wang and Hiruki, 1998).

HMA offers an ideal method for studying the dynamic nature of phytoplasma populations in different origins. The same strain of phytoplasma such as CP or AWB showed the genetic differences in the 16S rRNA gene and 16/23S spacer gene between the different isolates that were collected in the same field in different years. Therefore, HMA can be used to monitor phytoplasma sequence diversity and to track the evolution of phytoplasmas so as to provide useful information for the study of phytoplasma disease epidemiology and disease control. HMA also can be used to detect the mutations of some important genes in pathogenesis and transmission of phytoplasmas. Previous study on popular witches'-broom by HMA also indicated that phytoplasma isolate causing popular witches'-broom in France was different from that in Germany, and suggested that the less severe symptoms caused by the German isolate may be correlated to the slight change in its nucleotide sequence (Cousin *et al.*, 1998).

It is very interesting that the ornamental plants grown in the same area are caused by two types of phytoplasmas. So far we have not found mixed infection in these diseased plants. The host range of phytoplasmas in AY subgroup I and II was broadened in this study. We, for the first time, reported in Alberta that phytoplasmas associated with French marigold, cosmos, clarkia, California poppy are closely related to AY27 phytoplasma strain (subgroup I), while phytoplasmas associated with queen anne's lace, scabiosa, swan river daisy, are the members of the subgroup II. Pot marigold yellows disease and purple conefolwer yellows were found associated with phytoplasmas by electron microscopy in Canada in 1997 (Hwang *et al*., 1997a, b). However, the pathogens were not identified at that time. We identified that PMY phytoplasma belongs to subgroup II in AY group. RFLP analysis of 16S rDNA fragment amplified from purple coneflower yellows phytoplasma showed restriction patterns identical with AY27 using four restriction enzymes (*Alu*I, *Hha*I, *Rsa*I and *Sau*3AI) (Khahair *et al*., 1997). Our results of HMA indicated that PCY was different from AY27 and belonged to subgroup II.

Two types of AWB, CP and PWB phytoplasmas were, for the first time, identified by HMA in this study. Phytoplasmas of both types can cause witches'-broom of alfalfa plants and potato plants, proliferation of clover plants. However, phytoplasma of type I was common in CP and AWB while phytoplasma of type II was common in PWB. The sequence differences were also indicated in previous study by DNA sequencing (Khadhair et al., 1997). Mixed infection of an individual plant by two types of phytoplamsas are still in investigation.

Summary

This paper reports the identification of phytoplasmas of different origins by a highly sensitive diagnostic technique, DNA heteroduplex mobility assay (HMA). The closely related phytoplasma isolates clover proleration (CP), potato witches'-broom (PWB), and alfalfa witches'-broom (AWB) collected from different fields in different years and standard isolates were used to amplify the entire 16S rRNA gene and 16/23S spacer gene by polymerase chain reaction (PCR). The PCR-amplified DNA fragments were subjected to RFLP analysis and HMA. The genetic divergences of these phytoplasma isolates were detected by HMA while RFLP analyses showed the identical RFLP patterns among them. Fourteen phytoplasma-associated samples were collected from field and used for DNA extraction. HMA was employed to analyze the PCR-amplified 16/23S spacer gene from these field samples. In aster yellows (AY) group of the phytoplasma isolates used in this study, the following three subgroups were classified by HMA. Subgroup I: AY27 and phytoplasmas associated with French marigold (*Tagetes patula* L.) yellows, cosmos (*Cosmos bipinnatus* Cav. cv. Dazzler) yellows, clarkia (*Clarkia unguiculata* Linkl.) yellows, California poppy (*Eschscholzia californica* Cham. cv. Tai Silk) yellows, and monarda yellows; subgroup II: aster yellows from apricot and phytoplasmas associated with queen anne's lace (*Ammi majus* L.) yellows, scabiosa (*Scabiosa atropurpurea* L. cv. Giant Imperial) yellows, swan river daisy (*Brachycome multifida* (DC.) G.L. Dvis. cv. Misty Pink) yellows; subgroup III: paulownia witches'-broom. Two types of phytoplasmas in CP group were identified by HMA. Phytoplasmas in type I were common in CP and AWB while phytoplasmas in type II were common in PWB. The results indicated that HMA is a simple, rapid, highly sensitive and accurate method not only for identifying and classifying phytoplasmas but also for studying the dynamic nature of phytoplasma populations of different origins.

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Session 5 – Tree biology and tree care

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Limits and possibilities of controlled pruning of tree root systems

Introduction

The root-system of a tree is an indispensable organ because it has fundamental functions. Therefore the protection of roots is written down in many rules and decrees. Nevertheless root systems get damaged very often in urban areas (BALDER, 1988; 1990; 1998; BALDER et al., 1997). Especially the use of heavy machines in underground and road constructions as well as landscape measures often cause mechanical injuries. This results in a loss of roots, the death of a part of the root system and often leads to a decline of the tree which can be seen in the state of the crown earlier or later. The attack of pathogens, especially wood-destroying fungi, causes a rottenness which is followed by further hard operations in tree care for safety.

Studies of wound reactions after mechanical injuries as well as the understanding of the compartementalization effects of roots make a better proceeding of interventions in trees possible. This is important in the discussion of a preservation by construction works. In practise the limits and the possibilities of interventions in tree stands are unknown, so in many cases the pruning is incompatible (BALDER et al., 1998).

Root reactions after mechanical injuries

Pure bark injuries are very wide-spread in constructions by manual work and in sanitation of tree stands. They have no effect on the roots´ wood-tissue, the providing of the root is still possible. Normally the development of the callus effects that the wound closes quickly. In the youngest annual ring there is tylosis and aczessoric substances are laid in, so the compartementalization is very effective.

The lopping of roots causes more stress for a tree because parts of the root system get lost. Furthermore not only the bark but also the wooden body is injured. The consequence is always dryness of the root cuts followed by callus development and root regeneration (Fig. 1). A root regeneration depends on the age and the thickness of the root: an older root is conditional able to form new roots (Fig. 2). Inside a characteristic funnel-shaped discoloration goes into the root in the old tissue. In general root regeneration decreases and discolouration increases the thicker a root gets.

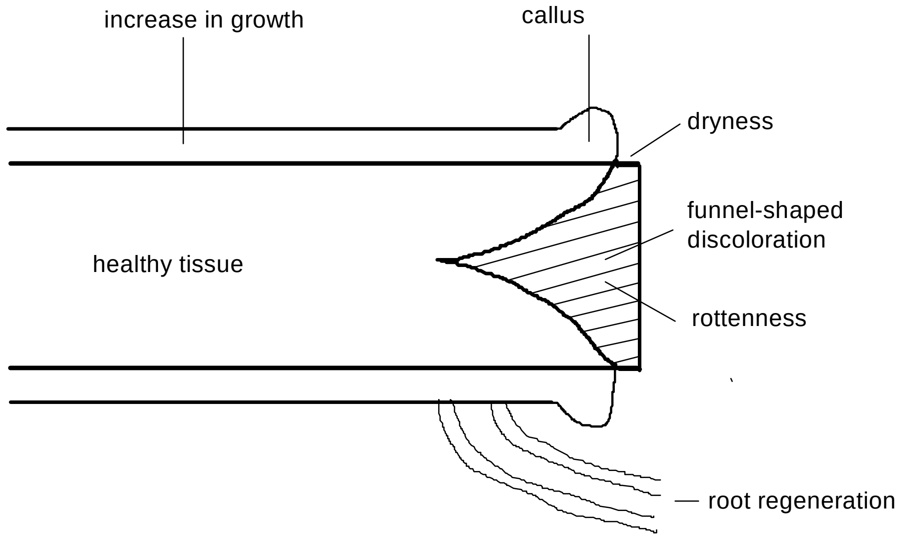

Figure 1: Root reactions after lopping (BALDER, 1998)

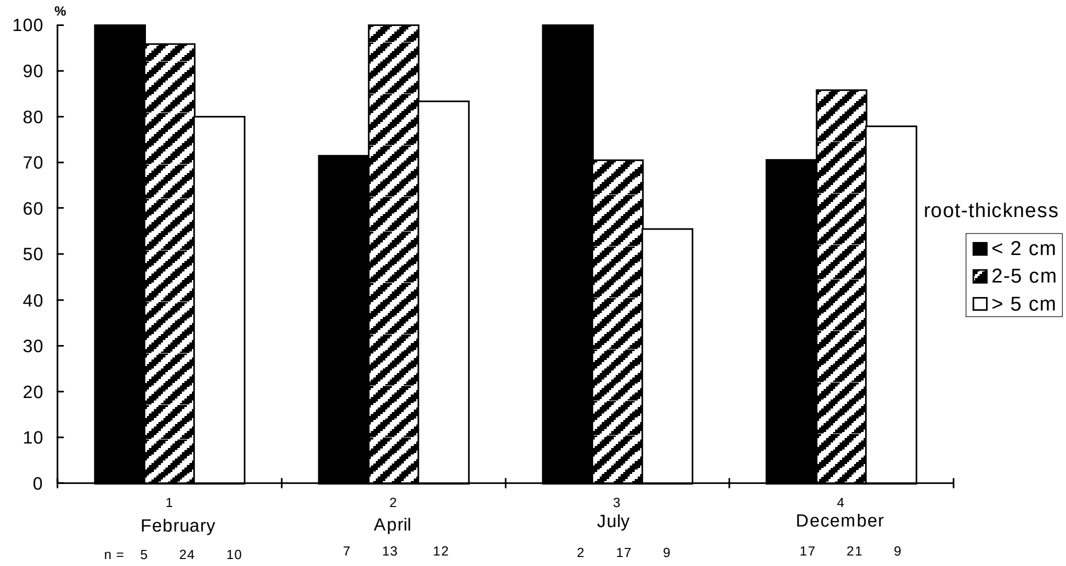

Figure 2: Ability of roots of *Quercus rubra* L. to regenerate in dependence of the lopping time (BALDER, 1998)

Very important for the wound reactions are the time and the place of an injury. Mechanical wounds show a better compartementalization in the vegetation period than in winter time (Fig. 3), they are more effective the longer the distance to the trunk. Root regeneration is very intensive close to the trunk. Pruning after uncontrolled injuries advances compartementalization as well as root regeneration and reduces rottenness. The cutting-form has no considerable influence (Fig. 4). These processes depend on the kind of tree. Whereas beech, lime-tree, maple and oak are very effective in compartementalization, soft-wooden trees react only in a poor manner (BALDER, 1998).

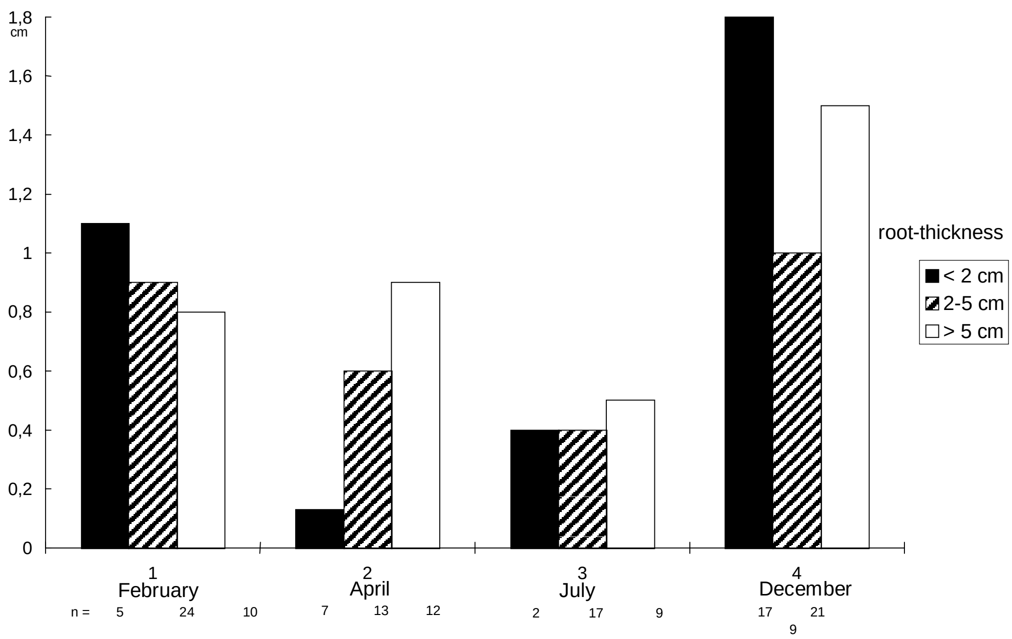

Figure 3: Length of discoloration of the roots of *Quercus rubra* L. in dependence of the lopping time (BALDER, 1998)

Present wound dressings have only small influence on wound reactions, especially they can not prevent the attack of wood-destroying fungi. Wood preservatives and disinfectants are phytotoxic on the living tissue. All actual studies produce the result that the effect of a wound treatment is to see against the background of tree biological influences. Therefore kind, place and time of an injury as well as the age of the root have more influence on the wound reaction than a product (BALDER et al., 1995; DUJESIEFKEN, 1995).

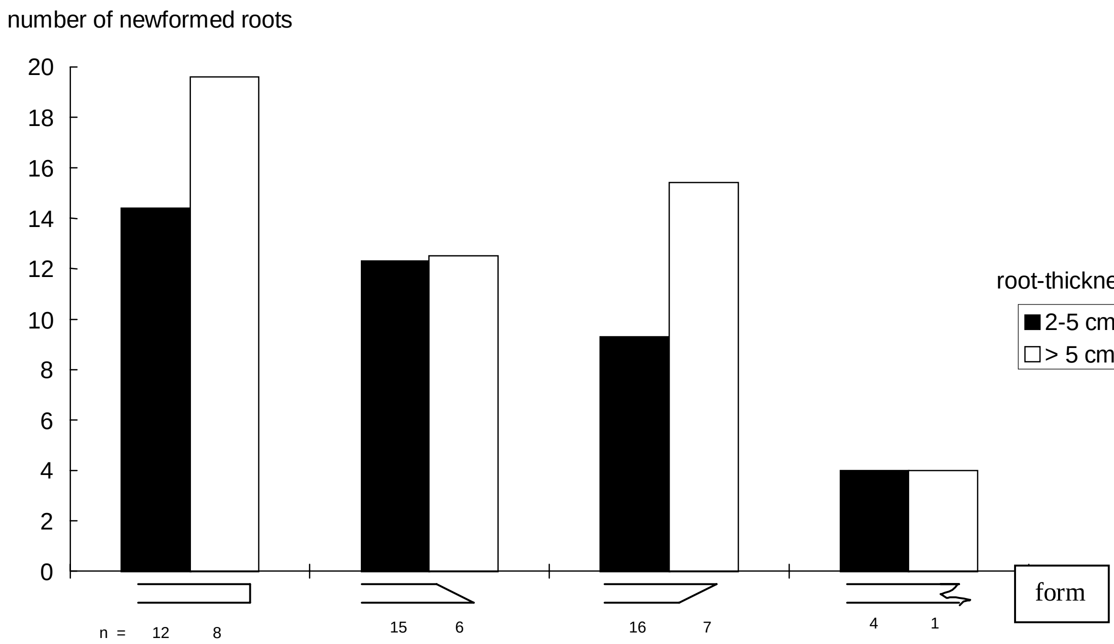

Figure 4: Ability of roots of *Quercus rubra* L.to regenerate in dependence of the lopping-line (BALDER, 1998)

Recommendations for controlled measures in tree care

The best root protection is to avoid any damage. Therefore preventive root protection measures should be preferred to all other acts. If a root intervention is unavoidable following aspects are important at first:

- uncovering a root system without any damage
- protection of uncovered roots for hard climatic conditions, mechanical injuries and pathogens, for example by wrapping up or covering up with suitable materials
- care of uncovered roots
- early preparation of transplanting big trees
- construction of a root curtain

In planning a controlled pruning it is necessary to have a real overview about the individual root system. Careful in craft work it is to analyse the spread of the roots in the area to check the amount of roots which will be lost in the case of lopping. The spread of the roots depends on the type of the root system and the influencing factors of the local situation. It is to differentiate between a stocky one and an expanding one. If the loss will be more than 40 %, there should be no real chance to get a health and vital tree after the intervention. Therefore in the case of a stocky root system the lopping-line should be not closer than 2,50 m, in other situations more than 3 m to the trunk. This is the result of a study of so-called „root-curtains“ in practise (BALDER et al., 1994).

The controlled lopping of roots is to realize if possible more than one year before construction works will start. The building of a root-curtain is the best way to decrease the consequences of the intervention (Fig. 5). This means the following steps:

- digging out a ditch by hand in the line of lopping

- careful lopping of the roots with strong instruments
- wound treatment
- building of a steady, pervious wall on the side of the ditch to the later hole
- put a suitable substrate into the space
- correct care to further the root regeneration (watering, fertilizing, plant protection)

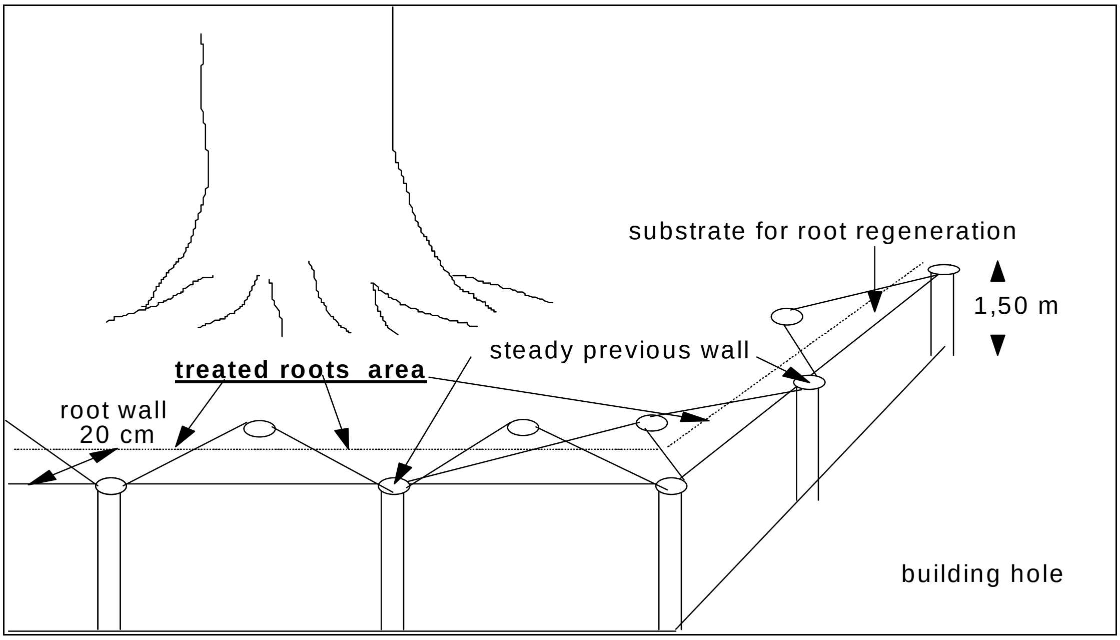

Figure 5: A sketched root-curtain in his components

The same steps are necessary for preparing the transplantation of big trees. The success depends on the knowledge of the root systems and the wound reactions as well as a careful action. The controlled lopping should be a new interest work for companies spezialized in tree care (BALDER, 1995; BALDER et al., 1995).

Summary

Conflicts of the preservation of trees are common in the discussion of constructions. The wound reactions of injured roots were summarized with a spezial view to compartementalization. These results give a better understanding for the limits and possibilities of controlled pruning. The building of a so-called root-curtain is demonstrated as an example of good practise.

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Comparative analysis on bark shelters in transplanting operation in urban areas

Introduction

In transplanting operations of tree species, trees were usually sheltered with a coat of lime. During the last year, trees were sheltered also with jute in order to reduce the transpiration through the trunk lenticels and to prevent burns whose effect is premature senescence of trees. Further to the latest assumptions, some people did not share this point of view as they said that bark shelters did not ensure any advantageous effects. This research aims at investigating if the presence of a shelter on the trunk is useless, that is to say if the shelter helps the tree in taking roots and reduces the negative effects (such as high temperature and high transpiration activity) coming from the transplantation. The available information are not yet conclusive since the test is not yet over and we are collecting data that will be then valid for statistics.

Materials and Methods

The selection includes Nos. 12 *Fraxinus excelsior* which are located one next to the other, from North to South. The whole line includes 60 trees. All the selected trees live in the same climatic conditions, that is under the same shade, in the same isolation, in the same soil and therefore with the same supply of water, minerals, etc. The circumference of all the trees is cm. 25-35- large, at 1 metre from the ground. The trees grew in a nursery in order to be sold. The dimensions of the selected ash trees correspond to the average dimensions of ash trees which are usually chosen to furnish the boulevards.

The 12 trees are divided in 3 groups: Nos. 4 trees with no bark shelters;
Nos. 4 trees with jute shelters;
Nos. 4 trees with shading cloth.

An installation composed by a central exchange and local probes monitors the trees.

The probes read the light and temperature values. They are installed at 1,50 metre-high from the ground as follows.

- The Sub-Bark Probe (hereinafter called S-B P) is located in the sub-bark position; the probe was inserted vertically in a T-shaped cut; here it reads the sub-bark tree temperature; this procedure was carried out on all the selected trees;
- The Internal Probe (hereinafter called I P) is located inside the tree; the probe was inserted horizontally in a hole, 3 cm-deep from the bark; here it reads the internal tree temperature; the diameter of the hole has the same size of the probe and the procedure was carried out on all the selected trees;
- The External Bark Probe (hereinafter called EB P) is located on the bark of only the trees with no bark shelters and reads the air temperature;
- The External Air Probe (hereinafter called EA P) is located in the air and reads the air temperature; only one of these probe has been installed.

Probes are tied with plastic bindings. Cuts and holes were closed with mastic to avoid the alteration of the taken data.

A CR 10 datalogger stores and reads all the information. The CR10 is a fully programmable datalogger and controller in a small, rugged, sealed module. The overall probe accuracy is a combination of the thermistor's interchangeability specification, the precision of the bridge resistors and the error in the linearisation polynomial. In a "worst case" example, all the errors add in one direction to yield accuracy of +-0,4 °C over the range from –20 °C to + 48 °C. Data are stored at intervals of 20 minutes and then transformed in graphics.

Results

This is the first set of available data through which we could check the correct operation and the effectiveness of this electronic device for the scientific purposes.

Abbreviations

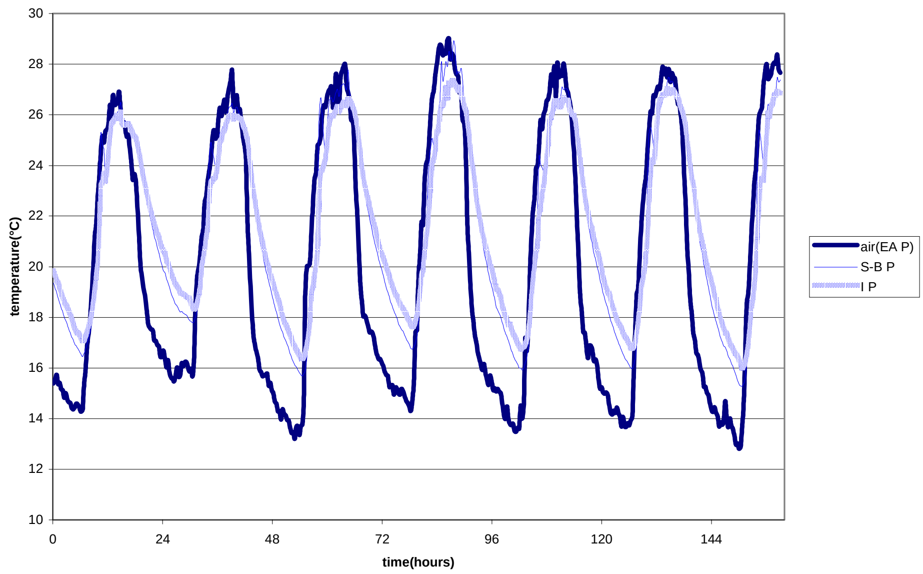
S-B P	Sub-Bark Probe - sub-bark temperature
I P	Internal Probe - temperature inside the tree
EB P	External Bark Probe - air temperature on the bark
EA P	External Air Probe - air temperature

Trees with shading cloth

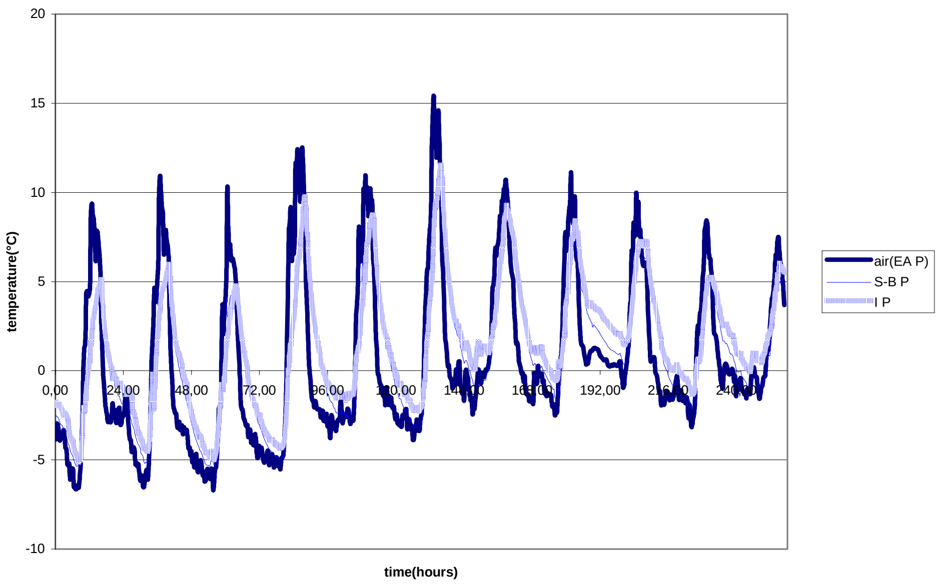
During the summer time, the air temperature (EA P) showed:

- negative peaks higher than the peaks taken by the S-B P and I P;
- positive peaks a little higher than the peaks taken by the S-B P and IP.

GRAPHIC 1 (summer)

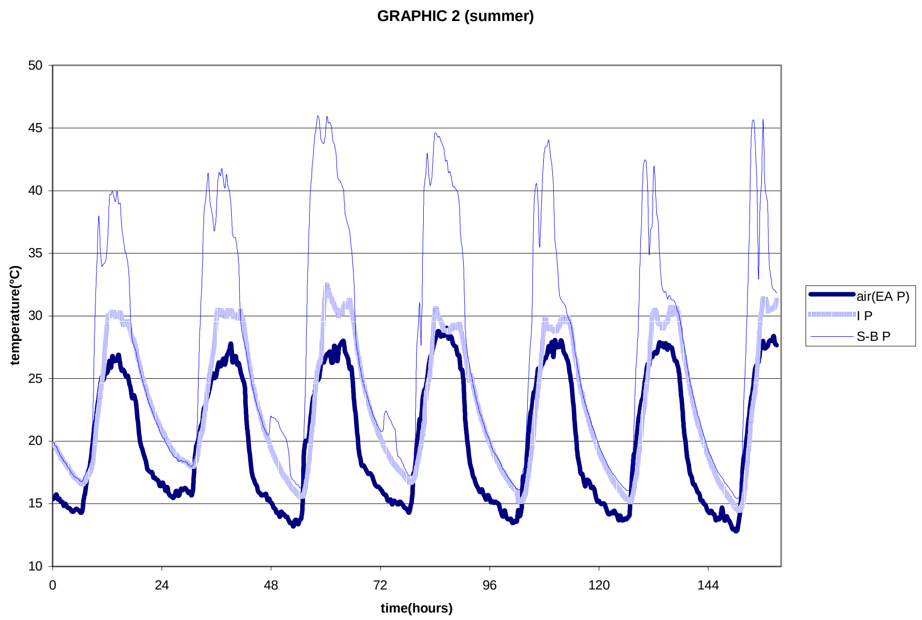


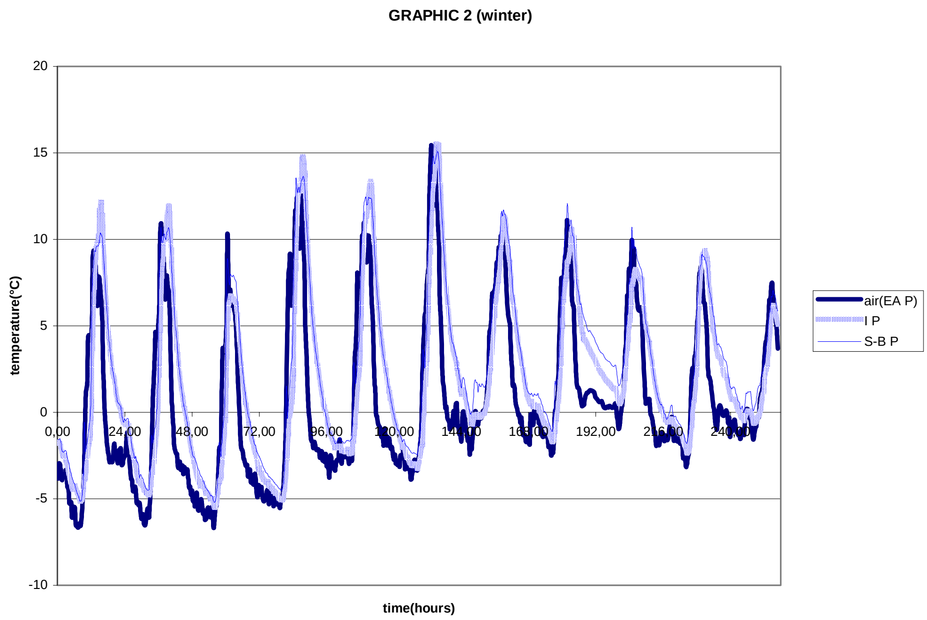
GRAPHIC 1 (winter)



The sub-bark (S-B P) and internal (I P) temperatures were similar, even though the positive and negative peaks of the sub-bark temperature (S-B P) were a little higher than those of the internal temperature (I P).

<u>Trees with jute shelter</u>





During the winter time, the air temperature (EA P) had positive peaks higher than those of the sub-bark (S-B P) and internal (I P) temperatures. The negative peaks of the air temperature (EA P) were a little higher than those of the sub-bark (S-B P) and internal (I P) temperatures.

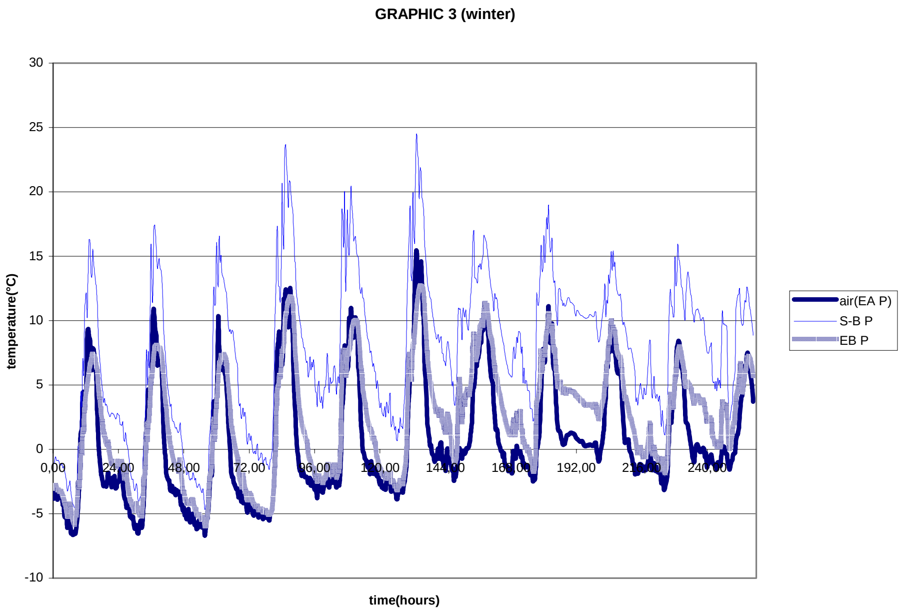
In any case, the sub-bark temperature (S-B P) had always peaks a little higher than those of the internal temperature (I P).

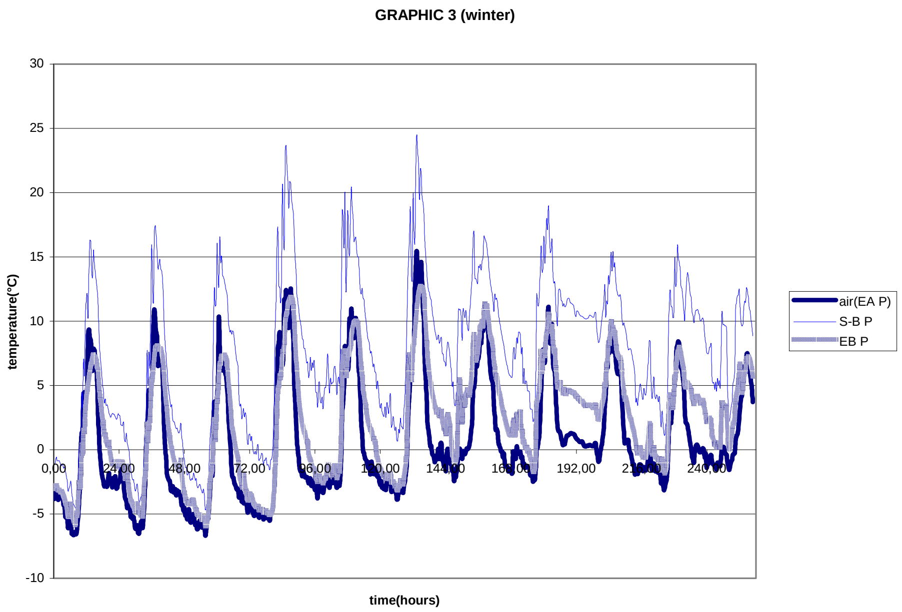
During the summer time, the external (EA P) and internal temperatures (I P) showed similar temperatures.

The sub-bark temperature (S-B P) is similar to the internal temperature (I P) in the negative peaks, but with higher positive peaks.

During the winter time, the temperature taken by the 3 probes is similar, even though the air temperature goes down some time before the other temperatures.

Trees with no bark shelters





During the summer time, the negative peaks taken by all the 4 probes are similar.

As to the positive peaks, the internal temperatures (SB P and I P) are higher than the external temperature s (EA P and EB P).

During the winter time, the internal temperature (I P) was not taken since the probe was out of order. Positive peaks of the sub-bark temperature (S-B P) are higher than those of external temperatures (EA and EB P), while the negative peaks are lower.

Analysis of the results

The temperatures taken on the above mentioned positions show the following results.

During the winter time, the temperatures taken in the trees with either jute shelter or shading cloth show a similar trend. The temperature values taken in the air, under the trunk bark and inside the tree are the same.

As to the trees with no bark shelters, the sub-bark temperature shows higher values.

During the summer time, the temperature in trees with jute shelters has peaks which are almost the double than those of the sub-bark probe.

As to the trees with no bark shelters, the internal temperature is much higher than the others.

The temperatures taken in trees with shading cloth show a similar trend.

Further to these starting results, bark shelters influence the trend of the temperatures in all the selected positions of the tree. Now it shall be focused the relation between the temperature and the normal physiologic growth of the tree, that is to say how the tree takes roots and grows after transplantation.

Conclusions

The temperatures were taken in different positions of the selected trees, with different bark shelters, and gave very different results. This means that bark shelters may influence the tree temperature.

To acquire the correct information that can assess if bark shelters are effective or not, the taken data should be compared to the data which show the growth and the possible alterations on the selected ash trees. This analysis will allow to understand the results given by the effects of bark shelters in the transplanting operations in the urban area.

Abstract

In transplanting operations of tree species, trees were usually sheltered with a coat of lime. During the last year, trees were sheltered also with jute in order to reduce the transpiration through the trunk lenticels and to prevent burns whose effect is premature senescence of trees. Further to the latest assumptions, some people did not share this point of view as they said that bark shelters did not ensure any advantageous effects.

This is a comparative analysis on different bark shelters. To investigate the effects of bark shelters on the tree temperature, the temperatures were taken in different positions of the selected trees, that is under the bark, inside the tree trunk and outside the tree.

Further to these starting results, bark shelters have a direct influence over influence the trunk temperature. Now it shall be focused if the above results have also a direct influence in the tree physiology, especially during the period of taking roots and of growth.

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Twig abscission (cladoptosis) as a decline symptom in *Quercus robur* L. (European oak)?

1 Introduction

The regular shedding of leaves, blossoms and fruits is a well known phenomenon. Less known, however, is the regular abscission of twigs and branches in woody plants (cladoptosis). This phenomenon has to be separated entirely from the passive shedding which occurs in all tree species as a result of structural weakening of the branch due to infestation with fungi after dieback (ROLOFF 1993). In the few publications dealing with the phenomenon of cladoptosis the causes of this process remain controversial (HUBER 1955; BUCK-SORLIN AND BELL 1998).

European oak – which in this paper means *Quercus robur* L. including *Qu. robur* ssp. *robur* and *Qu. robur* ssp. *petraea* because we do not treat these taxons as separate species (KLEINSCHMIDT et al. 1995) – is one of those tree species which are able to abscise twigs and branches under conditions which have not yet been explained comprehensively. So far, the twig abscission phenomenon in oak has been paid little attention. At two major conferences focussing on oak decline, twig abscission was ignored (SIEWECKI AND LIESE 1991, WULF 1995, WULF AND KEHR 1996). However, since cladoptosis is the oak's main mechanism to control the architecture of its crown, it deserves a detailed examination in the context of oak decline.

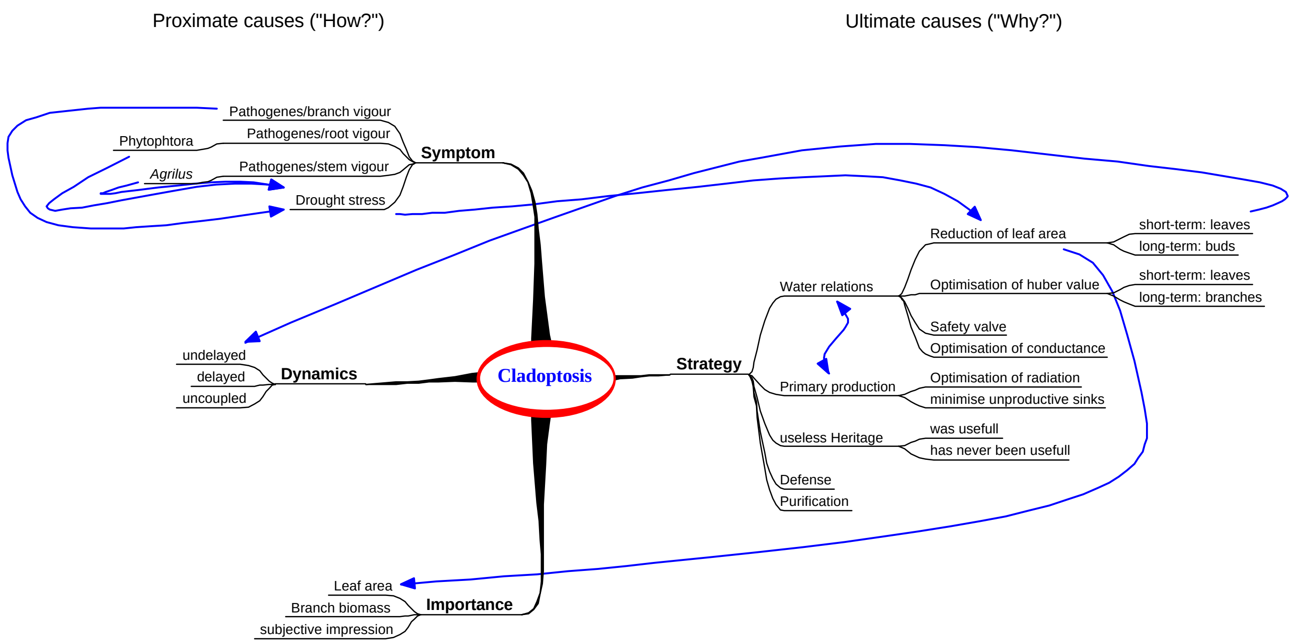

Figure 1: illustrates the complexity of the phenomenon of cladoptosis, summarising some points of departure for our study. Under the heading of "ultimate causation", we find ways to interpret cladoptosis as part of a strategy for European oak. Under the heading of "proximate causation", we have listed the more obvious questions of how cladoptosis as a mechanism works and is visible to the manager.

In this paper we summarise first results shedding light on the dynamics of cladoptosis and the anatomy of the abscission zone.

2 Methods, Material and Results

2.1 Anatomy and Histology

In this paper, 'abscission zone' is defined as an altered anatomical zone which differs from the surrounding tissue and is located at the base of leaf petioles, and in this special case, of twigs. The 'abscission layer' is the distal portion of the abscission zone, which is formed during abscission when the zone becomes meristematic. This comprises the development of several rows of hyaline cells, leading to the final abscission. The abscission zone can, however, be deactivated by the formation of regular xylem, thereby ultimately integrating the twig into the branching pattern of the crown.

The abscission zone was investigated at the base of twig systems of solitary, mature, and juvenile oaks in the vicinity of Dresden. About 2000 junctions were examined micro- and macroscopically.

The branch junctions in European oak are characterised by an anatomically and histologically altered zone which enables the process of abscission. The radial formation of the conduits within the abscission zone compared to regular xylem of the internode is shown in Figures 2 and 3. The cycloporous system, typical of oak, is nearly vanished. In late wood the tracheids are arranged in radial rows or clusters.

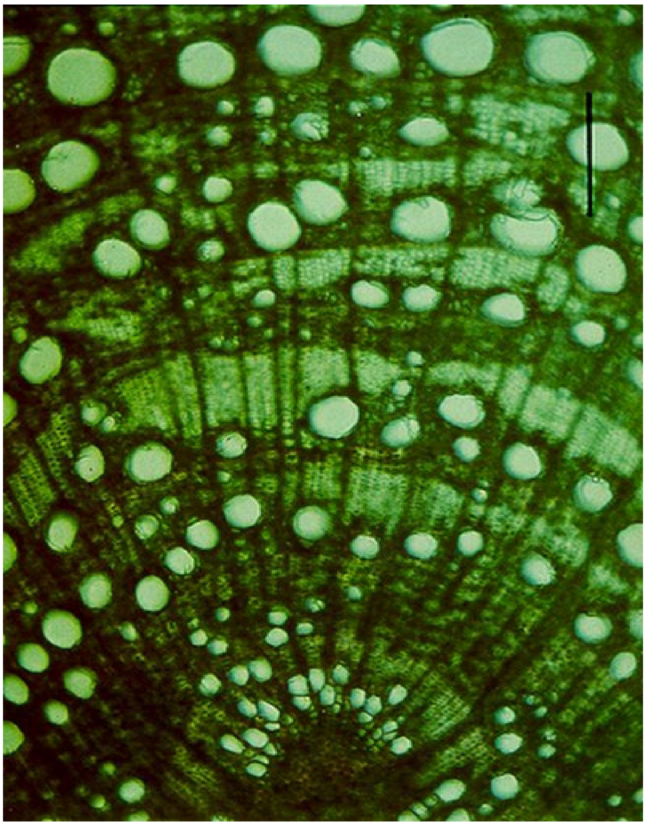

Figure 2: Cross-section of the regular internodal xylem of European oak (bar = 0.2mm)

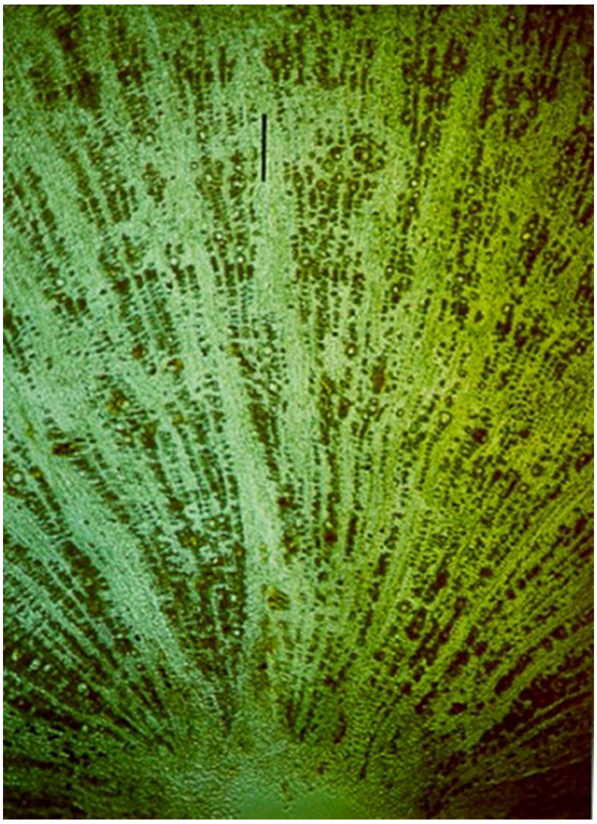

Figure 3: Cross-section of the xylem of the abscission zone (bar = 0.2mm)

The most important difference between the internodal wood and the xylem of branch junctions is probably the reduction of the water-conducting transverse section (SALLEO ET AL. 1982, TYREE AND ALEXANDER 1993). This, however, applies to the abscission zone to a much greater extent, and has not yet been investigated. Therefore, the diameter of conduits of side and main axes as well as the abscission zone were measured on 50 six years old branch junctions. The measurement focused on the conduits of the outermost growth ring because of their importance to water conductance. To water transport in model xylem '*Hagen-Poisseulle's law'* applies (ZIMMERMANN 1983), stating that conductivity of capillaries is proportional to the 4th power of the radius. Therefore the hydraulically weighted mean conduit diameter was calculated according to SPERRY and SALIENDRA et al. (1994), since this value correlates well with xylem hydraulic conductivity (RUST 1999). The data indicate a lower conductance of branch junctions with an abscission zone (Fig. 4). A lower hydraulic conductance reduces the operating range of stomata of the leaves distal to the zone, as the tree aims to prevent catastrophic xylem embolism (TYREE and SPERRY1988).

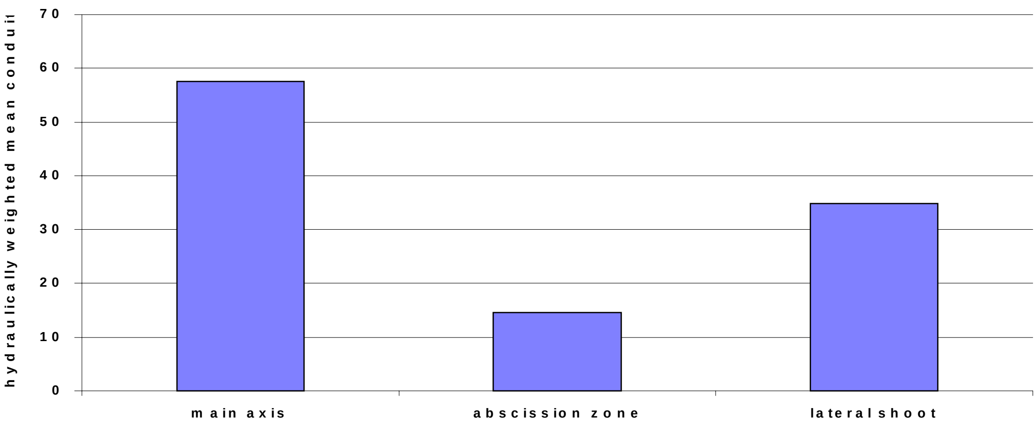

Figure 4: Hydraulically weighted mean radius of xylem conduits in the main axis, abscission zone and lateral axis

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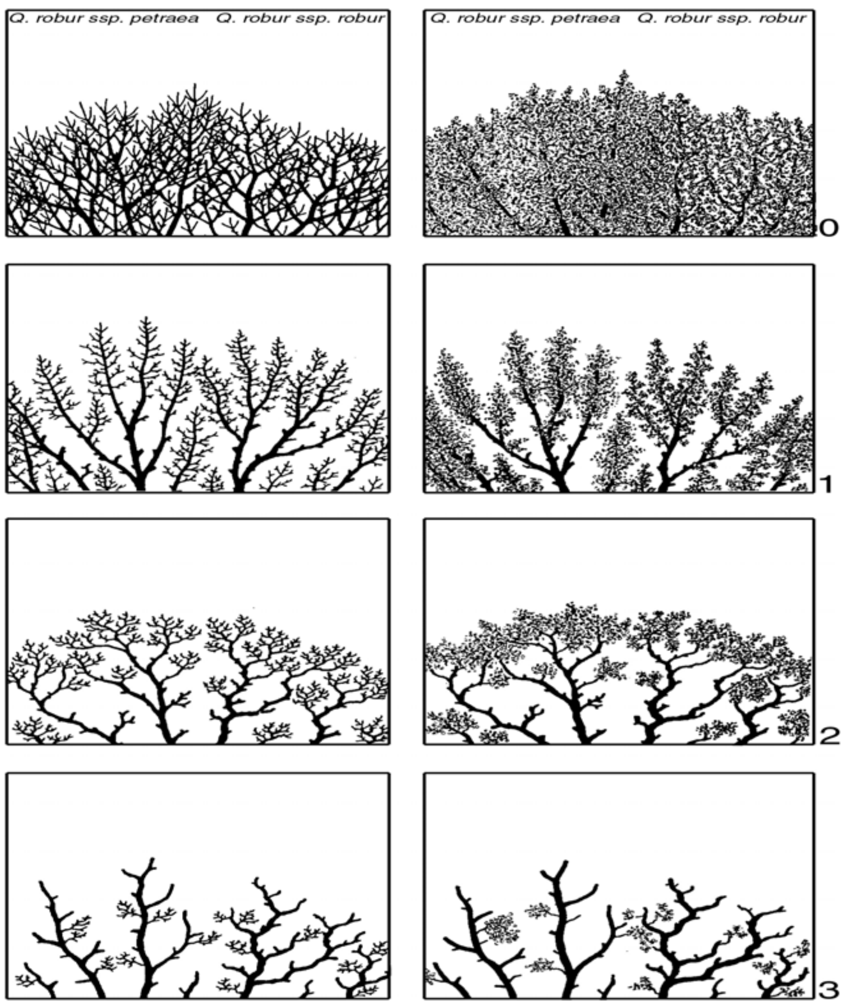

Figure 5: Vitality classes of European oak (from ROLOFF 1993)

2.2 Deactivation of abscission zones

The deactivation of the abscission zone was investigated in 900 branch junctions as well as in 200 epicormic shoots of mature solitary oak trees and juvenile oaks.

The samples were classified according to STRAHLER (1964). Hence, the shoots of the first order are unbranched, while those of the 2nd and 3rd order are branched.

The vigour of the investigated trees was classified on the basis of vitality classes (Fig. 5) determined by the branching pattern (ROLOFF 1993). To consider the foliation percentage is problematic in oak (spec. pedunculate oak) and leads to clear results only in vitality class 3. In the exploration stage (vitality class 0 = VC 0) the entire peripheral crown of oaks consists of a dense network of greatly elongated shoots (ROLOFF 1993). Decreasing vigour is apparent by the reduction in shoot lengths and a characteristic modification of the branching pattern Without exception abscission zones were located at the base of side axes. All abscission zones occur at the base of shoots which were formed from lateral buds. In no stage of ontogenesis of *Quercus robur* any abscission zone was found at the base of terminal shoots. Hence, shoots developed from terminal buds are not able to abscise.

Preformed abscission zones exist in all lateral buds. Whether and for how long the formation of an abscission zone will continue is of particular interest. Figure 6 illustrates the presence of abscission zones with respect to the branching order and the vitality class.

The ability to integrate branches is chiefly influenced by the vigour of the tree. The rate of integration decreases with declining vigour (Figure 6). The difference in integration rates is obvious. The investigated shoots of the 3rd branching order of VC 0 (most vigorous - the left pair of columns) were integrated completely, whereas 40-90% of the twigs of VC 2 (least vigorous – the right pair of columns) could still be abscised. In lateral shoots of VC0 an increased rate of integration is correlated with a lower age and a higher increment. Declining vigour alters both parameters. This change in growth dynamics is clearly demonstrated in VC 2. The increased bud scar frequency together with the reduced shoot elongation indicates a diminished branching rate (ROLOFF AND KLUGMANN 1997).

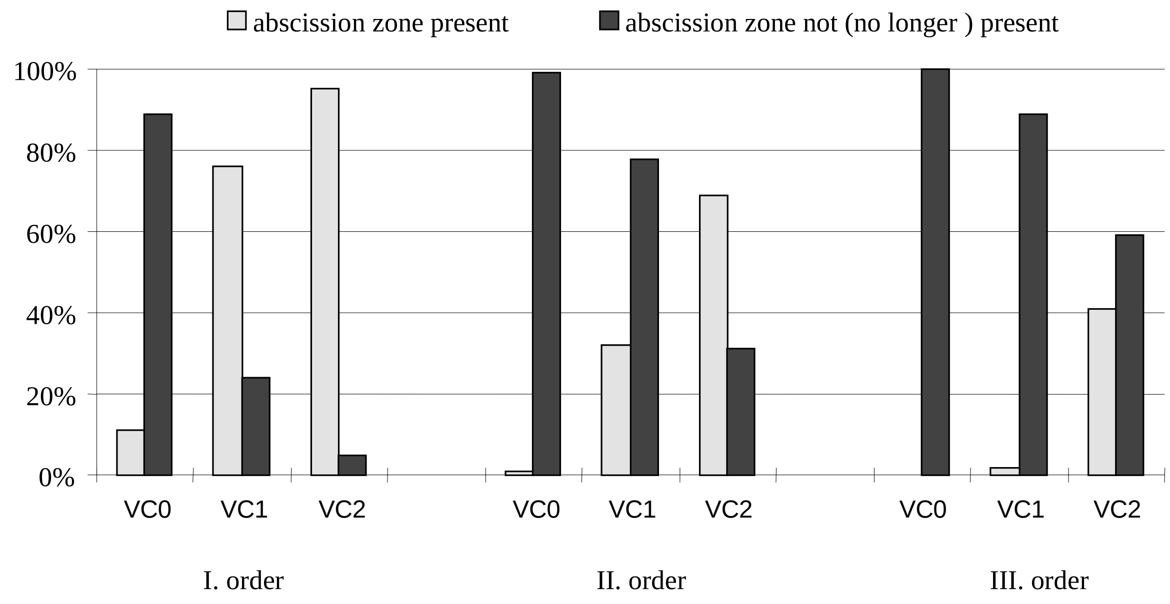

Figure 6: Presence of abscission zones depending on the STRAHLER branching order and the vitality class (VC)

3 Discussion

In *Quercus robur* the hydraulic conductance of branch junctions containing an abscission zone is apparently reduced as a result of its special anatomic features. As a consequence, average stomatal conductance might be lower distal to the zone. Twigs with an abscission zone at their base are connected to the hydraulic system of the tree only preliminary. Therefore, twigs with an abscission zone in their junction are in a situation designated as **'indifferent stage'**. In this stage the twigs are **'hydraulically separated'** from the regular macroporous system of the tree. The formation of regular xylem leads to their integration, whereas abscission disconnects the twigs finally. The integration of the longer (more vigorous) shoots improves their water supply, because the abscission zone-induced resistance decreases (RUST and HÜTTL 1999).

During ontogenesis, the hydraulic architecture of European oak undergoes fundamental changes because it is capable of cladoptosis. In stem junctions of juvenile oaks the formation of regular xylem takes place immediately after flushing, disabling abscission. In mature trees, the rate of integration decreases with increasing age and declining vigour (Fig. 7). This process has been confirmed by the rise of the number of abscission zones with tree age as well as with declining vigour.

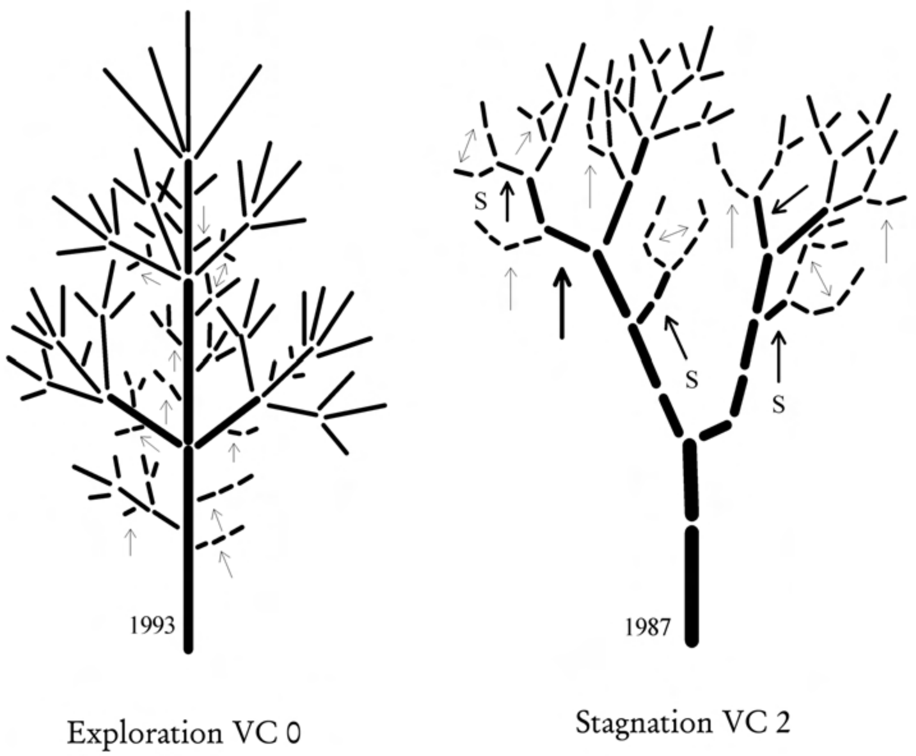

Figure 7: Twig abscission in different vitality classes

A secondary modification of the crown architecture by the abscission of less vigorous shoots becomes apparent. Our results indicate a mechanism which optimises the allocation of water and could contribute to the known drought resistance of European oak.

The absciseability gives an insight into the portion of branches where junctions with an abscission zone are still present. When this quantity is observed during a period of time (e.g. a growing season), it increases due to the formation of new abscission zones (shoots derived from lateral buds) or decreases due to integration or abscission.

Obviously, integration of absciseable twigs is predominant in years of high vigour and increased shoot elongation. In unfavourable years abscission zones are conserved, i. e. present abscission zones are not integrated. The reduced rate of integration increases the number of abscission zones within the crown. The consequence is a gradual increase of the hydraulic resistance within the peripheral branches. This is shown by the presence of abscission zones within the junctions of the higher branching orders. According to SPRUGEL ET AL. (1991) this is a basic requirement for attaining branch autonomy where branches do less compete than co-operate to ensure the survival of the whole organism. The ability of oak to abscise twigs enables the tree to modify the architecture of the crown in a secondary selection process among the hydraulically separated twigs and branches.

Obviously, absciseable twigs respond very sensitively to changes in soil moisture regime, which is demonstrated by the higher rate of twig abscission during summer droughts. The stimulus starting abscission could be a reduced rate of assimilation caused by lower average stomatal conductance in twigs with abscission zones, because their lower xylem conductance limits the operating range of the stomata in order to prevent xylem embolism. This reaction enables oak trees to continue photosynthesis of integrated twigs while assimilation and transpiration of the less vigorous separated twigs successively cease (Fig. 8).

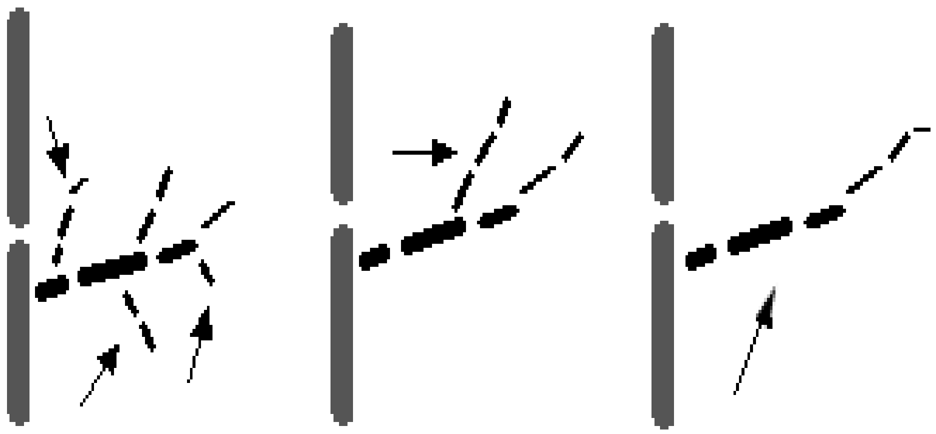

Fig. 8: Succession of cladoptosis

Based on our results a causal relationship between the symptomatology of the die-back process and twig abscission becomes evident.

At the beginning of oak decline synergistic factors like repeated insect feeding, frost, infestation with fungi, and periods of summer drought affect the vigour of the tree. During extended summer droughts the hydraulically separated twigs in the indifferent stage can suffer from higher drought stress than integrated twigs and their vigour is diminished. Additional loss of leaves by grazing caterpillars can then induce the abscission of the less vigorous twigs. Up to a certain level the damage can be sustained by the tree. However, a serious risk arises when negative factors prevail, preventing the compensation of lost storage substances. In this situation severe frost as well as fungal infestation (e.g., by *Phytophthora* spec., see BLASCHKE 1994a, b, JUNG AND BLASCHKE 1996) may lead to an irreversible damage to the root system. Often large parts of the fine roots, which are vital to water uptake, decay. Predisposed this way, the tree is particularly vulnerable to further fungal attacks which additionally reduce the xylem conductance due to tylosis formation. This set of factors directly affects the water supply of the crown (BLANK 1997). In this situation the tree is no longer able to sustain its older absciceable twigs in addition to the young shoots and the crown consists of integrated leaders with young shoots on their tips only. The special trait of European oak to optimise the allocation of a limited water supply via twig abscission results in a degeneration of the crown. The typical habit of this chronically damaged oak crown can be described as 'brush-like' leaf clusters (Fig. 9). Only at the beginning the die-back of oaks induced by 'complex causes' is reversible, because vigorous oaks manage to compensate the loss of twigs abscised in preceding years by epicormic shoots.

4 Summary

The process known as cladoptosis has been investigated in *Quercus robur* L. The results show an ontogenetic modification of the hydraulic architecture in pedunculate oak, which is controlled by the vigour of the tree.

A pre-formed abscission zone is present in all lateral buds during bud dormancy. Only terminal shoots do not form an abscission zone at their base and therefor can not be abscised. During juvenile ontogenesis the absciseability of the lateral buds in pedunculate oak is lost immediately after sprouting. In the further course of ontogenesis the formation of regular xylem (integration) within the stem junctions of the lateral shoots slows down. The absciseable twigs and branches are in an indifferent stage in which they are separated from the regular hydraulic system of the tree. In this stage hydraulically separated shoots are either connected by integration or disconnected by abscission. Unfavourable conditions increase the number of indifferent shoots. In this situation integration only occurs in the junctions of the most vigorous twigs.

Fig. 9: Declining symptom in European oak – brush-like leaf clusters

The constricted conduits within the abscission zone increase the hydraulic resistance. The increased number of abscission zones induced by unfavourable environmental conditions might enable the tree to confine runaway embolism during excessive droughts to the least vigorous branches. Thus, photosynthesis of the least vigorous twigs is reduced relative to the youngest and the integrated twigs because of reduced stomatal conductance during drought years. This special reaction optimises the water supply by distributing a given water flow selectively within the crown.

The seasonal dynamics of twig abscission reflects the environmental situation during the growing season. In years with favourable conditions (sufficient water supply) integration is predominant, vice versa water deficiencies increase abscission. Additionally, favourable conditions support formation of shoots from latent buds to compensate cladoptosis-induced loss of branches. Twig abscission points to a strictly enforced equilibrium of absorbing (root) and transpiring (leaf) surface in pedunculate oak.

Probably a vigorous root system is the prerequisite for the high capacity of European oak to regenerate. A root system weakened by unfavourable environmental factors is rarely able to sustain an active growth.

Finally the declining root system invokes the root/shoot feedback system. The obligatory response to the degenerated equilibrium is the increase of twig abscission which starts in the lower parts of the branches. The inability to compensate for the continuous loss of abscised twigs leads to the well-known symptoms in declining oaks: leaf clusters on young or integrated twigs and branches.

KEY WORDS: *Quercus robur* L., twig abscission, cladoptosis, hydraulic architecture, hydraulic conductivity, xylem anatomy, decline

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Studies on the complex of lignivorous microorganisms and wood decay fungi in relation to pruning techniques and wound treatments.

1. Introduction

Reduction of the tree crown by pruning in urban areas is often a need in order to avoid shading of building fronts, reduce discomfort of resident people and permit trucks and other large vehicles to move unhindered in the streets. Pruning of urban trees is one of the major problems in the management of urban landscape and, although necessary, it may be one of the main way of entrance of pathogenic fungi in the wood.

Pruning represent, perhaps, the most important predisposing factor of rot attacks. Rots are caused by a combination or succession of organism usually characterised by pioneer organisms (Bacteria, Mitosporic Fungi, Ascomycota), that overcome wood physical and chemical defences (Shortle *at al*., 1978; Anselmi and Govi, 1996). Wood decay fungi usually follow some months after pruning. Rot development is modulated by several factors (Vigoroux, 1999).

Compartmentalisation and high water content of wounded tissues represent the mechanisms of resistance that counteracted rot fungi (Basidiomycota) colonisation (Boddy and Rayner, 1983; Shigo, 1984; Chapela and Boddy, 1988; Boddy, 1992; Anselmi *et al*., 1996). However the extent of wood decay is also related to the ability of the tree to heal the wounds. Wound healing depends on the area of the wounded surface (Anselmi *et al*., 1996), but also on the time and technique of pruning and eventually on the protective treatments applied on the cut surfaces. In fact time, frequency and size of the amputations have different consequences on the physiology of the tree and on its behaviour toward wood destroying attacks (Raimbault, 1995; Clair-Maczulaitys *et al*., 1999). Commonly pruning must be limited to what is strictly necessary and should be avoided on large branches. Unfortunately pruning in urban contest, depending on reasons other than technical, is often carried out on large branches. Furthermore the effectiveness of protective treatments occasionally performed on wounded surfaces is not always evident (Shigo, 1984; Nicolotti *et al*., 1994).

In spite of many studies carried out in the last decades on these topics, results are often contradictory and incomplete. The aim of the present work is to evaluate the effect of time and technique of pruning, and type of protective treatments on the complex of micro-organisms involved in the rot phenomenon, as well as on the wound healing process and plant vigour.

2. Materials and Methods

The trials were conducted in a public park in Rome on 80-year-old sugar maple (*Acer negundo* L.) trees. Trees were 12 m high and 30 cm in diameter; main branches were numerous and sited at about 3 m (Fig.1). The last pruning was carried out in 1980.

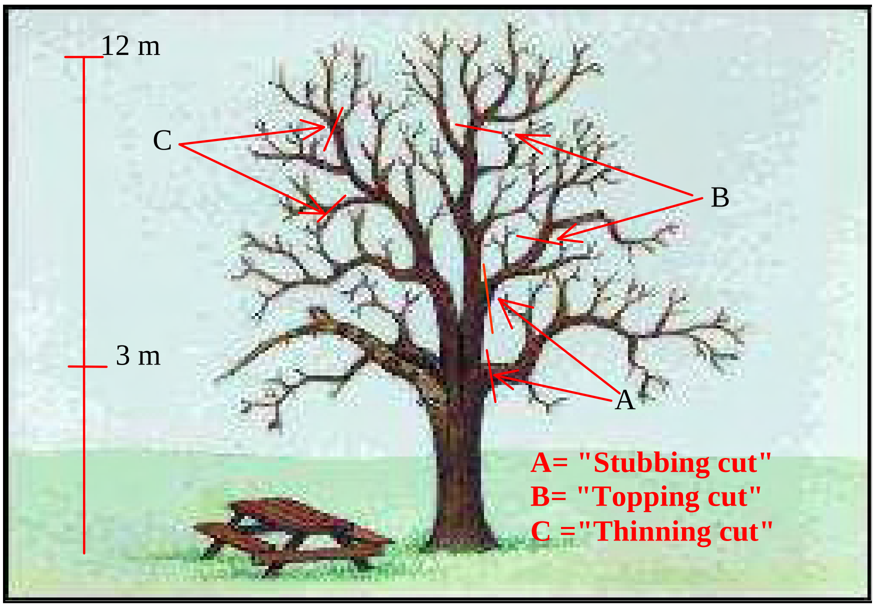


Fig. 1 - Pruning typology

Three typology of pruning were compared (Fig.1):

“stubbing cut”: it consists in removing the entire branches with cuts carried out near big branches or trunks. Cutting diameters are between 5 and 20 cm;

“topping cut”: it consists in cutting the branches leaving long stubs (1,5-2 m) with cuts far from lateral branches. Cut’s diameter are comprised between 5 and 12 cm;

“thinning cut”: it consists in cutting the branches leaving long stubs, with cuts close to lateral smaller branches. Cut’s diameter ranged between 5 and 10 cm.

Pruning was carried out monthly over a period of one year (Fig. 2).

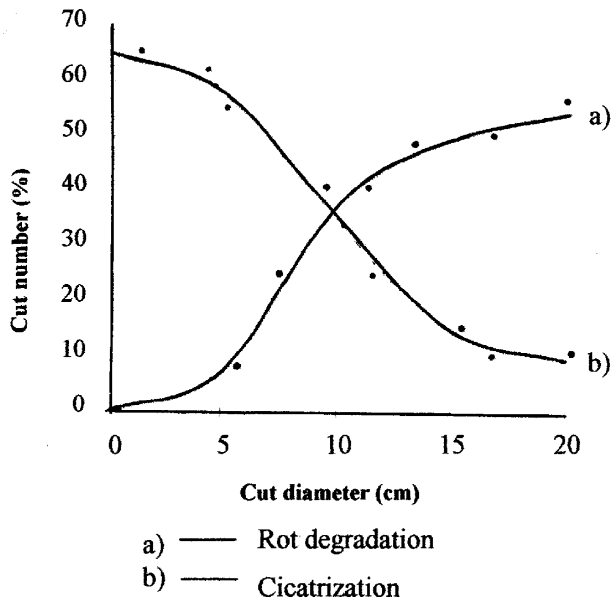


Fig. 2

At each pruning time, six trees were pruned with “stubbing cut” and “thinning cut”, and six with “stubbing cut” and “topping cut”. The resulted cutting surfaces were randomly treated as follow: (a) Lac Balsam®

(healing treatment); (b) Lac Balsam® mixed with 5% of Cu_2So_4; (c) Bayleton SK® (Bayer), containing Triadimefon as active principle; (c) no treatment (control).

The following parameters were evaluated over a 18 months period after pruning: the length and diameter of sprouts; the progress of leaf drop; the healing of cuts over 5 cm in diameter; the presence of callus tissues; the rot of cutting surfaces; the mycoflora just below the cutting surfaces; the presence of fruiting bodies on cutting surfaces.

Analysis of the wood mycoflora was carried out after 8 and 18 month from pruning on wood cores (2 cm of diameter) removed at a depth of 1,5-2 cm below the cutting surface. Following superficial sterilisation, each core was grind in a mortar with sterile distilled water in order to obtain an homogeneous pulp. Drops of this suspension were plated in Petri dishes containing Malt Agar + Streptomycin (60 ppm) or Malt Agar + Streptomycin (60 ppm) + Benomyl (4 ppm). The first Medium was selective for fungi; the second one was specific for Basidiomycota (Dhingra and Sinclair, 1986).

Most of the fungal isolates have been identified on the basis of morphology of their reproductive structures obtained on artificial media. In order to induce the formation of fruiting bodies in those isolates not able to reproduce on artificial media, they were inoculated in twigs of *A. negundo* and incubated for 4-6 weeks at lab conditions.

All data were processed with SAS System Program.

3. Results and Discussion

3.1 New vegetation.

Diameter and length of sprouts after one year from the pruning resulted different depending on time of pruning. Trees pruned in summer produced shorter and thinner sprouts than those pruned between December and April. Pruning period also influenced leaf drop that was delayed in trees pruned in Summers, determining risks of damages for early frost.

3.2 Cuts healing.

Healing of cuts was greatly affected by pruning period. As showed in Table 1, healing of cuts was greatly reduced in trees pruned between June and November. However ability of trees to heal the wounds was also related to the size of the pruned branch and pruning technique. Stubbing and thinning cuts promoted a rapid healing of cutting surfaces below 8-10 cm of diameter; these results are in agreement with those reported for other tree species (Anselmi *et al*., 1996). Percent of healed surface decreases by increasing the cutting diameter. Cutting surfaces in “stubbing cuts” over 20 cm in diameter showed less of 40% of healing (Fig. 2). Differently “topping cuts” slowed down the healing of wounds; only the stumps with a diameter below 5 cm showed a remarkable healing. All stump with diameter over 10 cm did not show any callus formation and rapidly were colonised by lignivorous fungi (Tab.1,2; Fig. 3).

3.3 Mycoflora colonisation.

A considerable number of fungal species were isolated from wood cores sampled 1-2 cm under the cutting surface. Among Mitosporic fungi and Ascomycota the most frequent were *Alternaria* spp., *Fusarium* spp., *Phialophora* sp., *Phoma* sp., *Acremonium* sp., *Gliocladium* spp., *Sclerotinia* sp., *Colletotrichum* sp. and occasionally *Cephalosporium* sp., *Drechslera* sp., *Graphium* sp., *Rhyzopus* spp., *Trichoderma* spp., and *Ulocladium* spp. (Tab. 3). Many isolates of Basidiomycota were obtained whose identification is still ongoing. Incidence and composition of fungi flora resulted associated with the typology of cutting, the protective treatments applied, and the time passed since pruning. Sensible differences were evidenced in the mycoflora composition obtained from isolation between “topping cuts” and “stubbing cut” (Tab. 3). Several stain fungi and a number of soft rot agents as *Acremonium*, *Phialophora* and *Fusarium* were isolated from “topping cuts” while only some ruderal fungi as *Penicillium* and *Rhyzopus* were obtained from “stubbing cuts”. In regard with Basidiomycota, the incidence of these fungi was higher in “topping cuts”, where wood degradation was evident, than in “stubbing cuts”.

With particular regard with "topping cuts", it has to be highlighted that incidence of Basidiomycota fungi, assessed after 1 year from pruning, was higher in cuts carried out in Summer than in those carried out in Spring (Tab. 3).

Antifungal treatments on cutting surfaces showed a sensible effect in reducing the percent of isolation of fungi (Tab. 3). Antifungal protection has never been absolute. Treatments with Lac Balsam alone didn't reduce fungi presence; in cuts carried out in winter this treatment seemed quite favour the development of fungi in the wood (data not showed).

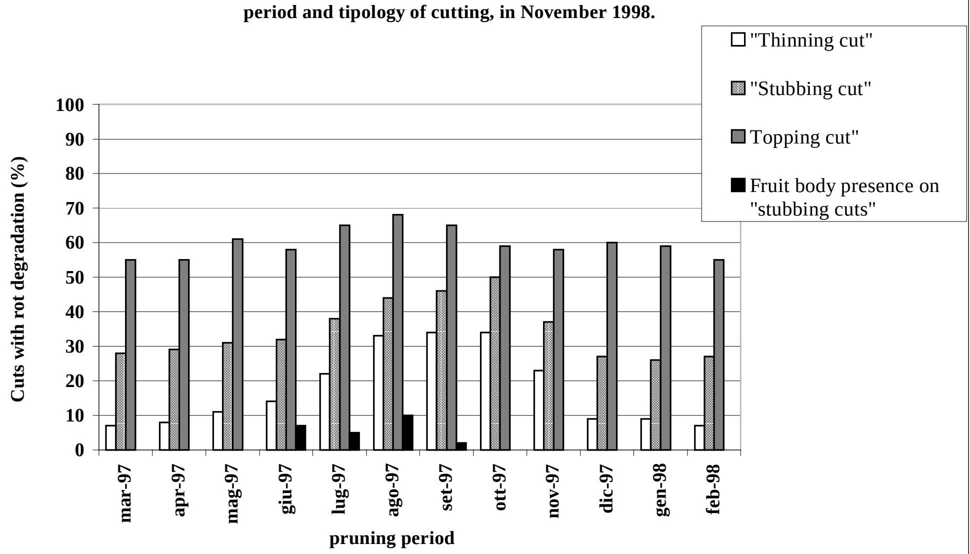
Tab. 1: Pruning on *Acer negundo* trees in different period of the year. Cicatrization of "topping cut" in relation with period of pruning and diameter of cutting surface in November, 1998
+ fair (cicatrization present on over 50% of cutting circumference)
- moderate (cicatrization present on 20-50% of cutting circumference)
-- weak (cicatrization present on less than 20% of cutting circumference)
--- very weak or absent (cicatrization present on less then 5% of cutting circumference)

Pruning period		**Diameter (cm)**		
n	**Date**	**<5**	**5<d<10**	**10<d<15**
1	March, 5th 1997	+	+-	-
2	April, 4th 1997	+	+-	-
3	May, 5th 1997	+	+	-
4	June, 5th 1997	--	--	---
5	July, 5th 1997	--	--	---
6	August, 5th 1997	--	--	---
7	September, 5th 1997	--	--	---
8	October, 5th 1997	--	--	--
9	November, 5th 1997	-	-	-
10	December, 6th 1997	+	+-	-
11	January, 5th 1998	+	+-	-
12	February, 6th 1998	+	+-	-
13	March, 5th 1998	+	+-	-

Tab. 2: Pruning on *acer negundo*: Percentage of "topping cuts" with evident wood degradation and presence of lignivorous fungi fruiting bodies, in relation with period of cutting in November, 1998.

Pruning period		**"Topping cut"**							
N°	Date	Control		Lacbalsam		Lacbalsam + Cu_2SO_4		Triadimefon	
		Necrotic stump (%)	Fruiting body (%)	Necrotic stump (%)	Fruiting body (%)	Necrotic stump (%)	Fruiting body (%)	Necrotic stump (%)	Presence of Fruiting body (%)
1	March,5th1997	55		58		53		55	
2	April, 6th 1997	55		60		55		55	
3	May 5th 1997	61		60		60		65	
4	June, 5th 1997	58	7	60	10	60	2	63	4
5	July, 5th 1997	65	5	63	6	70	6	73	0
6	Aug., 5th 1997	68	10	65	27	70	6	69	2
7	Sept., 5th 1997	60	2	58	2	65	0	63	0
8	Oct., 5th 1997	68		62		60		60	
9	Nov., 5th 1997	65		55		58		57	
10	Dec., 5th 1997	59		57		55		55	
11	Jen., 5th 1998	58		57		53		55	
12	Feb., 5th 1998	60		58		56		55	
13	March,5th1998	55		55		58		55	

Fig. 3 - Percentage of non treated cuts (10-12 cm in diameters) with evident rot phenomenona in relation with period and tipology of cutting, in November 1998.



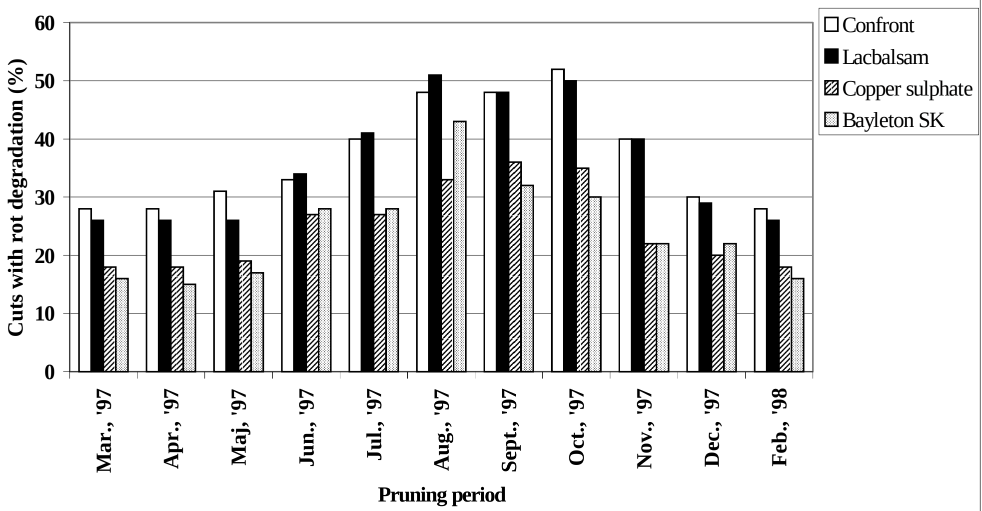
3.4 Rot development.

Wood degradation of cutting surfaces was due to “white rot” fungi. Rots developed more rapidly in “topping cuts” than in “stubbing cuts” and “thinning cuts”. Furthermore wood degradation was more evident in cuts carried out during Summer (Fig. 3). Particularly interesting is the effect of treatments on insurgence of rots. In “topping cuts” protective and antifungal treatments produced no relevant effect. In "stubbing cuts" treatments with Bayleton SK and Lac Balsam + Cu2SO4 produced a sensible reduction in the presence of rots compared with the control and Lac Balsam alone, that did not show any relevant effect in preventing rot phenomena (Fig. 4).

3.5 Fruit bodies development.

A number of fruiting bodies of Basidiomycota developed on “Topping cuts” surface (Fig. 3), in pruning carried out in Summer, independently from protective treatments. Among the most frequent: *Schizophyllum commune* (L./Fr.), *Coriolopsis gallica* (Fr.) Ryv., *Coriolopsis trogii* (Berk.) Dom., *Lopharia cinerascens* (Schwein.) G. Cunn and *Stereum* spp.

Fig. 4 - Percentage of "stubbing cuts" on stumps over 10 cm in diameter showing rot degradation in relation with pruning period and protective treatments.



Tab. 3: Pruning on *acer negundo* trees: Fungi isolated under cutting surface from "Topping" and "stubbing" pruning in relation with pruning period and protective treatments.

Pruning period	**March, '97**															
Pruning typology	**"Topping cuts"**								**"Stubbing cuts"**							
Sampling period	**November '97**				**November, '98**				**November, '97**				**November, '98**			
Fungi Genera	Triadimefon	Lacb.+Cu_2SO_4	Lacbalsam	Control	Triadimefon	Lacb.+Cu_2SO_4	Lacbalsam	Control	Triadimefon	Lacb.+Cu_2SO_4	Lacbalsam	Control	Triadimefon	Lacb.+Cu_2SO_4	Lacbalsam	Control
Acremonium		***		*		**		*								
Alternaria		*	*	***	*	*		***		*	*			**	**	**
Basidiomycota			**		*	*	**	**							*	*
Colletotrichum								**								
Drechslera																
Fusarium	*	*	*	*		*		**	*	*	**	***		*	*	***
Gliocladium																
Graphium																
Phoma									**	**	***	***		*	*	**
Phialophora					*	*				*	*	***	*	*	*	***
Rhyzopus																*
Sclerotinia							*									
Trichoderma																
Ulocladium																

Pruning period	**August, '97**											
Pruning typology	**"Topping cuts"**								**"Stubbing cuts"**			
Sampling period	**November, '97**				**November, '98**				**November, '98**			
Fungi Genera	Triadimefon	Lacb.+Cu_2SO_4	Lacbalsam	Control	Triadimefon	Lacb.+Cu_2SO_4	Lacbalsam	Control	Triadimefon	Lacb.+Cu_2SO_4	Lacbalsam	Control
Acremonium			***		**			*				
Alternaria	**	*	*	***		*						
Basidiomycota					**	*	***	***			*	*
Colletotrichum										*		
Drechslera								*				
Fusarium	*		*				*		*		*	*
Gliocladium												
Graphium												
Phoma									*	*	**	***
Phialophora					*			*			*	*
Rhyzopus		*				*						
Sclerotinia						*	**					
Trichoderma												
Ulocladium												

* = Rare
** = Frequent
*** = Very frequent

4. Conclusions

In conclusion it appear evident that the pruning technique, the dimension of cutting surface, the time of pruning and the protective treatments are factors to be seriously considered in management of trees in urban areas. As showed in the Results and Discussion the above mentioned factors has a sensible effect on re-sprouting, healing of cutting surfaces, colonisation by pioneer and rot fungi, and insurgence of rot phenomena.

Some practical suggestions can be made on the basis of the reported results on pruning activities in Mediterranean areas:

- it is important to carry out pruning between December and April and never postpone or anticipate it;
- "thinning cuts" represent the best pruning typology to be used; however in the cases it cannot be applied, "stubbing cuts" should be preferred to "topping cuts";
- the diameter of branches to be pruned should not exceed 10-12 cm, in order to guarantee a rapid and complete healing of the wound and reduce the risk of rot phenomena.

It would bedesirable to tests new antifungal products useful for cutting surfaces protection, including biological ones.

Finally further efforts should be put in studies on the role of different fungi in rot processes and their possible presence in woody tissues as endophytes; in this case use of protective products should be re-examined.

Abstract

Different typology of pruning, to evaluate the effect of time and technique of pruning, and type of protective treatments on the complex of micro-organisms involved in the rot phenomenon, as well as on the wound healing process and plant vigour, were conducted in a public park in Rome on 80-year-old sugar maple (*Acer negundo* L.) trees.

Pruning period, diameter of cutting surface, chemical wound treatments influenced sprouts development, cutting surface cicatrization and rot development in *A. negundo* trees. In the Mediterranean area pruning carried out in December-April produce the best results.

Pruning carried out too early (October-November) or too late (May-June), have negative effects on sprouts development. Pruning carried out during summer greatly reduce sprouts length and diameter, delays the healing of wounds and the leaf drop. Furthermore it has been evidenced a high incidence of rot fungi and wood degradation in cuts carried out in this period

Pruning technique also affects healing and occurrence of rot phenomena. "Thinning cuts" and eventually "stubbing cuts" should be preferred , diameters of cuts not exceeding 10-12 cm.

Use of protective treatments on cutting surface was not always encouraging. In any case, protection was never total.

Acknowledgements

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Keywords: pruning, protective treatments, wood decay fungi.

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Pruning in order to ensure a natural growth pattern of young trees

Introduction

What does pruning mean ?

Pruning causes rejuvenation of the tree. If the tree shows sufficient vitality, new shoot growth develops. New shoot growth ist stronger, if pruning is done in winter after leaf drop as opposed to pruning during summer.

Pruning leads to more pronounced branching with more lateral shoots.

New shoot growth after pruning ist connected with healther leaf development.

Since pruning causes more shoot growth, the vegetative growth suppresses flower bud set.

Outline for growth development

The higher the position of a shoot within the tree is, the stronger the shoot will grow. This means, that the shoot at the top of the tree develops the strongest growth.

The steeper the branch angle at the inserting point to the trunk is, the stronger the branch will grow.

Side branches on the same level stemming from different positions of the trunk show the same growth pattern. A higher position of the top of the branch means stronger growth and a lower position means weaker growth.

New shoot growth preferably will develop from the upper side of the branches.

Targets for ensuring natural growth pattern

Natural shaping typical for each species should be maintained, thus ensuring a healthy growth development. Crown development true to species at a young age is characterized by the following points.

The top of the tree regarded as trunk elongation must have a dominating position.

Side branches are situated much lower than the top - but on the same level.

Side branches are well filled with smaller twigs.

A young tree in healthy conditions shows sufficient yearly shoot growth.

Problems in shaping a tree crown in a natural way

The position of trunk elongation is too high. Crown evolves into an oblong shape.

The leading shoot is not dominating, consequently the top and the lateral branches grow as a fork.

The crown develops in an unbalanced way because of different branching angles and different levels of side branches.

The competition branch outgrows the leader shoot.

Faulty distribution of side branches causes obstruction of the leading shoot.

New shoot growth on the upper side of branches or on bent trees emerge.

Bad wound healing of trees with poor vigour occurs.

Solutions

Young aged faulty branches or shoots should be removed in order to maintain true to species trees, since big wounds on older trees can lead to tree losses.

Only through natural crown development can healthy growth and sufficient tree stability be achieved.

Pruning within the vegetation period leads to better wound closing and reduction in shoot growth.

Pruning in the summer may favour generative growth, that is more blossom bud set may be produced and also flower buds may burst a year in advance.

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Modern models in tree architecture as a helpful tool for natural pruning

<u>Introduction</u>

Pruning is a more or less intense traumatisation of trees. It is desirable to do so in accordance with a tree's nature and not against it. The skill to prune naturally either requires long practical experience or good models and programs. In order to predict how a certain tree will react on an arborist's work its growing strategies should be understood. For the practical use in tree work, morphological models are sufficient.

Every tree variety has its typical silhouette. The specific silhouette also occurs when a group of the same variety grows close together and it will even be restored by reiterates some years after a severe traumatisation (e.g. thunderstorm, snow load, incorrect pruning). Recent approaches have been made by F. Hallé (*Modular Growth*, 1986) and C. Edelin (*Organization Patterns*, 1991). For tree work it is necessary to overview a tree crown as a whole. The *Model of Competition* helps for this purpose (Pfisterer, 1999 b). A second tool for natural pruning is to understand the different branching patterns in trees and shrubs. Typical branching leads to a corresponding *architecture* (Hallé at al, 1970, 1978). For practical purpose in tree work one architecture model (Rauh's model) was designed too wide ranging by the authors, so it has to be separated into 3 subdivisions (Pfisterer, 1998 a).

<u>Model of Competition</u>

Darwin's proverbial 'Struggle for Life' not only occurs between neighboring trees within a forest stand. Remarkable competition also exists within a tree crown (Pfisterer 1999 b). The mechanism seems to be primarily a source-sink relationship (Huber 1928, Zimmermann 1983, Bauerle et al. 1999). In any branch, a distinct correlation exists between water supply and photosynthetic rate. The better a branch is irradiated, the higher its photosynthetic rate and the higher its need for – and supply with – water. A well supplied branch produces a higher amount of hormones to control its undernourished neighbors, growing in the shadow or lower in the crown. This competition leads to an imbalance between dominant and suppressed branches. Whether a branch is dominant or not can be assessed by its shoot length and growing direction. Erect branches reaching to the canopy usually dominate their flat growing, lower neighbors.

The model contributes to a better understanding of the correlations within a tree crown, formerly described as *Apical Dominance* (Troll 1959) or hierarchic and polyarchic Pattern of Organization (Edelin 1991). The amount of competitive power between leader and side branches decides whether a tree crown's organization is hierarchic or polyarchic. The crown of a fir (*Abies spec.*) is hierarchically organized. All trees with a single leader do the same. In contrast adult french pussy willows (*Salix caprea*) and sycamore maples (*Acer pseudoplatanus*) usually have flat, polyarchic crowns with several axes of corresponding dominance. Young trees of both varieties are hierarchically organized.

Shrubs generally develop into colonies of codominant axes. An axis itself may be organized more or less hierarchically. This is why large, old shrubs may grow into a tree shape (e.g. common elder, *Sambucus nigra)*.

Hierarchically organized trees can do the same after the leader (and the apical dominance) has been weakened or lost.

Even one single branch from below may straighten up (*Epinasty*) and develop a secondary crown (*Reiteration*; Oldeman 1974). The purely morphological description can be used for tree work, if we assume, that the different patterns are the result of the actual quality of competition, typical of a certain tree at its present age.

During a tree's long life the crown may change its hierarchy and even its branching pattern (*Crown Metamorphosis*, Edelin 1986; Pfisterer 1998 b). Crown metamorphosis occurs in all tree architectures typical of temperate climate (except palms and bamboo). Competition and metamorphosis as its result can be used for planning tree work.

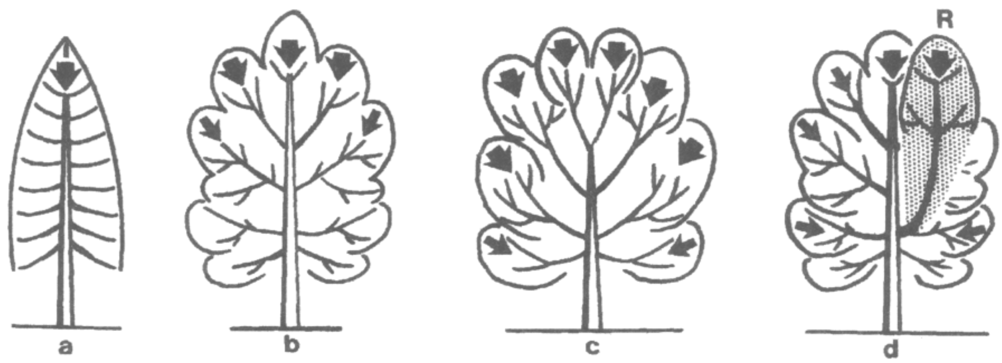


Figure 1: Various degrees in competition.
a Tree crown with absolute hierarchy.
b Small colony of codominant leaders.
c Polyarchically organized canopy.
d A suppressed branch has produced a reiterat (R). After having reached the canopy the reiterat develops a dominance similar to the leader.

In addition to the concept of competition there is another model which is important for natural pruning: the catalogue of Tree Architecture, revised for tree work.

Models of Tree Architecture

In 1970 Francis Hallé and Roelof A.A. Oldeman published their 23 models of tree architecture (Hallé and Oldeman, 1970, Hallé, Oldeman, Tomlinson, 1978). For temperate climate, the catalogue can be reduced to ten. The models describe the different branching patterns and growing strategies in woody plants. Trees of a similar architecture can be pruned similarly. The authors named their models after famous botanists; for better understanding typical trees are added in brackets.

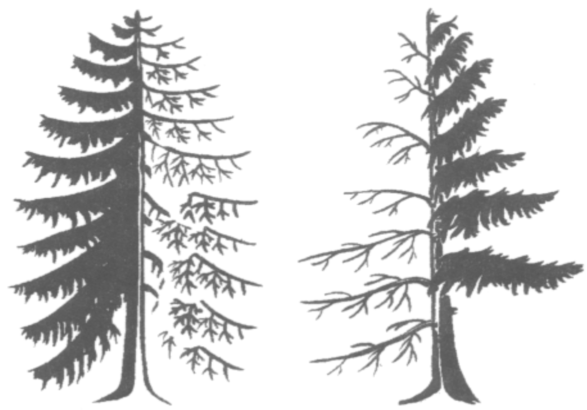


Figure 2: Massart's Model (left) and Attim's Model (right)

Massart's Model (*Abies* Type), Attim's Model (*Cupressus* Type)

Trees with an orthotropic trunk with tiers of plagiotropic branches. Massart's Model: regular tiers (e.g. *Abies, Picea, Sequoia, Metaseqoia, Cedrus, Taxodium, Taxus, Ginkgo, Ilex aquifolium*). Hierarchy may be complete or it may decline when the tree grows old (*Cedrus, Ginkgo, Ilex*). Attim's Model: in temperate climate there is one family only: *Cupressaceae*. Branching is less regular. Pruning of both models is similar. Crown thinning and raising is recommended. Crown reduction is difficult. Heading leads to a multiple crown.

Rauh’s Model

The architecture is determined by a monopodial trunk which grows rhythmically and thus develops tiers of branches, the branches themselves being morphogenetically identical with the trunk. One of the most popular architectures in temperate climate. For the purpose of pruning the concept of this model was too wide ranging, including trees with a regular growth such as pine, poplar and maple, trees with a more irregular growth such as live oak, walnut and most of the fruit trees and thirdly shrubs of both branching patterns regular: e.g. cornelian cherry, irregular: e.g. hazelnut, juneberry. For practical use it was necessary to divide this model into three sections (section I: trees of regular growth, section II: trees of irregular growth, section III: shrubs, Pfisterer 1998 a). To separate the shrubs was not necessary, their reactions after being pruned are similar. Shrubs of this architecture show an extreme basitony and mesotony. This is why pruning inside an axis is not recommended.

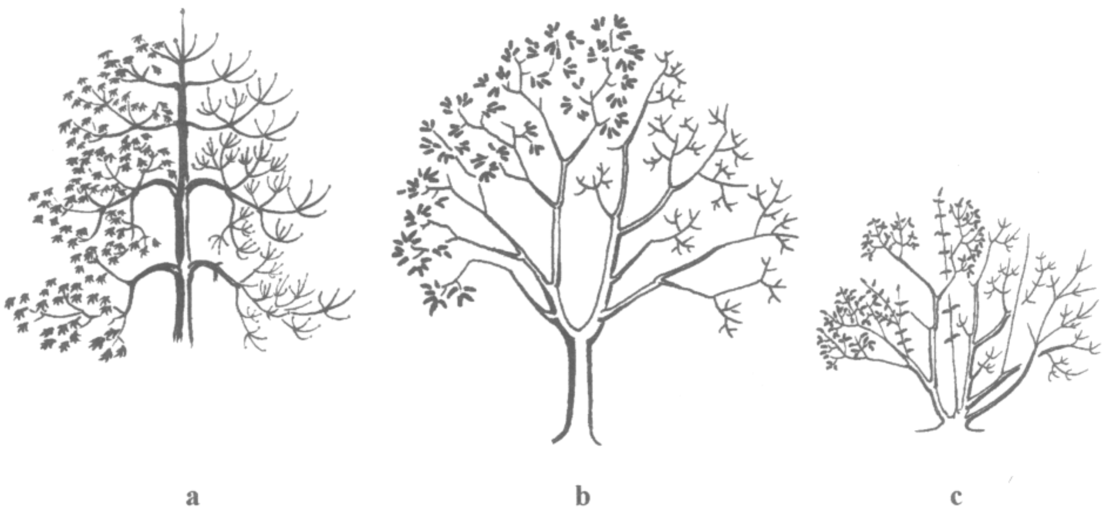


Figure 3: the different shapes in Rauh‘s Model. a: Section I (Candelabrum Shape), b: Section II (Fruit Tree Shape), c: section III (Shrubs of architecture a and b)

Rauh’s Model, Section I: Candelabrum Shape (*Acer-Pinus* Type)

Candelabrum-like crowns (e.g. *Pinus, Acer, Populus, except P. tremula, Quercus rubra*). Lateral branches preferredly develop at a shoot’s top leading to dense crown surfaces and bald inner parts. Crown thinning and raising are easy to do. Crown reduction is only possible if the crown is sufficiently branched in its inner parts. To keep a large growing tree small (e.g. for shade tree purposes or in a cemetery), the crown can be colonized at an early stage (removal of the leader).

Rauh’s Model, Section II: Fruit Tree Shape (*Malus* Type)

Instead of terminal clusters (Rauh I) lateral buds occur in a spiral arrangement along the axis. This makes the architecture more flexible. Aged crowns are more or less polyarchic. Most temperate fruit trees develop according to this architecture, examples are *Quercus, except Q. rubra* (Rauh I) and *Q. palustris* (Massart); *Juglans, Crataegus, Sorbus* etc.).

Rauh’s Model, Section III: Shrubs (*Spinosa* Type)

Shrublike plants of Rauh’s model from either section I or section II. A more distinct differentiation is not necessary because pruning is nearly the same. Their extreme mesotony is the problem. If a stem is shortened, the rest of it will be covered with reiterates next year. So shrubs of this model can be thinned only by completely removing some older axes. Most of the *Rosaceae* e.g. *Amelanchier, Choenomeles, Malus x floribunda, Potentilla fruticosa, Prunus spinosa, Rosa*. Candelabrum shape e.g. *Cornus mas, Cotinus coggygia, Daphne cneorum, Hippophae rhamnoides.*

Troll's Model (*Fagus* Type)

The second architecture which is very popular among temperate trees and even more flexible than Rauh's model. In contrast to Rauh II Troll's model describes tree forms typically decurrent. All axes develop plagiotropically, the architecture being built by their continual superposition. Young trees may develop a leader, aged crowns usually are polyarchic. Pruning is similar to Rauh's model, section II (*Malus* Type). *Carpinus, Celtis, Fagus, Tilia, Ulmus,* and one coniferous genus, *Tsuga*.

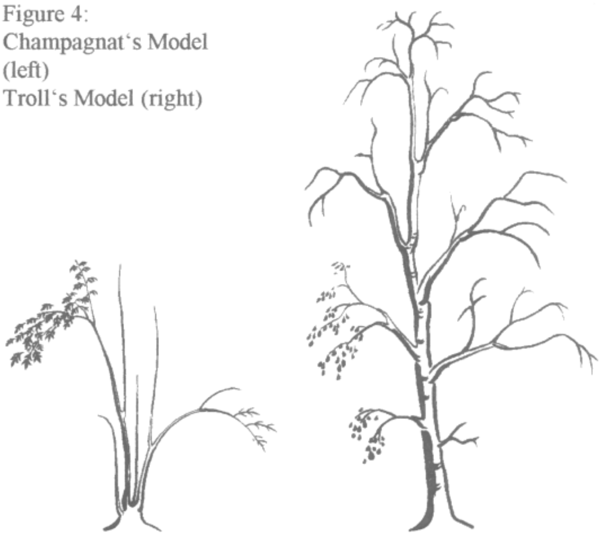


Figure 4:
Champagnat's Model (left)
Troll's Model (right)

Champagnat's Model (*Sambucus* Type)

Shrubs of an architecture resembling Troll's model. Shoot elongation is done with reiterates (mesotony). Reiterates occur from the base (basitony) or an axillar bud develops into a new leading branch (mesotony). Aged main axes can be pruned back to a secondary leader without provoking reiterates. Shrubs of this model can be pruned in a more sophisticated manner than shrubs following Rauh III (e.g. *Buddleja, Forsythia, Philadelphus, Sambucus, Spiraea, Tamarix*).

Scarrone's Model (*Aesculus* Type)

Development of the trunk resembles Rauh's Model. Branches grow orthotropically, ramification is sympodial because of terminal flower buds. Branches elongate from axillar buds. In temperate climate two typical representatives: adult trees of *Aesculus* and *Liriodendron*. During their life span both species undergo a metamorphosis. Young *Aesculus* develop after Rauh I, similar to *Acer*; young *Liriodendron* develop after Massart, similar to *Ilex.* Pruning of young trees follows the rules described for Rauh's or Massart's model. In aged trees crown thinning is possible as well as reducing branches that are too long. The polyarchy of aged canopies must be respected. Crown reducing should be carried out on all or at least most of the codominant leaders.

Koriba's Model (*Ailanthus* Type)

Ailanthus and *Catalpa* are typical representatives of this model. In contrast to Aesculus (Scarrone's Model) the stem also develops sympodially. This is why *Ailanthus* becomes decurrent at an early stage. Crown thinning and raising is easy. Crown reduction must respect the canopy's polyarchy.

Fagerlind's Model (*Cornus* Type)

Usually shrubs. Typical representatives are flowering dogwoods, e.g. *Cornus controversa, C. florida, C. kousa, C. macrophylla*; *Arbutus, Enkianthus.* A monopodial stem bears tiers of sympodial branches. Flowers develop from terminal buds. Hierarchy is not very strong, Reiterates may occur from the bottom or from inner parts of branches. Trees of this architecture model develop flat canopies when aged, shrubs expose flat layers of branches on different levels. Crown thinning and removing of suckers (*reiterates*) only are recommended. In old shrubs senescent main axes can be removed completely, if young shoots have developed.

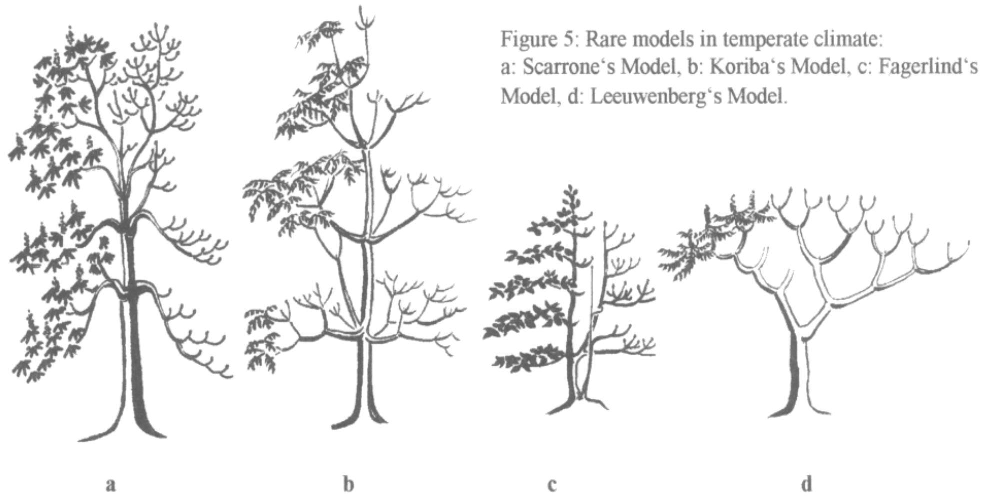
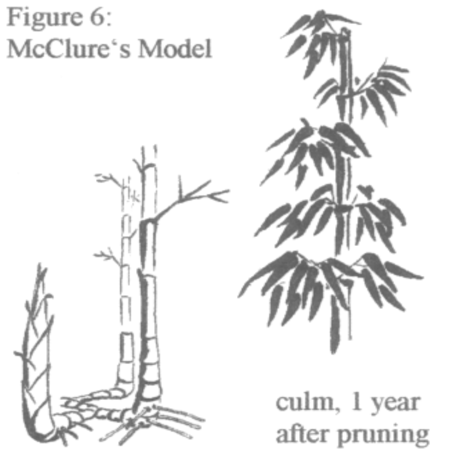


Figure 5: Rare models in temperate climate:
a: Scarrone's Model, b: Koriba's Model, c: Fagerlind's Model, d: Leeuwenberg's Model.

Leeuwenberg's Model (*Syringia* Type)

The model with the most polyarchic architecture in our parks. Adult plants bear terminal flower buds on every branch. Branch elongation occurs sympodially by lateral buds; terminal buds usually develop a flower. Side branches show similar dominance. No leader exists, old plants have flat canopies. Plants typical of the architecture are *Rhus*, *Syringia*, *Pieris*, *Rhododendron*. Crown thinning and lifting is easy to do. Crown reduction is only possible on small twigs. Buds for rejuvenation should be visible. Pruning back to sleeping buds will damage the natural structure for years.

Figure 6:
McClure's Model



Mc Clure's Model (*Bamboo* Type)

Two distinct systems of axes: plagiotropic rhizome systems underground, above ground grass like stems of two different axes. Main axe bald and orthotropic, side branches in layers and bearing leaves. Orthotropic axes do not reiterate and stop growing after an extension which is genetically determined. Axillary buds exist at the bases of side branches. A main axe pruned back cannot extend a second time. If side branches are shortened, axillary buds reiterate dense layers of foliated branches.

Discussion

Modern morphological tree models can contribute to a better understanding of a tree's development either undisturbed or disturbed. The individual architecture of a certain tree is the result of three genetically determined regulating mechanisms, BRANCHING PATTERN, COMPETITION between the axes within a tree's crown and the ability to REITERATE. Ramification, typical of a certain variety leads to a corresponding branching pattern of stem and crown. The quality of competition leads to a certain organization pattern within a crown. A dominant leader will develop a new crown organized in an absolute hierarchy.

Weaker leaders develop crowns with a less strict hierarchy. Leaders of similar or weak dominance lead to polyarchic crowns or shrub-like forms. The ability to reiterate decides how a tree will react to a traumatisation. Reiteration from sleeping buds leads to new shoots (i.e. suckers) polyarchicly organized. Reiteration by epinastic movement of an existing branch leads to a new shape of crown which is nevertheless organized in a fashion similar to the crown before it was traumatized.

Observation of the different mechanisms regulating a tree's individual shape assists in the planning of any tree work in strict accordance with the particular tree's nature (Pfisterer 1996, 1997, 1998 b, 1999 c). A tree can naturally be pruned for different purposes (Pfisterer 1999 a), rejuvenated (Pfisterer 1998 d) and even Bamboo plants can be pruned according to their nature (Pfisterer 1999 e).

Summary

Modern models in tree morphology refer to our actual knowledge of plant physiology and recent research with branching patterns and growing strategies of woody plants. The article refers to the practical use of recent tree models typical of woody plants in temperate climate: the *Model of Competition* and the *Models of Tree Architecture*. The models serve as a basis for a program in natural pruning.

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Session 6 : Methods and procedures for plant protection in urban areas

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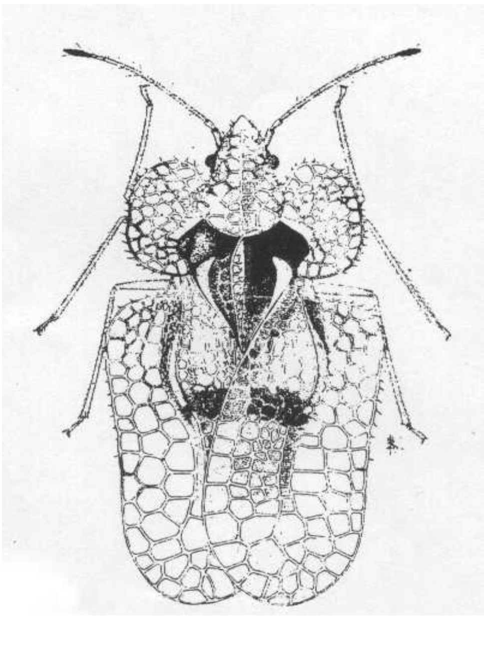
Implementation and upgrading of Integrated Pest Management as part of urban biodiversity's challenge

Introduction

Early in this century, we will have to deal with the global climatic warming and higher pollution, especially in our crowded cities. Coming from the East and the South, some new pests will probably threat our parks. The dispersal behaviour of such well acknowledged pests as *Cameraria ohridella* , *Corythucha ciliata* and *Metcalfa pruinosa* will seriously emphasise the need to take redeployed management programs based from Integrated Pest Management in agriculture. So far, whilst considerable effort has been devoted to pest control in agriculture and horticulture (Simon et *al.*,1998; Rieux, Simon et Defrance, 1999) very few attempts have been implemented for urban forest pest control in Europe. Such an obvious factor as productivity, which mainly sustains IPM programs elsewhere, is rather absent from urban forest management. Therefore, aesthetic injuries seem to slip away the durability of the stressed trees themselves. Before a large phenomena of depressed and depleted urban forests occurs, we should quickly set up highly specific packages of technologies and know-how, both being usually too disconnected from each others for our concern.

The plane lace bug, a typical european, non indigenous, urban forest pest : a mini-review

The plane lace bug, *Corythucha ciliata* Say - *Heteroptera Tingidae* - also called the "tiger" bug, is a phytophagous bug of approximately 1/8 to 3/16 inch long. It feeds at the lower face of the leaves of *Platanus* spp. on their cellular content. This alimentary specificity is only observed in the European dispersal range of the insect. Adults are yellowish-white in colour with a brown spot on the elytra. It's now acquired that since its spread over Europe from Padova in the mid sixteen (d'Aguilar, 1982) to Nantes - where it is now a pest - , in France, traffic and transportation have considerably enlarged the dispersal area of the pest (Malausa, 1998, pers. com.). Apart this somewhat foreign reason to the insect's biology, this bug has some interesting biological particularities. Amongst them, the female stays in the vicinity of its young progeny : this is, typically, maternalism.



The plane lace bug

As a result, during the first larval stages, the larvae stay in patch beside the leaves and quickly scatter before falling together at the slightest disturbances. This can be observed as well if one or two larvae are selectively disturbed in the patch. We know that an alarm pheromone is released in the group (Aldrich *et al*., 1985). All of those behaviours have to be carefully studied within an Integrated Pest Management program. In Europe, *C. ciliata* has very few efficient acknowledged predators. As a result, noticeably in the East of France, the foliage can be totally whitened- with, sometimes, in hardly attacked trees, more than one thousand eggs by leaf ! – in the mid summer (Euverte, 1981). Then the leafs drop before autumn. Note that the eggs - oviposited in the leaf- are noncleiodic that is dependent on surrounding leaf tissue for moisture to complete development. If we now look into the interactions between the bug and its predators, it appears that some species of chrysopids larvae are more susceptible than the others to the exsudate fence and exocrine secretions produced by the bug. The lethal activity of this exsudate – which contains acetogenins acknowledged as nematoicidal (Neal, Oliver and Fetterer,1995) - to natural enemies has still to be experimented. So, a lot of work has to be performed in order to control this pest which has developed peculiar adaptive behaviours which offer to it a highly survival rate in our European countries. Interestingly, while in Europe the bug overwinter at the adult stage, in Florida, it's at the egg stage. If we take care of the weather conditions, global climatic changes have quickened the dispersal of the pest towards the North (Jancel, pers. comm., 1998). Under favourable climatic circumstances, scare sources of bugs can, in few years, wholly attain the planes of a town (Dupont, pers. com., 1998). Also, it's important to know that Plane water deficits should determine the feeding preference of *C. ciliata* as it is observed with C. *arcuata* on *Quercus alba* (Connor,1988).

<u>Conducting a multidisciplinary approach for a successful urban Integrated Pest Management ; some important disciplines to set up</u>

- First of all, applied entomology tackle the screening of the beneficial arthropods and natural enemies. For beneficial arthropods, there is a need to look at them in the natural dispersal area of the pest (for the sycamore lace bug, it will be in the United States). Then, the acclimatisation of such non indigenous predators has to be carefully taken in consideration (Rabasse, pers. com., 1999).
- Invertebrates pathology devote to the screening of entomopathogenous strains and micropesticides
- Chemical ecology and organic chemistry study the exsudate defence and pheromonal secretions, the use of pheromones and other semiochemicals in targeting, trapping and monitoring (Nordlund, 1976, Jones, 1994).
- Vegetal biology and horticulture help to select minutely the right plant to the respect of the conclusions of others skills within Urban Integrated Biodiversity program.
- Applied physics and technologies devote to the building up of new monitoring systems (see below)
- Of course, there is a political background which determine the land use. So, to work jointly with politicians and urbanists is one of the determining priorities for urban ecological projects achievement.
- Finally, urban ecology and, for our concern, its biodiversity counterpart, is a difficult discipline which implies the reunion of numerous specialities developed in a paradoxical environment where mankind like some natural resting-places within a somewhat artificial way of life.

Howbeit, every people who really play a role in urban green spaces have to think differently, with determination, the way they do their job.

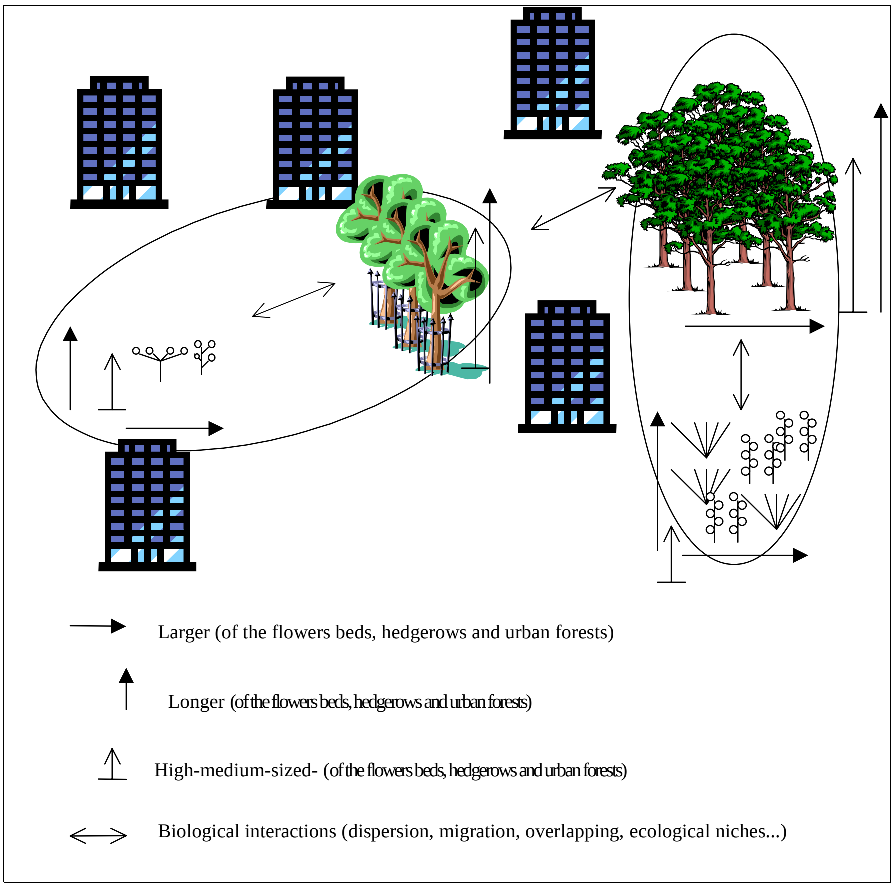
<u>Some recommendations in order to favour sustainable development in urban green spaces:</u>

Intended to horticulturists and gardeners, multifoliate varieties that traditionally replace natural varieties bearing pollen and nectaries should be selected then planted with great discernment in order not to lesser parks biodiversity and favour, then maintain auxiliaries in the vicinity of the preys. So, Honey flies that feed on nectar will oviposit on each plant which will host, for example, aphids. With others predators, by cleaning the plants, they can eventually prevent the installation of the ants which breed and carry aphids (probably coccids also). Nonetheless, it's true that ants contribute to the destruction of numerous caterpillars and insect pests. Some aphidophagous insects like ladybirds feed on pollen or nectar as substitution or transition meal (Hemptinne, 1989). If such meal if not present at the right time and at the right place, some important predators may fly away or disappear. The situation is the same for predatory mites (Baudry, 1999, pers. comm.). A lot of perennial plants protect numerous natural enemies during winter (Thomas *et al*., 1991). Hedgerows can host a lot of arthropods and the choice of appropriated species is important for urban biodiversity and pest management (Simon *et al*., 1998). What can be a severe factor of destruction or drastic diminution of overwintering predators is the complete removal of dead leafs and dead twigs in parks. We know the importance of shelters in insect pests management (Lewis, 1970). In some cities, even the leafs fallen into hedgerows, and which can offer shelters for winter, are forced out and collected. It's a typical example of the application of sanitation policies in urban green spaces which are based on a total misinterpretation and erroneous understanding of urban biodiversity. Of course, such cleanings will also affect insectivorous birds which fed on little invertebrates of the litter or in dead wood (Cottu, 1999). The removal of dead leafs, multifoliate varieties and herbicidal treatment –even selective treatment of susceptible areas- act, separately and synergistically, as major factors for recurrent infestations. So, all the complexity of trophic levels in urban ecosystems, which is widely dissimulated, actually appears when we try to understand and manipulate this environment in a way that tends to favour biodiversity and quality of life. A urban forest, moreover a young one, can be compare with a cereal crop. It will be highly susceptible to insect pests and will host very few predators if we do not care to its appropriate management (Watt,1965). Also, a factor which determine a dramatic and successful dispersal of pests in future is their resistance to pesticides. About pesticides, it seems once more necessary to remember their major role in the great weakening of urban biodiversity. To the respect of varieties with nectars and pollen, the main restrictions to their coming back are linked with some venomous pollinators or vespids which can be dangerous in the near vicinity of restaurants for example. There, of course, sterile varieties can be still planted on. But municipalities and gardeners will have to conduct important information campaigns in order to communicate all necessary information on new green spaces policies within the scope of urban biodiversity and quality of life. It will imply furthermore the use of information technologies which will be part of technical improvements made in future in urban environment. This is, of course, a complete renewal of traditional practises. In Paris, Radio Frequency Identification System is already acquired for the management of more than 70.000 trees (Jeanne-Beylot, 1999).

<u>Some speculations and technical appraisals of the urban biodiversity problem</u>

We have to adopt new methods and new assessments for urban insect pests management. We have to think not only in biological quality and quantity (Kiritani and Dempster, 1973) but also in space and interactions within green spaces for the harmonious development of urban ecosystems. A mathematical model can establish a correlation between the volume which have to be given to the flowers beds and hedgerows (related to their biodiversity and its efficiency in the positive biological interactions between each other) and the distance separating them from the urban forests in order to perform the principles of Integrated Urban Biodiversity. Integrated Urban Biodiversity that is biodiversity principles and better pests management practices within the scope of sustainable urban environment. So, for our concern, we correlate the volumes of the flowers beds, hedgerows and forests and the distance from each other with the choice –for the flowers beds and hedgerows- of perennial or annual flowers and bushes, shrubs, grasses and ferns which will play a role in beneficial arthropod populations and will serve as overwintering shelters for natural enemies (see drawing 1 below). This can be issued from experiments in arboriculture (Rieux, Simon et Defrance, 1999). We have also to take into account the populations dynamic of insects but also the structure of the plants (Rieux, pers. comm., 2000). The model will help to understand the complexity of urban ecosystems and, written in a practical form, will serve for gardeners as a support for urban green space management.

Flowers beds and hedgerows can be selected in order to improve the health and biological quality of the forest as well as positive interactions between green spaces. In fact, however, it is the first task and goals we have to tackle. Then, in a much more speculative manner, if we consider an actual urban forest, we may assume that the volume of the flowers beds and hedgerows which can be planted in its vicinity is a function of the volume of the forest. Considering that the volume of the flowers beds is itself a function of the biological quality and quantity theoretically obtained by the biological composition of the beds especially chosen in function of the actual biological quality and quantity of the forest. Quality and quantity are information established from biological indexes, biocenotic principles and beneficial interactions within trophic levels between the forests and green open spaces. We can say that such volumes depending on biological data and interactions are "biological volumes". Now, in an other way, if we plant a new forest, we can consider that its "biological volume" (and, in this case, its minimal one) will be a function of the flowers beds and hedgerows all around and of their supposed positive interactions within the urban ecosystem. The feasibility and reproducibility of such models can be successfully achieved with the support of all scientists and technicians who work for the favouring of urban green spaces and quality of life in towns. If we take into account that a lot of the most interesting plants for horticultural purposes are still in some collections all over the world, we can easily combine our requirements with aesthetic value. So, from the assessments and principles made above and a multidisciplinary work, we can try to predict the relationship between urban green spaces within the goal of Integrated Urban Biodiversity in a new approach of Integrated Pest Management.



Drawing 1: Some supposed and simplified interactions between urban green spaces

<u>Which technologies for the future: a brief review of some techniques which can be useful for (urban) pests management</u>

- The association of information technologies and high technologies opens up the application of remote technologies with Radio Frequency Identification.
- Advanced technologies permit autocide control by radio sterilisation of males
- The development of biosensors coupled with neural nets offer the opportunity to detect potentially all biological cues in the environment (Kauffman, 1999).
- Scientists elaborate tracking technologies with fluorescent markers that can be very useful for insect pests management.
- Chemists work on new molecules (like cyclodextrine) that contribute to increase the efficiency and lesser the prices in insect pests trapping strategies.

Unhappily, those techniques have some limitations: noticeably the prohibitive prices for radio-sterilisation and the difficulties to conduct such experiments in urban green spaces (Kenis, 2000, pers. com.); for biosensors and neural nets, at the start, the lack of consciousness of their potential use and great utility in new insect pests management strategies. Nonetheless, nowadays, we can succeed in determining the seasonal behaviour or the biorhythm of the insects by advanced or high technologies and if we apply biosensors with tracking technologies, trapping and monitoring devices, we can elaborate an accurate alert and monitoring system. Also, a better understanding of dispersal and flight behaviour by a pest will lead to the development of control techniques involving computer simulation models that can predict when, where and how far a pest is going to disperse. Prospective views of the use of high and new technologies in urban green spaces management and urban pests management are available on demand.

Conclusion

The management and gardening of urban green spaces on scientific basis taking in consideration the ecological, botanical, zoological and insect pests management factors has to change radically the work and skills of landscape gardeners. It will be the only right way in an environmentally safe battle against urban pests, unless we develop new jobs and professions - what should be quickly done- . Not only those insect pests who are non indigenous and threat as well European and exotic urban trees but also indigenous insect pests have to be seriously studied. So, it will help to preserve our urban green spaces in good health and it will give inhabitants some more feelings of security and quality of life. This will be reflected, invariably, to more personal attitudes towards a better protection and respect of urban environment. In future, we can hope the urban horticulture will associate technological and human intellectual improvements for an urban sustainable development. It will reinforce and help to maintain the stability of somewhat, till now, precarious ecosystems in stressing environments. Those goals will meet altogether the requirements of new rules and policies in the way of increasing urban green spaces to go against the overflow of cars.

Summary

This contribution is intended to highlight the necessity of an adequate urban insect pests management within the sustainable development of our cities and quality of life. The urban biodiversity problem is presented with some advises and speculations for a better appreciation of the urban ecosystem and its complexity. Also, in order to meet the requirements of plant health in urban horticulture and insect pests management, some uppermost techniques are cited as useful and possible tools in future.

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Management and protection of urban forests and urban trees in Kołobrzeg (Kolberg)

Introduction

On the example of the exeptional, middle-size city and health-resort localized at the Baltic Sea, at the mouth of the river Parsęta it was presented how the history of the city combines with the current management and protection of the urban green areas. In the brief historical sketch the achivements of certain people were shown. These people created and now they maintain, broaden and appropriately protect the green compositions and the trees grouped in parks, gardens and urban forests, forming relic alleys and double rows of the valuable trees growing along the streets and communication arteries but also individual trees and nature objects that are under strict protection.

Another objective of this elaboration is to point out the forms of contemporary cooperation between the administration and the local government authorities and the city institutions or the arboriculturist companies invited for the cooperation. The teamwork concerns difficult and responsible care and protection works in the nature objects located within the Kołobrzeg district.

Despite the fact that the demands are much higher than the city budget expenses we observe the aspirations of the city authorities to replace the forms of protection and exchange the fragmentary ones into more complex. The trees would get under legal protection according to the act of „Nature protection“ in our country.

Green areas in Kołobrzeg - historical sketch *

In the early medieval, when in the mouth of the river Parsęta to the Baltic Sea first settlements - rudiments of Kołobrzeg started to appear, the whole territory was covered with swamp and marsh. The settlements were established on small hills. Alongside the sea cost a belt of dunes extended. Only in the east, close to currently existing towns Podczele, Stramniczka and Bagicz a bigger forest complex existed. When on 23 May 1255 on the basis of Lübeck law, the new city was called, thanks to the owner of that land, Pomerania prince Warcisław the III and Herman, the bishop of Kamień the forest became a city-forest. The rests of it are still present and it is called the Kołobrzeg Forest (Stadtwald, in German).

The dunes along the sea cost were kept in a natural state for hundreds of years. It was at the beginning of the XVIIth century that the need of forestation was noticed. Lorenz Heitke, the city councillor was the initiator of that action. In 1612 the first trees were planted on the left side of the mouth of the river. After several years a grove called Maikuhle came into existance (current Polish name Załęże). It is reported that at the beginning there were many birches there. The other side of the river, the east cost, was also planned to be forestated but here a strong objection of the military authorities was met (Kołobrzeg has already been a fortress). They believed that the direct foreground has to be empty, so that the approaching enemies were visible.

In the first half of the XVIIIth century a small group of trees was planted by the Saint Nicolas church, which nowadays is the neighbourhood of Solna street, Zwycięzców street and 1 Armii WP street. Unfortunately, during the 7-years war, in 1758-1761 Russians that beseged the fortress cut all the trees.

That kind of situation continued till thirties of the XIXth century. At that time, still on the territory of the fortress a spa started to arise (sea and salt water baths). Załęże grove had to be prepared to this new task. Walking alleys were marked out, the passages to the women bath-house through the dunes were built, new trees were planted, and a summer theatre Arena was constructed in 1847. That was „a grove full of charm“. On the dune hills quiet view points were arranged, of which one was called „Royal“ (Königssitz). It was

* This part of the paper was prepared by Dr. Hieronim Kroczyński, the director of the Museum of Polish Weapon in Kołobrzeg, on the basis of his own book „Das alte Kolberg” – „The old Kołobrzeg” published in 1999. Authors want to express their gratitude for him.

posssible to reach Załęże through a wooden pontoon bridge, which used to be deconstructed in winter and the ferry comunication was put in motion.

At the same time the City-Society of Embellishment (Städtische Verschönerungsverein) organized an action of a social care for green areas. The signes with the following information appeared:

„Bürger, schützt eure Anlagen“	and others:
„Burghers, protect your green areas“	„Lass die Blumen stehen! und den Strauch! Andre, die vorübergehen, freun sich auch“. which could be translated as: „Passer-by, do not pick the flowers! Do not break the bushes! So that the ones that come here after you

The local police joined the action and propagated the following document:

> „Colbergs treue und wohlmeinende Bürger rufen wir hierdurch auf, sich mit uns in der Aufsicht auf die Strand-Plantagen, die Pflanzungen auf dem glacis, auf der Reeperbahn, der Münde, auf dem Süderlande und in der Maikuhle zu vereinigen und nicht dulden zu wollen, daß von Frevelhänden wieder zerstört werde, was mit Sorgfalt für daß Gemeinwohl, was zur Verschönerung unserer nächsten Umgebungen geschehen ist. Unsern gemeinsamen Bemühungen wird es gelingen, Schaden abzuwenden von dem, was ja alle erfreut in den Stunden der Muße!-
>
> Colberg, den 15. Mai 1832
>
> Königl. Preuß. Polizei - Directorium“

Trusty and kind burghers of Kołobrzeg, we appeal to you for your cooperation in protecting of the bank plantations, green areas on the fortress slopes, by the road to the harbour, in the Ujście area, in Süderland (*present Jedności Narodowej street, author's addition*) and in Załęże, join us and do not let the foulty hands to destroy again, what was done for everybody's benefit and for embellishing our neighborhood. We will succeed in our attempts. We will prevent destroying what we all like best in our leasure-time!

Kołobrzeg, 15 May 1832

The Directorate of the Royalish-Prussian Police“.

The above mentioned City-Society of Embellishment built new roads within health-resorts (so called Kolberger Münde - Kołobrzeg Outflow). These roads were planted with trees. In the region of current Mickiewicza street - Towarowa and Spacerowa streets a clump of trees, called bosquet with a concert conch was created. Later, a till now existing hornbeam - *Carpinus betulus* covered walks (Laubengang) arose.

The belt of sea dunes at the right side of the mouth of the river was still a problem because the military authorities did not want to cede. The finall compromise was settled in 1863. The authorities agreed to planting of the trees there, but under condition that in case of a war everything would be cut. Since that time, from the mouth of the river in the east direction a current sea park was generated. A monument was erected in memory of the person most engaged in the action - city councillor Glagau. It was thanks to him that the park reached present Ściegiennego street.

In 1872 the fortress went into liquidation. The military regions were slowly taken by the city. The new urban premises were established for a resort city located on the former fortress.

An important event in this proces was an „industry and developement of green areas“ exhibition, organized by the city authorities in 1881. In memory of the fairs a medal was stroken signing

„ZUR ERINNERUNG AN DIE GEWERBE U. GARTENBAUAUSSTELLUNG ZU COLBERG IM JAHRE 1881“.

Since that time a prominent gardener Henryk Martens (25 II 1856 - 22 IX 1929) joined Kołobrzeg and became an official director of city gardens since 1887. It is thanks to that man, that city has beautiful green areas, mostly existing till today.

Martens continued planting of the sea park. The last fragment of it, near current amphitheatre, was completed in the end of XIXth and in the beginning of XXth century. Also the Dune Promenade (Dünenpromenade) was elongated along with the progress of the works on park developement. It was an attraction for walking people - over the dunes' ridges, along the sea cost.

The first significant work of Martens was the improvement of Emperor's Place (currently March 18 Place), in 1888. City authorities wished (after long discussions) that this would be a representative and decoration place. Martens designed a fountain, walking alleys and planted very rare and adequate trees, still present there. Some time later three more monuments were erected in the place. The next works of Martens were: Plac Zwycięstwa (Victory Place), without name currently, Plac Pruski (Prussian Place, currently Przybylskiego Place), Neettelbeck Park (H. Dąbrowskiego Park) and many roads, ways, among them the main artery - current Walki Młodych street. All of the streets were planted with different trees species. Some of them survived till nowadays. The heavy fights in 1945 and flowing time only thinned the stands. As a result of the II World War operations approximately 90% of the city was destroyed (Bochiński and Zawadzki 1999). The beautiful rose garden arranged by Martens in 1892, with park architecture near health-house, called Coast Palace, did not survive the years. That was a common destiny of many nature objects.

City authorities, in consideration of the merits of Henryk Martens founded a monument of him, after he died in 1929. It stood nearby the current concert conch (it was destroyed in 1945).

The city and current green areas in Kołobrzeg

Both the history of Kołobrzeg and the history of currently existing green areas are combined together, creating a strong thread that links past with present and future. All of the events happened and happen on the ground of the magnificent Kołobrzeg nature, which lasts immovable for thousands of the years.

The trees planted in parks, gardens, along the streets within Kołobrzeg, forest complexes, especially those forming sea-cost belt, but also those around the city, play a very important role.

In 1999 two beautiful album-books about Kołobrzeg were published: by Gauer (1999) and by Kroczyński (1999). The detailes of the history and the present beauty of an exeptional city - both a spa and a big tourist resort, localized at the Baltic sea, where forests, parks, gardens and trees have to be considered as exceptional nature phenomenon are presented there.

The localization of Kołobrzeg on the edge of the land and the open Baltic Sea, influences the nature and forms the specific sharp and capricious climat. The specificity of it is a result of continuous change of a daily wheather. Very often a foggy and rainy morning turns suddenly into a fine afternoon, and the day ends with a picturesque sunset. One of the highest sum of the rainfall and high daily mean temperatures elongate the vegetation period in Kołobrzeg, which has main impact on the growth and development of different trees and shrubs species.

There are 49 000 residents in Kołobrzeg nowadays. There is about 134 m^2 of green areas per one citizen. The city was rebuilt after the II World War, and is still developing. Thanks to remarkable sea beaches, unusual parks and gardens and the trees growing along main streets and alleys it is a fascinating health-resort, relaxation and touristic city.

In the spa zone stretched along the sea cost you can find many sanatoriums and some health-resort hospitals, which dispose of 7000 places for curative and leasure stays. In the spring, summer and autumn almost all of these places are used.

Treating in health-resorts became popular in the first half of the XIXth century. Shortly before World War II Kolobrzeg was a famous spa, approved and fashionable all over Europe.

Spa values of Kołobrzeg result from: strongly influencing climat, which stimulates immune system; clean, non-allergen air, which contains elements of the sea-aerosol - helpful for treating respiratory system disorders; mineral and salt water springs, used for treating and inhalations; excavation of turf of high quality, used for compresses and turf-baths.

The resort specialises in treating following complaints: respiratory system disorders, including bronchia asthma, limb disorders, blood circulation diseases, metabolism sicknesses: diabetes and thyroid gland disorders.

The establishing and developement of many parks and green areas is in relation with the continuous progression of the spa. Around the sanatoriums and health-resort hospitals very fine compositions of high plants with the ornament species of conifer trees and other ornament shrubs were arranged.

Table 1 shows the list and types (categories) of the urban green areas items in Kołobrzeg. The ornament woodlots, of small area, surrounding sanatoriums, hospitals, hotels and boarding-houses are not included in the Table 1.

Table 1. Present areas of the urban green areas of Kołobrzeg and their types (categories).

1. Remnant parks, for walks and leasure	- 134 ha
2. Grass-plots, greens	- 12 ha
3. Street greens	- 34 ha
4. Community greens	- 15 ha
5. Allotments	- 54 ha
6. Communal forests	- 30 ha
7. Eastern Ecopark	- 381 ha
TOTAL	- 660 ha

Additionaly there are about 16 ha of so called law plants areas within the municipal district of Kołobrzeg, composed within the urban landscape of the city and within some objects mentioned in Table 1. There have to be done very expensive and difficult garden care procedures on them, every year. These objects are: rosariums (8244 m^2), herb collections (872 m^2), hedges (6719 m^2), lawns (582840 m^2).

The most precious and remnant group of green areas in Kołobrzeg, liable to parliamental legislation of remnant protection and environment protection, is a group of 7 parks localized mainly in the coastal zone and in the centre of the city, formed in the beginning of XIXth century. They are under permanent protection and kept accordingly to the urban-gardening ideas of H. Martens, the city-gardener of the second half of the XIXth century. Seaside parks of special value were formed on forest type mainly composed of beeches (*Fagus silvatica*), oaks (*Quercus robur* and *Q. petraea*) and maples (*Acer platanoides and Acer pseudoplatanus*) but also other tree species that usualy form that kind of a forest site. In these parks you can find many old, graceful beech, oak and maple trees, which are qualified as monument trees, taken under special protection.

Another type of high plants, strictly protected and being cared for and preservated regularly are old trees growing in parks located within the city, and also along the streets, boulevards and alleys. Among these trees, the most precious were chosen as monuments of nature, according to the act of „Nature protection“ of 1991. These trees are under strict nature protection. Conducting any care or treating procedures need a Regional Conservator of Nature agreement, and the arboriculurist must posses highest qualifications confirmed with specialistic certificates.

Table 2: The list of trees that are presently Monuments of nature in Kolobrzeg, protected by the law.

Abies concolor	- diameter at breast height (Dbh) 260 cm, height 35 m, in the city park of A. Fredro
Aesculus cornea	- Dbh 385 cm, in the park of March 18
Fagus silvatica	- about 200 year old tree, Dbh 400 cm, height 25 m, in the park of March 18
	- a group of 7 trees, Dbh 485, 337, 391, 328, 360, 381, 360 cm in the Dąbrowskiego Park
F. silvatica var. laciniata	- Dbh 208 cm, in the park of March 18
Phellodendron amurensis	- one tree, Dbh 212 cm, in the locality of hospital
Platanus acerifolia	- an alley of 74 trees, Dbh from 150 to 350 cm, in two and partially three raws, at Łopuskiego street
Quercus robur	- a group of 16 trees, Dbh from 113 to 190 cm, aged from 250 to 270, in Dźwirzyn, by the road no W-101
Taxodium distichum	- two trees, Dbh 210 and 150 cm, height 20 and 14 m, in the park of A. Fredro
	- one tree, Dbh 200 cm, in the park of S. Żeromski
Tilia cordata	- two trees, Dbh 515 and 320 cm, height 25 m, at the Polish Mariners Boulevard

As a result of works aiming in taking stock of, care, treating and preservation the number of the tree monuments which are under strict protection and grow on the territory of Kołobrzeg or in the district of this city would still increase. Documentation works are in progress, too and the point in this case is also including under protection other big and old trees growing along the streets, in the communal forests and in the eastern Ecopark. In the future similar action would concern the old relic of hornbeam covered walks, the trees that build it, *Carpinus betulus*, are about 150 years old and need complicated and expensive reconstructing and preservation works.

Management and protection of the green areas.

On behalf of the City Office of Kolobrzeg the green areas are managed by an environment protection inspector, currently on this position a graduate of an Agiculture University is employed. She works in the Communal Departament of the City Office. The Communal Departament cooperates widely with the City Institution of Urban Green, Roads and Environment Protection, which has a status of a limited liability company (Ltd). The owner of the company is the Municipal Corporation of Kołobrzeg. They hire there a horticulture engineer, a graduate of the Agricultural University speciality: dendrologist, MSc, Eng., a horticulture technician and a forester technician. They superintend the processes connected with care and planting of the trees. This work is done by a group of manual workers trained in working with trees.

Every year works in the green areas are planned in the city budget, which is consulted with the citizens and ratified by the city councillors. In the proposals to the budget all of the green area tasks are concerned. The usual works planned are: renovations and preservations of plants from different parks or gardens, sanitary and technical cuts of the street trees, planting of trees and other ornamental plants, establishing and cutting of the lawns, etc. There are alltogether 60 persons permanently employed and 20 for the season to manage, maintain, care and establish new objects of greens.

The choice of the most necessary works to do is made after discussion with the city councillors, and depends mainly on the financial possibilities of the city budget. It takes many discussions and consultations to work out the final version of the budget, then tasks included are realized. The city sings contracts with the City Institution of Urban Green, Roads and Environment Protection to accomplish certain dutes in the urban green areas and forests. The quality of works is valued currently and after closing of the duty.

Difficult and specialistic works concerning care and treating or protecting of the valuable monument trees or whole objects under law protection, the City Office entrusts to scientific institutions and arboriculture companies that are specifically adequate and have an equipement and materials for that kind of work. Different kinds of reports and opinions concerning the procedures planned to be performed on the specially precious trees, and after completing them a documentation that describes the process and methods is prepared, including detail photographs.

These are the expert works performed on the single trees or trees growing in remnant parks in last few years: 1995 - treating and preserving procedures on monumental sycamore trees (*Platanus acerifolia*) growing at Łopuskiego street - Siwecki (1995), care and protecting works on fine manument trees of *Fagus silvatica*, on few oaks (*Quercus robur*), elms (*Ulmus laevis*) and yews (*Taxus baccata*) growing in the park of March 18 (Siwecki 1999). These efforts incorporate integrating methods of protection and treatment of trees, that are generally based on cutting and forming of the crowns, removing dried branches, exchange of the substratum around root collar and introducing biological and mineral-organic nutrients, usage of biological and chemical implants and the new generation of fungicides in a form of liquid, aerosole and paste to limit dangerous fungal diseases.

Other works were concentrated on expertising dendrological inventories, aiming in preparation of the revalorization and conservation works on the remnant fragments of the coastal parks - Siwecki and Rachwał (1997); Rachwał (1999).

<u>Dicsussion</u>

Only the most important problems of management and protection of the green areas, mainly urban forests and urban trees in Kołobrzeg were presented. It was presented on the example of a unique, seaside, middle-sized city how the history of a city, which main function is health-resort and tourist-leasure centre, combines with the contemporary lot of the protected and newly formed green areas. Valuable nature objects that we can find in the city, have an exeptional influence on present management and protection and on the future developement of the urban green areas and forests.

Nevertheless the old parks, gardens, tree alleys, old monument trees, communal forests and other nature objects are permanently attacked by harmful biotic and abiotic factors, strong anthropopressure and urbanization of the city.

It could be confirmed that the classical compositions of the urban projects of the gardener H. Martens created in the second half of the XIXth century in Kołobrzeg although several human generations have lived here and destructions were caused by wars the style is continued and expanded.

Very good cooperation of the administration authorities of the city and high qualities of the persons that manage the green areas and those that are directly responsible for the difficult work on trees, brings very good results for the level of the protection of the green as well as for the pro-ecological consciousness of the citizens in their active defence of so priceless objects of the nature.

Still the finances offered by the city budget are insufficient for the works that would satisfy the needs of the trees, parks and communal forests. That is why we undertake any possibility to gain assistance from national or foreign funds that are devoted to protection of urban nature and could support advisable investments.

The millennium year 2000 and the 1000-year anniversary of the Kołobrzeg bishopric existance subjected to the Gniezno archdiocese, established by the Polish king Bolesław Chrobry and the German emperor Otton III, would be a memorable occasion to improve the looks and esthetics of the urban green areas. There will be many new shrubs and trees, flowerbeds and flowerpots. The representative parks in the centre of city would be partially reconstructed and renovated.

Simultaneously, intesive labour continues to work out the documentation essential for creating a landscape park in Kołobrzeg, temporarily called „An assamble of the relic seaside landscape parks“. That kind of a park, as a highest form of nature protection (just after National Parks) in Poland would properly protect and unfold the incomparable beauty of the health-resort city.

Creation of that high form of nature protection according to the act of „Nature protection“ of 1991 obligatory in our country, will let the more organized and systematic works to be done on complex revalorisation and protection of all of the parks, existing forest complexes and other nature objects present in the city.

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Research efforts to control cypress canker in urban and peri-urban areas

Introduction

The management of urban trees in European historical town centres presents specific problems linked to the historical associations of these centres and an architectural configuration that has long since become fixed and can no longer be changed without causing objections from the public. In these old centres changes that can be undertaken are usually limited to single trees and therefore it is necessary to have an in-depth knowledge of each tree individually, and the functions it fulfils, before such changes are even proposed. Different methods of tending urban trees are necessary to manage peri-urban areas, parks and street sides. In all such environments, however, trees are exposed to numerous factors of aggression, which interact with each other in ways that are often not well understood. These factors have a negative influence on tree growth and senescence and render the trees more susceptible to certain parasites, which thereby may become more injurious.

Urban tree care presupposes a management system which depends upon good science, urban stress physiology, artistic concepts in tree protection, social consideration, as well as public education and awareness (Tukey 1999). A programme of urban tree care will have a full regard for ecological studies and proper plant selection, water usage, vegetation management and species diversity. It will also be constantly mindful of user needs.

Hitherto urban tree health has mainly been considered a subdivision of pathogen and pest management and has been confined to the identification of species and life cycles, and the chemical and biological interactions with the host tree. This view is however insufficient. It often happens that the scientific facts are known: the parasite is identified, its life cycle an open book, effective control methods are available, and yet this, for all its importance, is not enough. What the work of control management needs as well is the assistance of a whole range of other professionals, namely those skilled in education, conflict resolution, appearing at public hearings and developing public regulations.

A case study: the cypress in the urban and peri-urban landscape of Tuscany

Surrounding the towns of Tuscany there are many villas, gardens and avenues of historic interest that fit harmoniously into the natural beauty of the Tuscan countryside and rarely fail to display what is one of its most charming and characteristic features: the cypress tree.

With its elegant and elongated shape the cypress tree is ideal as a solitary presence in the landscape, though it is also highly suited to growing in groups, whether as pure stands or mixed with holm oak, pubescent oak or other typical Mediterranean tree species. And on account of the ease with which it may be pruned it is almost as good as the box tree for topiary purposes. Since classical times the cypress has possessed a strong aesthetic appeal owing to the essential purity and geometrical symmetry of its lines and its ability to fill a space and set off a perspective, giving life and variety to the rolling landscape and the hills of Tuscany. For a full description of the historic gardens and villas boasting cypress trees in Tuscany consult, among others, Clarke and Bencini (1990), Pozzana (1991), Lanzara (1995), Paoletti and Raddi (1998). In historical gardens, the cypress stands half-way between wild and uncultivated plants and is a reminder of the surrounding, untended countryside.

In recent years a serious illness has devastated the cypress in Tuscany and is continuing to do so. From an inventory in 1992 it appears that in Tuscany about 4 million cypress trees. From a recent investigation, half of them (2 million) now are more or less seriously affected by a canker caused by the fungus *Seiridium cardinale* (Wag.) Sutton and Gibson (Wagener, 1939).

The Cypress - Seiridium cardinale pathosystem

The common cypress, *Cupressus sempervirens*, has ever since classical times been considered a healthy and robust tree resistant to adverse circumstances. Because of its durability and its flame-like shape it has always been held to be a sacred tree. The uses of cypress are manifold. Suffice it to mention its cultivation as an ornamental tree in central Italy, particularly Tuscany, Garda Lake, the Côte d'Azur and the Greek islands, as a windbreak in Sardinia, the Rhône valley and Greece, as a sound barrier and as a forest tree. The causal agent of cypress canker was first recorded immediately after the Second World War, initially in France and since 1951 also in Italy (Barthelet and Vinot, 1944; Grasso, 1951). Since then it has caused recurrent and serious epidemics in countries surrounding the Mediterranean basin, putting the continued presence of the tree there at risk.

Since 1975 the Istituto per la Patologia degli Alberi Forestali (IPAF, Institute of Forest Tree Pathology) has undertaken a series of studies on the life cycle of the fungus causing such high disease incidence in Tuscany and possible measures to control it. Given the wide distribution of the cypress, its occurrence, whether singly or in groups, in the most varied environments (street-side trees, parks, villas, cemeteries, nurseries and periurban forests), given also the virulence of the pathogen and the epidemic nature of the disease it caused, it was immediately clear that the control of the canker would be a difficult and complex undertaking and would have to be based on both direct and indirect approaches (Fig. 1).

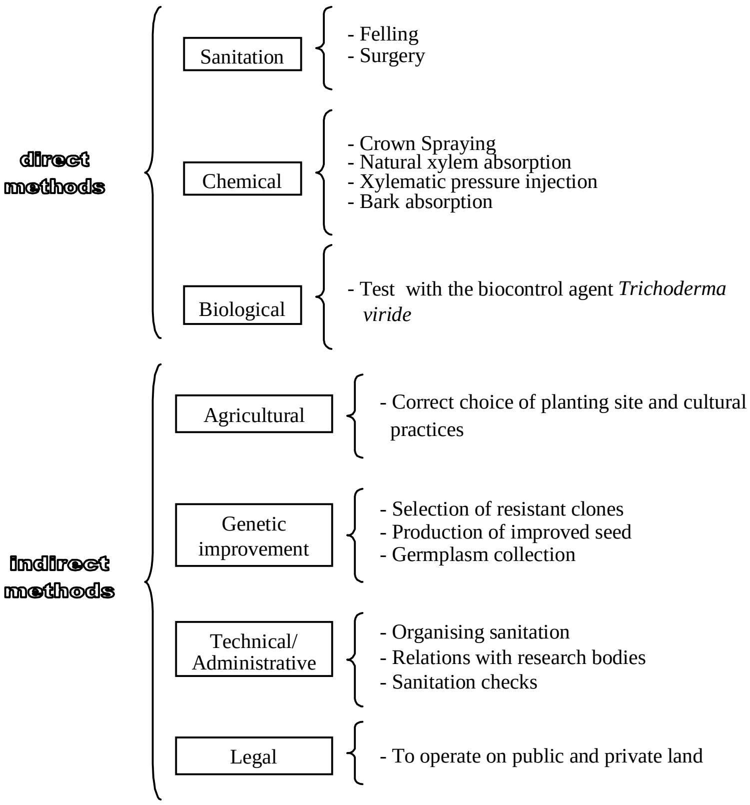

Fig. 1: The complex approach developed to control cypress canker

In cypress growing in parks and boulevards, sanitation involving the felling of affected trees as soon as possible after canker symptoms first appear has proved effective. Recent investigations have shown that ten years after a sanitation effort in an area, the average infection rate there was 5.1 %, whereas in areas that had never been sanitised it could be as much as 20.6 % (Panconesi, 1999). As part of the direct methods to control cypress canker a number of compounds with a certain ability to prevent or cure *S. cardinale* canker have been tried out (Parrini et al., 1976; Parrini and Panconesi, 1977; Panconesi and Parrini 1979; Panconesi et al., 1984; Panconesi et al., 1999). Particularly effective in prevention have been benzimidazole compounds (Benomyl, 100 g/hl and Carbendazim 120 g/hl) . Since *S. cardinale* fructifies at a temperature range between 5 and 32°C it can infect trees at almost any time of year and to ensure complete year-round protection numerous fungicide applications are necessary, which would be prohibitively expensive. Chemical treatment of ornamental plantings, especially if of a certain size, are often difficult to carry out, results are not guaranteed and are stressful to the environment, and here too costs are high.

Trees in town centres and historic villas present numerous problems relating to sanitation and the replcement of trees. Sanitation measures consist in destructive or surgical interventions (Panconesi and Danti, 1995). Destructive surgery is so called because it removes the entire organ together with the tree-part affected, and is carried out when the canker girdles the trunk or a branch and is located in the periphery of the crown, so that it does not irremediably destroy the functionality of appearance of the tree. In one such surgical intervention on 288 trees, no fewer than 227, or 78.8 % had become reinfected within four years. This finding was not surprising since all the trees involved were susceptible to canker, and the removal of infected parts of trees certainly does not enhance their resistance to the disease. On the contrary, if the sanitation wounds are not adequately protected they may actually favour reinfection.

Conservative surgery, with the removal of only the canker from the trunk and large branches when it is in the lower part of the tree and does not gird more than 25 % of the circumference, has given better results. Of 57 cypress with high ornamental and historic value treated in this way, only 32 % presented reinfections after four years. Here too the trees were genetically susceptible and thus at high risk of infection.

Felling an adult cypress in a town centre or an historic garden requires trained personnel and is expensive (more than 150 Euros per tree). Another problem is with what tree the felled cypress can be replaced without impairing the architectonic harmony of forms. Removing infected cypresses from hedges in villa gardens also presents practical and aesthetic problems. Leaving a gap in the hedge or arch may be unsightly in a way that is not easy to remedy and replanting new cypresses may cause an ugly “stain” in the hedge or other green formation.

Indirect control measures mainly concern the genetic improvement of cypress for canker resistance, as described below.

Genetic improvement of cypress for canker resistance

Since preventive chemical control methods, though feasible are difficult and expensive, and no effective cure has been found, the research effort of the IPAF has since 1975 been directed mainly to :

- the sanitation of infected cypresses over large areas, a short-term strategy, to reduce the amount of pathogen inoculum and populations of scolytids, the vector of cypress canker, and to protect existing plantings for as long as possible from encroaching deterioration;
- the genetic improvement and selective breeding of cypress for canker resistance, for a long-term solution to the problem.

Experimental studies conducted so far have shown that:

a) there is sufficient variability in canker resistance between and within cypress species;

b) variation in pathogenicity between all *S. cardinale* isolates so far examined has been very small. The fungus reproduces only asexually, i.e. clonally;

c) the reaction mechanism mobilised by the cypress to block the advance of pathogen mycelium is aspecific and consists in compartmentalisation of the wood;

d) the manner and time of response to canker infection by a cypress clone is also influenced nutritional, climatic and soil factors of the stand.

The experimental findings have pointed the way to the best genetic improvement strategy (Fig. 2) for the objectives aimed at, which are designed to satisfy the following demands from users:

1. for canker-resistant clones to be planted as single trees or small groups for ornamental purposes;
2. for canker-resistant clones representing multiclonal varieties especially suited for hedges and windbreaks, in parks, and as street-side trees.

A third objective, which only marginally concerns the subject of this paper, is the large-scale production of cypress seed to establish cypress forest plantings with a high frequency of resistance to cypress canker.

Recently attention has also been called to the assessment and preservation of germplasm of cypress in hedges of historic gardens and in roadside plantings of particular ornamental and historic significance. With this project the IPAF hopes to preserve the germplasm of cypress growing in such formations, assessing it in experimental fields for canker resistance, and selectively breeding canker-resistant individuals so that these can in future replace dead cypresses. In this way colour stains or dissonances in crown architecture will be avoided that occur when new trees replace dead trees in existing hedges or roadsides. This project has just begun and can be successful only if there is active participation from historic gardens, the local authorities, scientific institutions the Ministero dei Beni culturali (Cultural Heritage Ministry) and the Ministero dell’Ambiente (Ministry of the Environment).

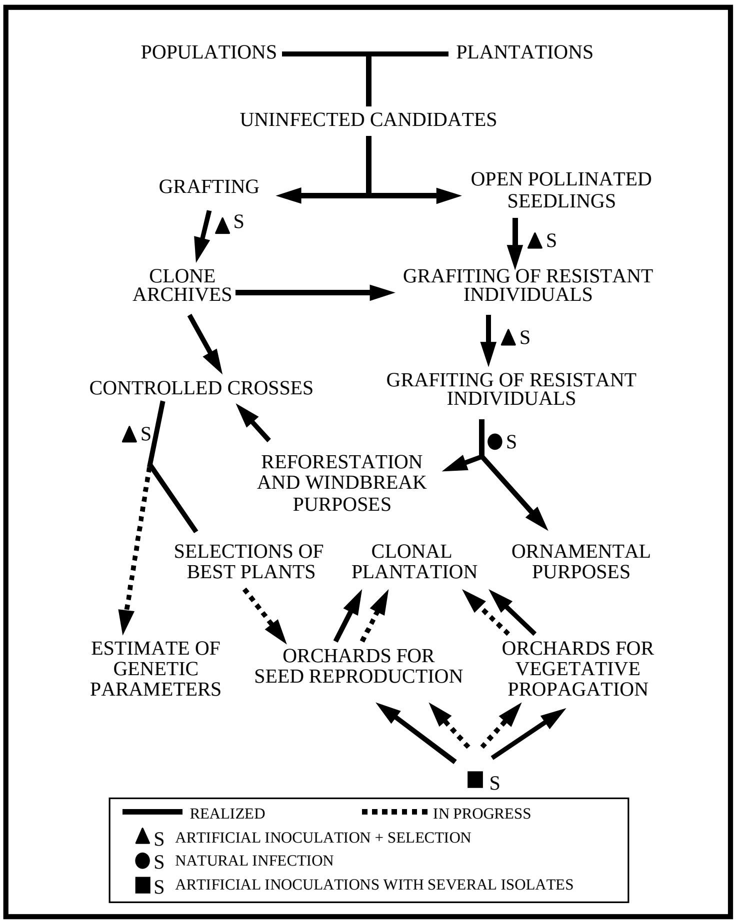

Fig. 2: Strategy to select canker-resistant cypress material

The positive research results achieved by the IPAF over the years, owing not least to funding received since 1980 and continued today by the CNR, the EU and the Tuscan Regional government allow the following conclusions:

- the knowledge is available to intervene successfully in the control of cypress canker in urban and peri-urban areas;
- the important advantages of the sanitation of cypress infected with cypress canker in order to reduce the risk of further infection are well known. Periodic interventions of areas that have already been sanitised should now be planned immediately to eliminate trees with new infections;
- clones of canker-resistant cypress already exist and should be used to replace infected trees in such numbers that the risk posed by monocultures or genetic uniformity is avoided.

The knowledge gained can stimulate new legislation making it possible to intervene in public and private-lands, including restricted areas, with timely sanitation activities. Sanitation must be followed by restoring the plantings to their original state with canker resistant cypress clones suitable to preserve the ornamental and historic assets. In this way a commitment to urban tree health will improve the quality of urban life through a better understanding of the growth of healthy cypress.

Summary

After a brief mention of peculiarities in the management of green spaces in historic town centres and the criteria that such management must fulfil, strategies to overcome cypress canker where it occurs are discussed. The need to sanitise cankered trees in a manner that respects aesthetic and architectural criteria as well as tree health is clarified. Guidelines adopted for a genetic improvement programme of cypress are presented. Funding from the CNR, EU and local authorities over the last twenty years have yielded positive

results, with the patenting of several canker-resistant clones. Efforts are now directed to the preservation of cypress germplasm, the production of multiclonal varieties and the establishment of collection orchards to produce élite seed. The need for effective legislation to provide for timely cypress sanitation in public as well as private lands is also treated.

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Biological control of *Botrytis cinerea* Pers. ex Fr. by antagonistic yeasts

Introduction

Grey mould, caused by *Botrytis cinerea* Pers. ex. Fr., is a very important disease in many countries all over the world and attacks more than 200 plants at different parts, such as shoots, leaves, flowers and fruits (Jarvis, 1980; Maude, 1980). The mode and the time of infection is different in different plant species. *B. cinerea* is known as wound invading pathogen, causing high losses especially on fruits in storage. Other infection strategies of the pathogen are the attack on young or old and senescent plant tissue. The pathogen also causes diseases in fruits by infection of senescent flowers and invasion of the fruit in very early stages of development. The last mode of infection is the most important in strawberries and is the main cause for symptoms occurring on the mature fruit after harvest. Symptoms of grey mould could also occur on flowers and immature and mature fruits before harvest (Powelson, 1960; Schönbeck, 1967; Maas, 1984; Snowdon, 1990).

The most important control method against *B. cinerea* is the application of fungicides which is carried out in dependence on the mode and time of infection. In strawberry the treatments are necessary during flowering to avoid high infection rates in fruits (Maude, 1980; Maas, 1984). In the near past some problems related to the use of fungicides occurred. One problem is the fungicide resistance reported for strains of *B. cinerea* (Washington et al., 1992). The other aspect which should not be neglected is the public concern related to the use of fungicides. Both aspects show the need for alternative methods which must be safe and effective to partially replace fungicide treatments (Wilson and Wisniewski, 1989). Therefore, the search for biological control agents has been intensified in recent years and several micro-organisms with high activity have been identified (Tronsmo and Raa, 1977; Janisiewicz, 1988; Droby et al., 1992).

Materials and methods

Culture and preparation of pathogen inoculum and antagonist preparation

The inoculum of *B. cinerea* for laboratory trials was obtained from cultures in petri-dishes on malt extract medium (25 g/l malt extract (Fluka 70167) + 16 g/l AgarAgar (No. 0081-900-500; Otto Nordwald KG); pH ca. 5.5) incubated at 25°C in the dark. Inoculum of *B. cinerea* was prepared by adding the conidia to a sterile saline solution (0.85% NaCl), counting the conidia with a counting chamber (Thoma chamber) and adjusting the conidial density at $1x10^4$ per ml.

The antagonist was cultured in malt extract medium (25 g/l malt extract (Fluka 70167) at pH 5.5 in 300 ml Erlenmeyer flasks at 20°C. After 3 to 4 days yeast cells were yielded by centrifugation (2250 g, 20 min.) of the culture suspension. The separated cells were suspended in sterile saline solution (0.85 % NaCl), the density was determined by counting in a counting chamber (Thoma chamber) and adjusted to the desired density. For laboratory trials on detached leave disks Tween 80 (0.05 %)(DIFCO 3118) was added to the preparation. The antagonist suspension for field trials was formulated by addition of Manucol®DH (Sodium Alginate; Monsanto), Keltrol®F (Xanthan Gum; Monsanto) and Cellulose (Serva 14205).

Inhibition of conidial germination

Strawberry fruit pulp was suspended in distilled water at a concentration of 1%, filtered, adjusted to pH 5.5 and autoclaved. Conidia of *B. cinerea* were added to the suspension and the concentration adjusted to $1x10^4$ per ml. Tests with the antagonist were performed using the cell suspension adjusted at $1x10^6$ cells / ml. For the test, 450 µl of conidia suspension were mixed with 50 µl of the cell suspension. Of this mix, 20 µl were pipetted into each of the 5 chambers of the microscopical slide and incubated at 25°C (Droby et al., 1993). Controls were prepared with saline solution instead of antagonist preparation. The evaluation after 6 and 24 hours included determination of the germination rate, measurement of germ tube length (after 6 hours) and a classification of germ tube length (<100 µm or >100 µm; after 24 hours) of 60 and 100 conidia (5 chambers of 20 conidia each), respectively.

Activity on detached leave disks

Leave disks of 1 cm in diameter were cut from ca. 10 days old strawberry leaves. Ten leave disks for each of the 3 repetitions were put in 100 ml sterile distilled water and shacked for 1 hour on a reciprocating shaker. Afterwards, the disks were put on sterile gauze which were placed on wet filter paper in 9 cm petri-dishes. The leave disks were first sprayed with the antagonist (cell density $1x10^6$) and then with a conidial suspension ($1x10^4$) of *B. cinerea*. The fungicide variant was treated with dichlofluanid (0.125%; EuparenWG, 0.25%). After each treatment the disks were incubated for 24h at 20°C in the dark. Then the disks were put on herbicide agar (6 g/l AgarAgar (Otto Nordwald), 0.2 g/l chloramphenicol, 20 ml/l deiquat) and incubated at 20°C with 12h darkness and 12h black light illumination for 7 days. The evaluation was carried out by estimating the conidiophore density of *B. cinerea* on the leave disks using the following scheme (modified after Peng and Sutton, 1991): Category 1: no conidiophore per leave disk; 2: 1-10 conidiophores per leave disk; 3: 11-20; 4: 21-50; 5: 51-100; 6: >100.

Field trials

Field trials were carried out in first year crops of strawberry. Young seedlings were planted in the preceding summer with 80 cm distance between raws and 35 cm within. The experimental design was completely randomised with 3 repetitions per variant. Each experimental plot contained 24 plants, 4 raws with 6 plants in each. The weed control was carried out by hooking and application of the fertiliser was in spring (6 kg/100 m^2 Nitrophoska (12+12+17+2+6), put in the vicinity of the plants). Antagonists were applied during flowering of the strawberries by means of a pesticide sprayer, on sunny days in the evening. Control plots were treated with water or with formulation substances. Two to 3 weeks before harvest the soil was covered with a thin layer of wheat straw around the plants. Fruits were harvested mainly twice a week, sometimes 3 times. After harvest fruits were separated into different categories (undamaged, frass damage, different disease symptoms) and counted and weighed separately. Only completely undamaged fruits were chosen for post harvest determination of latent infection by *B. cinerea*, put in an egg-container (30 eggs) and stored at room temperature. Fruits were checked visually every day for occurrence of disease symptoms and those with clear symptoms were separated. After 14 days all fruits were finally inspected for any symptoms.

For the experimental year 1996/97 the variety Elsanta was planted August 8^{th} 1996 on the plot CII of the experimental station in Berlin-Dahlem. Flowering began May 7^{th} 1997. The antagonists were applied the following data: 12.5.97, 16.5.97, 22.5.97, 28.5.97, 3.6.97. The antagonist was formulated with Alginate (0.1%), Xanthan (0.02%) and Cellulose (0.5%) and applied in a cell density of $1x10^7$ per ml. The fungicide variant was treated with Euparen WG (0.25%). The harvest for the experiments was carried out at 10 plants per replication.

Statistical analysis

Statistical tests were performed using the chi-square test for frequency data and the Man-Whitney test or the Kruskal-Wallis test for ordinal scaled data (Sachs, 1992). The categories of conidiophore density were transformed into category-mid-point-values of conidiophore density which were used for presentation of data and for statistical procedures. This transformation was as follows: category of conidiophore density = 1 equals category-mid-point-value = 0; 2 equals 5.5; 3 equals 15.5; 4 equals 35.5; 5 equals 75.5; 6 equals 150. Effectiveness of treatments was calculated according to Abott (1925). Significant differences marked in tables and graphs are based on 5% error probability.

Results

Activity of antagonistic yeasts in strawberry fruit pulp suspension

The four yeast isolates presented in figure 1 were able to suppress significantly germination rate and germ tube growth of *B. cinerea* after 6h in strawberry fruit pulp suspension. Highest effectiveness was observed for isolate 10391. Germination rate was reduced by 53% and germ tube length by 69% as compared to the control. However, after 24h germination rate was in a range of 80 to 91% for all yeast isolates, indicating that conidial germination was not completely suppressed by antagonistic yeasts (data not shown).

Activity of antagonistic yeasts on detached leave disks

Cell suspensions of the antagonistic yeasts were applied to detached leave disks to investigate their effectiveness on plant tissue. The effect of the yeasts was measured by means of the conidiophore density of *B. cinerea* formed on the leave tissue after infection. All yeast isolates reduced the conidiophore density significantly. The best result was obtained for isolate 23761 with a reduction of conidiophore density of 51%. The results for the other isolates were in a range of 26-41% reduction.

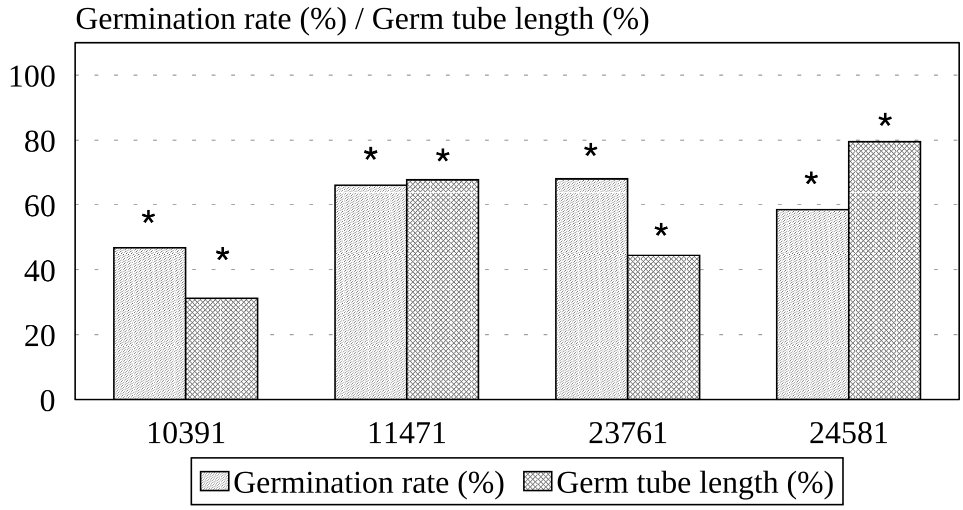

Fig. 1: Influence of different yeast isolates (cell density 1x10^5) on germination rate and germ tube length (%) of *Botrytis cinerea* after 6 hours in a strawberry suspension (1%) (Control=100; * = significant to control at α = 5 %)

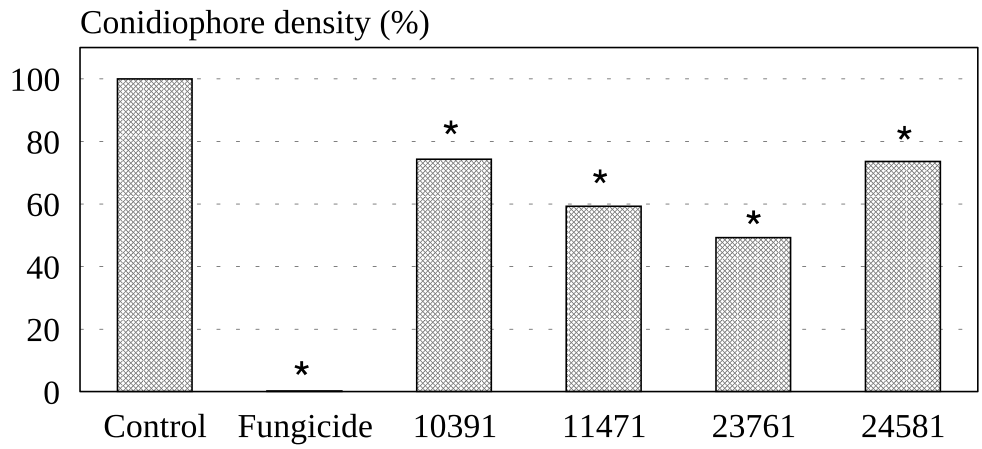

Fig. 2: Influence of antagonistic yeast isolates (cell density 1x10^6) on conidiophore density (%) of *Botrytis cinerea* after inoculation on detached strawberry leave disks at 20°C
(Control = 100 %; * = significant to control at α = 5 %)

<u>Field trials</u>

The antagonistic yeast isolates were applied as cell suspension during blossom of strawberries by means of a conventional pesticide sprayer. The influence of this treatment on occurrence of *B. cinerea* was established on ripe fruits after harvest. Highest effectiveness was observed for isolate 24581 (Fig. 3). This yeast reduced incidence of grey mould by 49% as compared to the water control. Isolate 11471 also reduced incidence of the pathogen significantly, whereas isolate 23761 had a minor effect on the occurrence of grey mould.

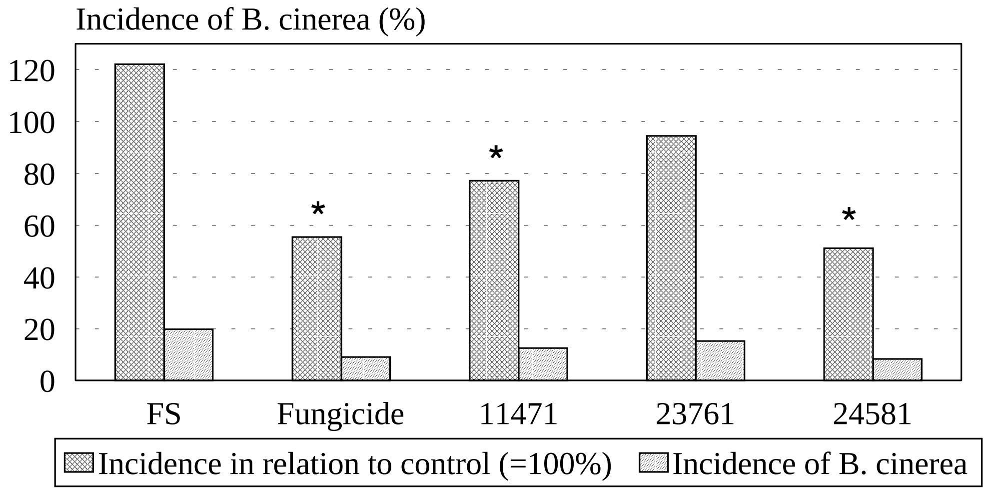

Fig. 3: Influence of the antagonistic yeast isolates on the incidence (%) of *Botrytis cinerea* on ripe strawberry fruits after harvest in 1997 (FS = Formulation Substances; (Control = 100 %; * = significant to control at α = 5 %)

Discussion

The effect of several yeast isolates on germination of conidia of *B. cinerea* was investigated in a suspension containing 1% strawberry fruit pulp. The nutrient concentration of the suspension was chosen thus low (compare Sorge, 1984) to simulate natural conditions in the phylloplane, where nutrient supply is most times very limited. The yeast isolates effectively suppressed conidial germination and germ tube growth of *B. cinerea* under these conditions, demonstrating the ability to compete for nutrients successfully. It is assumed that the effect on conidial germination after 6h is mainly dilatory since most of the conidia had germinated after 24h (data not presented). Due to these results the assumed mode of action is competition for nutrients. This mode of action could completely suppress conidial germination only under circumstances of very low nutrient supply or very high antagonist populations. However, the dilatory effect on conidial germination could also help to reduce the frequency of infection under natural conditions since the pathogen needs longer periods of favourable conditions until it is established on the host. Consequently, in periods of limited availability of favourable weather conditions (mainly moisture) for the pathogen, retardation could play a role in control.

Trials on detached leave disks carried out in petri-dishes showed that the antagonists reduced conidiophore density successfully. The effectiveness was not very high (as compared to some bacterial antagonists) since incidence of *B. cinerea* was 100% and the reduction of conidiophore density was in a range of 26-51% as compared to the control. However, it should be taken into account that the antagonists were applied in a relatively low density of $1x10^6$ cells /ml and that conditions for the pathogen were extremely favourable since humidity in the dishes was high for a long period. Therefore, it could be assumed that the antagonists would be more effective when applied in higher density or under conditions less favourable for the pathogen.

Field trials carried out by treating the strawberry plants with cell suspensions of the antagonists during blossom showed that the antagonists successfully suppressed *B. cinerea*. The incidence of the pathogen on ripe strawberry fruits after harvest was reduced by 49% by isolate 24581, which gave the best result. Isolate 11471 reduced incidence of grey mould by 23%, whereas isolate 23761 had only a minor impact on disease incidence. These results were obtained by treatments with yeast cell suspensions prepared with simple techniques and formulation. Since active cells depend strongly on weather conditions, survival could presumably be improved by the use of specific formulations which help the antagonist to establish high population densities on the plant surface. Further improvements are presumably possible by the use of cell suspensions with a higher density. The cell density of the applied suspensions was adjusted at $1x10^7$, which is not very high. However, the results obtained are promising and further investigations will be undertaken to improve the effectiveness of the antagonistic yeasts.

Summary

Several yeasts were isolated from mature strawberry fruits and tested for antagonistic activity against *Botrytis cinerea*, the causal agent of grey mould in strawberries. Conidial germination rate and germ tube growth of conidia of *B. cinerea* was inhibited by the cell suspension of the antagonists in aqueous strawberry fruit pulp suspension (1%) after 6 hours of incubation. The application of the cell suspension on detached strawberry leave disks reduced conidiophore density of *B. cinerea* by 26 to 51%. The application of antagonistic yeast isolates in field trials showed that the yeasts significantly reduced incidence of grey mould. The effectiveness of the most effective isolate 24581 was 49% as compared to the water control.

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Soil amelioration with urban trees and new plantations and its effect on vigor, shoot-root growth and water relations

1. Introduction

Freshly planted amenity trees are often weakened by the transplantation shock and exhibit problems to establish. Poor soil conditions may enhance the stress of such young trees. The aim of the present investigations was to find soil conditions which improve the soil water regime and the aeration in the rooting zone and hence improve the vitality of the trees in this first difficult stage. The idea was to add gravel-like material to the rooting medium in order to increase the aeration of the rooting medium but also the water storage capacity. It was expected that this would enforce the roots to exploit a larger soil volume in a shorter time. There are indications that a less favorable hydration encourage root growth of trees (Lyr and Hoffman, 1992). As a consequence, the resistance of the tree against drought would increase. In the context of the investigations, four questions were asked:

- How does soil amelioration affect tree development under different climatic conditions according to the condition in different cities of Switzerland
- What is the effect of the type fo admixture on different tree species
- How is the effect of soil amelioration on fine root growth of different tree species
- Does soil amelioration of tree grids with admixtures induce the same effect in old roadside trees as it does in young plantations?

2. Materials and Methods

To study the effect of soil amelioration on young amenity trees, three experiments were established.

2.1. Experiment 1

Admixture of expanded clay: effect under different climate conditions

The first experiment was set in 1987. It was run in parallel in three different cities – Basel, Bern and Zurich – with somewhat different climate conditions (Tab. 1).

Tab. 1: Annual rainfall (long-term average) per year

Basel	761 mm
Bern	1000 mm
Zurich	1128 mm

Three mixtures of soil with expanded clay (Leca®) were chosen. Six replicates were arranged in a fully randomized block design. Leca® is an opalinus clay that has been burnt in a special procedure to make it porous. All experiments were performed with a clone of *Tilia x europaea* L. var. *pallida* of the same size as used for planting in cities – about 3 m height at planting time. The experiment was run in coordination with a similar experiment in several German cities when lava was chosen as an admixture (Krieter, 1991).

The following conditions were tested:

- Control with 100% humus from local provenance normally used for plantings (see Tab. 2).
- Humus mixed with 50% expanded clay (mixing volume). This was achieved in addition to the gravel already present in the humus by mixing with expanded clay, unbroken granules of 10-20 mm

diameter. Due to the cavities between the granules, the effective admixture was much lower (20 vol% in Basel and Bern and 16 vol% in Zurich).

- Humus mixed with 60%, 40% and 20% expanded clay (mixing volume) stratified in layers of 50cm each (gravel increasing from top to bottom).

Tab. 2: Characterization of the humus used in experiment 1

	Basel	Bern	Zurich
Volume of the tree pit	7.5 m^3	8.5 m^3	6 m^3
pH($CaCl_2$)	7.3	7.4	7.3
organic C (%)	2.65	0.58	2.87
Clay (%)	35	28	25
Silt (%)	39	29	38
Sand (%)	26	44	37
Gravel (wt%)	8	10	17

2.2. Experiment 2

Admixture of lava rock: effect on different tree species

The second experiment was established in the nursery of the Stadtgärtnerei Basel. The aim of this experiment was to setup a quantitative series of admixtures with different tree species and to use lava rock as a cheaper admixture. Lava rock (Lavalit®) was added in proportions of 0%, 20%, 40% and 60% to the planting humus which was a calcareous silty loam. *Tilia euchlora* K. Koch and *Acer platanoides* L. were used in this experiment; in the case of *Acer*, the 40% admixture was omitted. The lava admixture contained 15% sand which was added to the fine earth fraction and 85% 2-32 mm ∅ which was treated as gravel fraction. The percentage given for the admixture refer to the volumes mixed together, hence the effective volumetric lava rock content of the 60% lava admixture was about 35 vol%. The volume of the tree pit was 6 m^3. Five replicates were used.

2.3. Experiment 3

Horizontal gradient of gravel: effect on fine root growth

In the third experiment, a horizontal gradient of sand and gravel including expanded clay was set up to encourage tree roots to penetrate into the surrounding medium which in the city of Basel mostly contains a larger amount of sand and gravel (river deposit). The design of the experiment is shown in Tab. 3. The volume of the tree pits was 6 m^3 (2x2x1.5 m).

Tab. 3: Conditions used in experiment 3

1	Mixture of 50% fine earth (calcareous silty loam) and 50% expanded clay (broken Leca®, 4-6 mm ∅)
2	Center: mixture 1, pitwall (50cm): mixture of 30% fine earth, 20% sand, 25% gravel, 25% expanded clay
3	Center: mixture 1, pitwall (50cm): mixture of 30% fine earth, 20% sand and 50% gravel

The experiment was conducted with three tree species: *Acer platanoides* L., *Platanus x acerifolia* (Ait.) Willd. and *Tilia x europaea* L. var pallida. The treatments were replicated five times.

2.4. Experiment 4

Soil amendments of old roadside trees

To test the effect of expanded clay on soil amelioration with old roadside trees, three conditions were tested:

- Control (no change of the tree grid)
- Increasing of the tree grid by removing the asphalt between two trees. The upper 20cm were broken up, mixed with humus and covered with chips of bark and wood
- Same as 2) with an 1:1 admixture of expanded clay (Leca® 10-20mm) to the humus

2.5. Measurements

After termination of shoot elongation, growth of the terminal shoots in the upper crown was measured once a year in August using a car lift. Leaf water potential was measured with a pressure bomb after a dry period either early in the morning (predawn water potential, experiment 1) or at noon when water stress was highest (experiments 2 and 3). Root distribution within the tree pits was determined by taking core samples with a Humax coring machine which extracts cylinders of 8 cm ∅ down to a depth of 1.25 m in fractions of 25cm. Roots were quantitatively removed from the cores, washed and analyzed for their length in the fractions <1 mm, 1-5 mm, >5 mm ∅ using a Delta-T image analysis system. After this procedure they were dried at 105°C and weighed. For measurement of the water potential in the soil, ceramic cup tensiometers were installed in 30 and 80cm depth. Saturated water conductivity was measured with a double ring infiltrometer (Eijkelkamp). Soil air was sampled using a soil air probe and analyzed for CO_2 by injection into an IRGA analyzer. Water storage capacity of the soil was calculated after Benzler et al., 1982).

3. Results

3.1. Experiment 1

The effect of the admixture of expanded clay was somewhat different in the three cities. There was no difference between the two types of admixture of expanded clay (homogeneous or stratified). The most striking effect was on shoot growth (Fig. 1). It was strongest in Zurich and weakest in Basel. Shoot growth was most significantly stimulated in the second and third year after planting, levelling off later on.

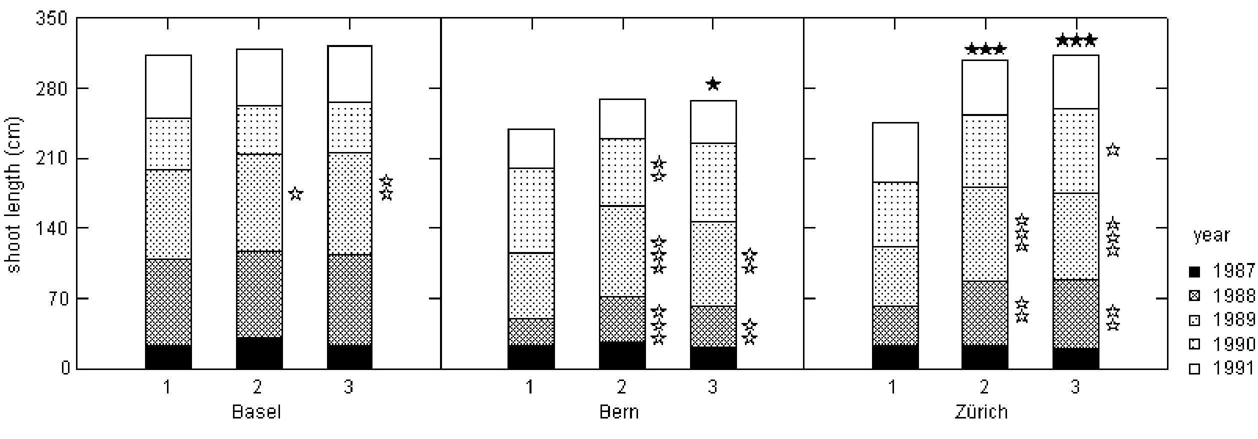

Fig. 1: Shoot growth of a clone of *Tilia x europaea* L. var. *pallida* in the cities of Basel, Bern and Zurich according to experimental condition. 1: control, 2: homogeneous admixture of 50% expanded clay, 3: stratified admixture of 60%, 40% or 20% expanded clay (increasing from top to bottom). Difference to control significant at *p<0.05, **p<0.01, ***p<0.001.

The soil water potential was significantly increased in the tree pits with admixtures of expanded clay, except in Zurich in the layered condition. Fig. 2 shows data from Basel.

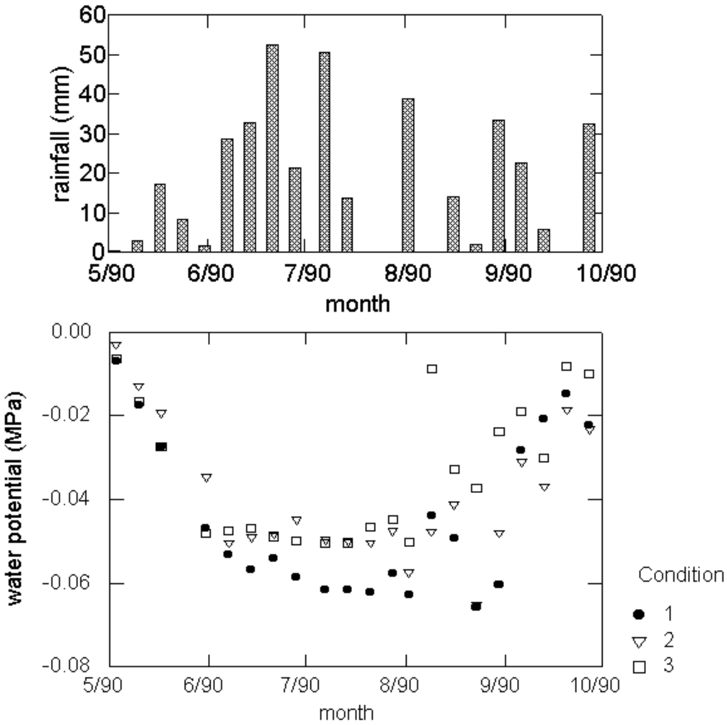

Fig. 2: Weekly rainfall (upper graph) and soil water potential as an example in Basel in 1990 (third year of the experiment), tensiometers in 80cm soil depth. Condition 1: control, 2: homogeneous admixture of 50% expanded clay, 3: stratified admixture of 60%, 40%, 20% expanded clay. The increase of the water potential in conditions 2 and 3 compared to condition 1 is significant in all cities and both depths examined (30 and 80cm, respectively) except in Zurich in condition 3.

Admixtures of expanded clay increased the soil water conductivity and decreased the CO_2 concentrations in the soil pores (Tab. 4, Fig. 3). Inspite of the higher soil water potential found in the experimental conditions with admixture of expanded clay, the predawn water potential in the leaves showed no significant differences (data not shown).

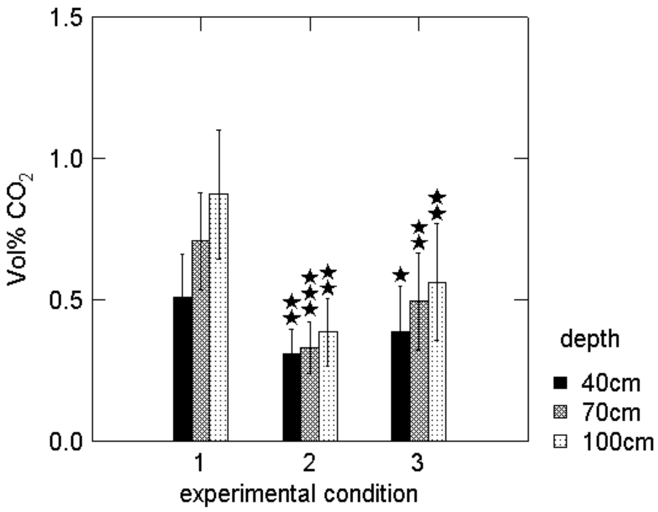

Fig. 3: CO_2 concentration in the soil pores in the Basel experiment (experiment 1). Difference in relation to control (condition 1) significant at *p<0.05, **p<0.01, ***p<0.001.

Tab. 4: Saturated water conductivity in experiment 1

City	experimental condition		
	1 (control)	2 (homogeneous admixture of expanded clay)	3 (stratified admixture of expanded clay)
Basel	0.26	0.64	0.52
Bern	0.35	0.62	0.56
Zurich	0.32	0.66	0.59

3.2. Experiment 2

The admixture of lava instead of expanded clay had significant negative effects on the shoot growth of *Tilia euchlora* but not of *Acer platanoides* (Fig. 4). Already an admixture of 20% lava to the planting soil induced a significant inhibition of shoot growth in Tilia in the third year while *Acer* reacted with a growth stimulation at the same time. The leaf water potential behaved similarly. In *Tilia*, leaf water potential in the conditions with 40% and 60% lava decreased significantly while *Acer* did not show any differences (Fig. 5). The water potential in the leaves was in accordance to the root coring results. Whilst *Tilia* showed significantly decreasing root biomass between 20 and 60% lava admixture in the tree pit, with *Acer* no significant reduction was observed (Fig. 6).

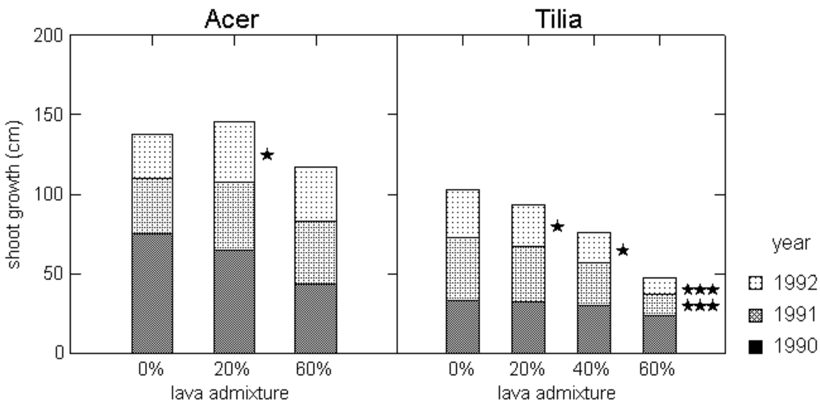

Fig. 4: Shoot growth of *Acer* (left) and *Tilia* (right) in different admixtures of lava. Significant differences in relation to the control (0% admixture) are indicated with *p<0.05, ***p< 0.001.

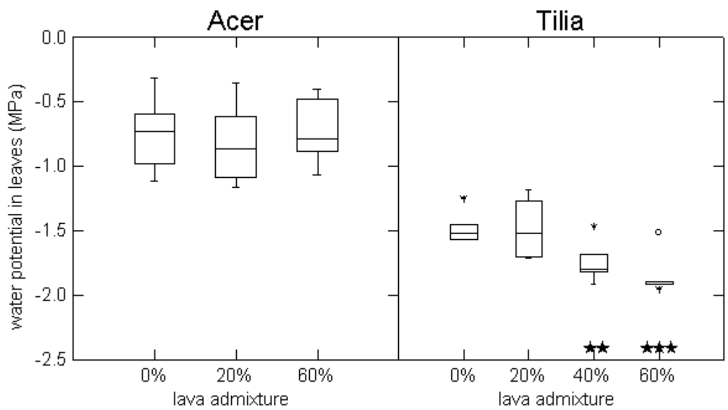

Fig. 5: Water potential in the leaves collected at noon on August 13, 1990. Significant differences in relation to the control are given with **p<0.01, ***p< 0.001.

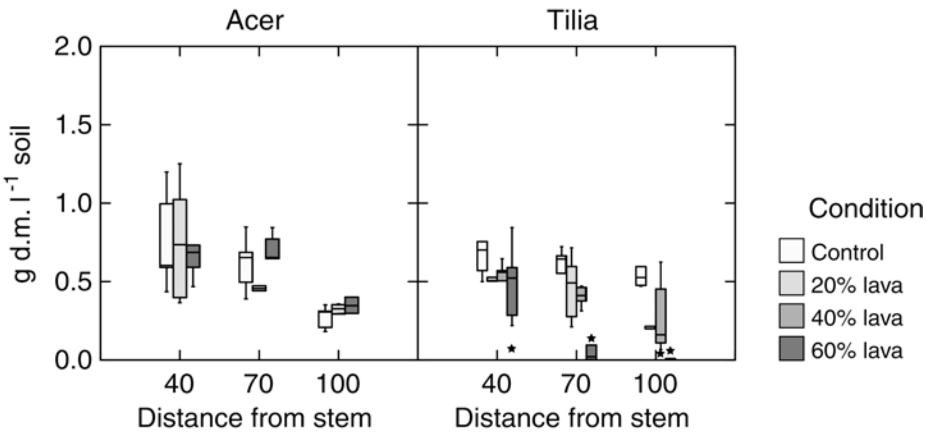

Fig. 6: Biomass of fine roots (≤5 mm ∅) of *Tilia* in different distances from the stem in 0-100cm depth with different lava admixtures 2.5 years after planting. Significant differences to the control are indicated by asterisks ($p<0.05$ to $p<0.001$). In the case of Acer, no significant differences were observed ($n=5$).

<u>Experiment 3</u>

The horizontal gradients imposed in experiment 3 induced a slightly accelerated fine root growth in condition 2 in *Acer*, *Platanus* and *Tilia*, in *Acer* also in condition 3 in the third year after plantation. With increasing root development in the tree pit, the effects on root density levelled off in 1997 (Fig. 7). In the third year, *Acer* and *Tilia* showed also an increased leaf water potential in condition 2 and *Tilia* in condition 3 (Fig. 8).

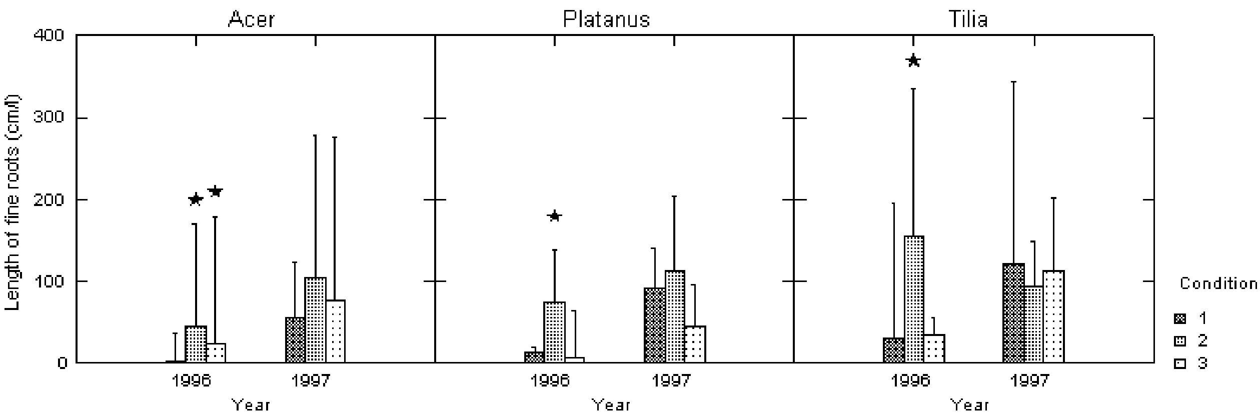

Fig. 7: Development of the root density in experiment 3 in a distance of 130cm from the stem. The bars represent the 95% confidence interval (calculation after root transformation). Condition 1 is the control, condition 2 an admixture of gravel, sand and expanded clay to the pitwall, condition 3 an admixture of gravel and sand only (see Tab. 3).

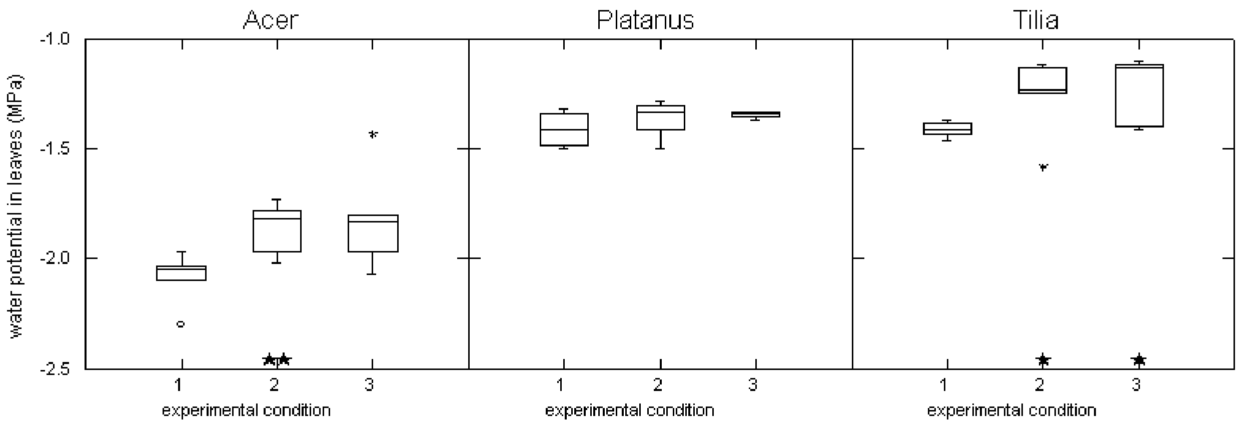

Fig. 8: Water potential in leaves at noon on September 6, 1996. Difference to control (condition 1) significant at *p<0.05, **p<0.01. Condition 1 is the control, condition 2 an admixture of gravel, sand and expanded clay to the pitwall, condition 3 an admixture of gravel and sand only (see Tab. 3).

3.4. Experiment 4

Soil amelioration of tree grids with old roadside trees revealed a significantly increased fine root formation especially in larger depths in the condition with expanded clay (Fig. 9).

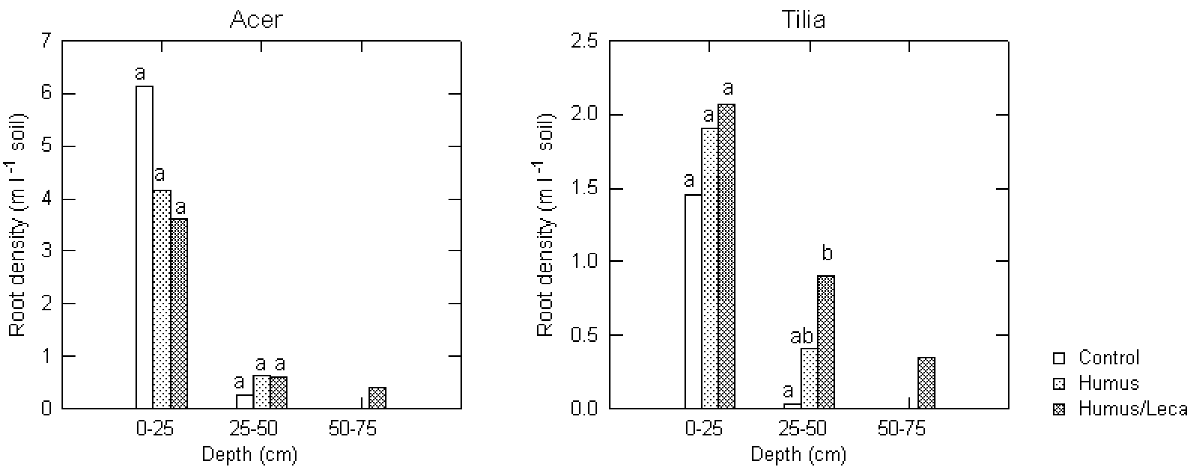

Fig. 9: Length of fine roots (≤ 0.5 mm ∅) of old roadside *Acer* (left) and *Tilia* (right) in different experimental conditions with increasing soil depth 4 years after the amelioration of the tree grids. Significant differences are indicated with different letters ($p<0.05$). For explanation of experimental conditions see section 2.4.

4. Discussion

The admixture of expanded clay had a positive effect on shoot growth and soil water relations as well as on the aeration of the tree pit in all three cities. However, admixture of lava had no similar positive effect on trees. Growth of twigs and roots of *Tilia* was strongly inhibited with increasing admixtures of lava while *Acer* showed a positive effect on shoot groth and no inhibition of root growth with an admixture of 20% lava. The growth reduction in *Tilia* due to lava admixture is in accordance with the observations by Krieter, 1991) who performed similar investigations as experiment 1 in different German cities with the same clone of *Tilia europaea* var. *pallida* but with lava as an admixture instead of expanded clay. The strong difference between expanded clay and lava rock cannot be explained as a physical effect alone. In experiment 3, where gravel from river deposits was compared to expanded clay, no or slightly positive results were obtained. Hence, chemical effects must also be considered. Pot experiments under comparable soil water conditions with ground expanded clay and lava rock (<2mm ∅) revealed also a significant inhibition of shoot growth in Norway spruce seedlings by lava.

According to data from the manufacturer, the storage capacity of the expanded clay for plant available water (25%) was higher than that of the fine earth mixtures used in experiment 1 (18.3-21%). It is therefore not surprising that the water potential during dry periods remained higher in the tree pits with expanded clay admixtures (experiment 1). An increased soil permeability may also enhance penetration of rainfall and thus wetting as well as aeration which is suggested by the decreased CO_2 concentration in the soil pores. The positive reaction of the trees to the experimental conditions in experiment 1 suggests that aeration is quite important as no differences in leaf water potential were found. Most often only water availability is considered when trees are planted in cities.

Old roadside *Acer* and *Tilia* reacted differently to soil amelioration of grids. *Tilia* showed a positive response of fine root formation when expanded clay was added to the humus. However, in the case of Acer no changes were observed. It is suggested that *Tilia* depends much more on favourable water relations and aeration in the soil compared to *Acer* as was also observed in experiment 2.

5. Abstract

The effect of different admixtures of expanded clay, lava rock and gravel to the soil of tree pits on freshly planted urban trees (*Acer platanoides* L., *Tilia x euchlora* K. Koch., *Tilia x europaea* L. var *pallida* and *Platanus x acerifolia* (Ait) Willd. was investigated. Expanded clay proved to be most favourable for Tilia. It improved the soil water regime and the aeration. Lava rock was deleterious for Tilia but not for Acer. The effect on the trees was not much different in the case of vertical gradients of the admixutre compared to a homogeneous mixture. A horizontal gradient with river gravel resulted in a slight stimulation of fine root development of all tree species and a better water relation in the leaves of *Acer* and *Tilia* in the third year after plantation. Soil amelioration with admixtures of expanded clay in the tree pits of old road side trees revealed significantly increased fine root formation in larger soil depths for *Tilia* but not for *Acer*.

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Controlled mycorrhization of urban trees

Introduction

In natural soils, plants are strongly dependent on mycorrhizal symbioses, i.e. an obligate, mutualistic association of roots with specialized soil fungi. There is a wide diversity of mycorrhiza types, depending on the taxonomic groups the plant and the fungus belong to. Among these types, one is particularly important : the *ectomycorrhizal* symbiosis with higher fungi is known to be an obligate association for most social forest trees families (Pinaceae, Betulaceae, Myrtaceae, Fagaceae, Salicaceae) outside the inter-tropical zone. The fungal symbiont, through its extensive hyphal network, takes up water and nutrients from the soil and transfers them to the root cortex. It also produces plant growth regulators affecting the plant development, and the mycelial mantel protects the short absorbing roots against soil-borne pathogens. The combination of these various mechanisms results in a wide range of tree response to the symbiosis, depending on the plant and fungal species and on the environmental conditions.

The use of this diversity of response is developing in forestry practice through the technique known as *controlled mycorrhization* . It consists of inoculating seedlings in the nursery with mycelia of ectomycorrhizal fungi selected for their better performance at stimulating tree growth, compared to the resident symbionts at the outplanting site (Alvarez et al., 1994; Le Tacon et al., 1992; Marx and Cordell, 1988). Controlled mycorrhization is an energy-saving and environment-friendly alternative to soil tilling, chemical fertilizers and pesticides for improving the early growth of forest plantations.

Many ectomycorrhizal tree species are also commonly planted in cities as ornamentals (e.g. *Tilia* sp, *Corylus* sp, *Quercus sp*) but their mycorrhizal status under these conditions is poorly documented (Danielson and Pruden, 1989, Nielsen and Rasmussen, 1999). The aim of this paper is to discuss the possibility of adapting controlled mycorrhization to avenue trees.

Specific conditions of urban plantations

Urban conditions differ from forest ones in that trees are much older and bigger when outplanted and are submitted to severe stresses such as air pollution by exhaust fumes, de-icing salt and soil compaction. Their root systems are also generally confined in a smaller volume and the air and water supply is often limited by sealed pavement; it is therefore appealing to use controlled mycorhization to alleviate these stresses. However, the specific conditions encountered by trees in urban plantations have to be examined for their consequences on the management of ectomycorrhizal associations.

3. Natural ectomycorrhizal status of urban trees and symbiont diversity

In 1989, Fienena, Churin and Garbaye (unpublished results) compared the ectomycorrhizal status of old (at least 10 years after planting) *Tilia cordata* along the streets of Nancy (a town in north-eastern France) and naturally-growing trees of the same species in forests surrounding the town (*T. cordata* is native to the region). They found the same 12 morphotypes of ectomycorrhizas in both ecosystems, but with a very different distribution pattern. In the forest, all types are almost equally represented, with few variations among trees. In contrast, in town, while all types are also represented when root samples from many trees are pooled, half of the morphotypes are missing on any individual tree and the missing types differ among trees. Nielsen and Rasmussen (1999) found with *Tilia cordata* in Denmark that forest habitats contained more morphotypes than urban habitats, but that urban trees had two dominant mycorrhizal types which were totally absent in the forest. We may therefore conclude that the stresses specific for urban conditions are distributed very heterogeneously and select specialized, tolerant fungal species.

Thus, when selecting fungal species or strains for controlled mycorrhization of urban trees, we should *a priori* expect better results with town isolates than with isolates already selected for forest plantations.

The mycorrhizas acquired in the nursery are also determinant for the establishment of the plantation. That is why we surveyed the diversity and distribution pattern of the ectomycorrhizal fungi asociated with 15 year-old *Corylus colurna* in a German nursery (Lappen Baumschule, Nettetal, Westphalen), using ribosomal DNA fingerprinting (ITS region) to identify species. The results (unpublished) indicate that there are at least 20 different ribotypes (approximatively corresponding to the same number of species and identified morphotypes). *Tuber albidum* and *Laccaria* spp. are dominant. This rather large diversity means that the potential range for selecting efficient strains is extremely wide, because selection is generally done at the isolate (strain) level. Some of the new fungal strains we isolated in this nursery are presently under trial in plantations of *C. colurna* in Paris.

4. Aims of controlled mycorrhization of urban trees

By analogy with forestry, where controlled mycorrhization is particularly effective under adverse planting conditions (drought, severe mineral deficiencies or soil toxicity: Garbaye and Churin, 1997; Marx and Cordell, 1988), we may speculate that the effect of ectomycorrhizal inoculation of urban trees could be even more interesting under unfavorable circumstances. Therefore, this technique may be worth developing in addition to the usual precautions whenever ornamental trees are to be planted under difficult conditions. For instance, optimizing the ectomycorrhizal symbioses could be a way of improving the success of plantations with tree species known for their poor survival after outplanting, such as *Corylus colurna* (Turkish hazel), permitting a wider variety of ornamentals in our cities.

In forestry, the main objective of any practice is to increase overall growth and wood production. Vigorous trees are also desirable in town, but excessive growth is rather a nuisance because it implies more space and/or pruning. Trees in town are primarily *ornamentals*, i.e. their primary function is an aesthetical one: they are supposed to look healthy, with a clean trunk and a balanced crown, and to display fresh green leaves as long as possible during the year.

The experimental results of Garbaye and Churin (1996) with *Tilia tomentosa* in Paris clearly showed that both objectives (growth stimulation and aesthetical improvement) can be effectively achieved through controlled mycorrhization. The three treatments with fungal inoculation markedly improved tree growth and the persistence of healthy green leaves. Foliar mineral analyses revealed that the treatments reduced yellowing through improved mineral nutrition of the trees (mainly calcium and magnesium). It is remarkable that these promising result were obtained with fungal strains from various origin, which were initially chosen for their efficiency under completely different conditions: *Laccaria laccata* S238N for controlled mycorrhization of Douglas fir forest plantations (Le Tacon et al., 1992), *Paxillus involutus* NAU for its performance with oaks (Garbaye and Churin, 1997) or *Cenococcum geophilum* NCY from a lime tree in the city of Nancy (Fienena, Churin and Garbaye, unpublished). It is thus reasonable to assume that selection work specifically aimed at urban trees would yield even better performing strains.

Our more recent work in Paris concerns *Corylus colurna.* Here too, mycorrhizal inoculation with various fungi (*Paxillus involutus* BOUX, *Cenococcum geophilum* NCY and an unidentified Thelephoraceae close to *Tomentella* sp. isolated from *C. colurna* roots in the German nursery) results in greener and longer-persisting leaves.

5. Inoculation timing and competitiveness of the introduced fungi

Planting stocks used in forestry are young seedlings, usually 1 or 2 years old. For controlled mycorrhization, it is easiest and cheepest to inoculate them when sowing in the nursery, after disinfecting the soil to suppress resident symbionts: the introduced fungus meets no competitors and forms abundant mycorrhizas which easily persist until outplanting. In contrast, trees planted in town are much older and it is likely that their mycorrhizal status changes between the seedling stage until outplanting 8 or 10 years later. Therefore, inoculation should take place either as late as possible in the nursery or at planting in town. But, in both cases, even if the soil packed around the root is disinfected and fungus-free, the roots are mycorrhizal and the introduced, selected fungus will suffer harsh competition from the already-established symbionts.

The results of Garbaye and Churin (1996) with *Tilia tomentosa* presented in Table 1, where the inoculum was applied in the planting hole in town, demonstrate that it is possible to inoculate sucessfully in spite of these difficulties. The introduction of *L. laccata* and *P. involutus* was clearly successful: the trees inoculated with these fungi had significantly more mycorrhizas of the corresponding morphotypes than the non-inoculated ones. But the case of *C. geophilum* is more surprising: *Cenococcum*-type ectomycorrhizas from the nursery were abundant on the roots at planting (not shown in Table 1; see Garbaye and Churin, 1996) but were completely absent three years later on the newly-formed roots. As the *C. geophilum* treatment had a significant effect on tree growth (Garbaye and Churin, 1996), we may conclude that the introduced strain of this species briefly formed mycorrhizas just after outplanting, then disapeared together with the strain(s) from the nursery. The reason of the very poor persistence of *C. geophilum* under the conditions of the experiment might be the irrigation of the trees which is routinely performed in Paris during the two years following outplanting: this fungus species is known to prefer dry soils.

Table 1: Effect of inoculation treatments on the ectomycorrhizal status of *Tilia tomentosa* three years after outplanting along Boulevard Suchet in Paris (from Garbaye and Churin, 1996). Identified mycorrhizal morphotypes as per cent of total short roots out of a random sample of 200 short roots (mean values of nine replicates). Values followed by an asterisk significantly differ from that of the non-inoculated treatment (ANOVA and Fisher LSD test).

Treatments	**Ectomycorrhizal morphotypes (% of short roots)**		
	Laccaria-type	*Paxillus*-type	*Cenococcum*-type
Non-inoculated	7.5	1.0	0
Laccaria laccata	25.9 *	0.1	0
Paxillus involutus	2.0	11.6 *	0
Cenococcum geophilum	6.2	3.2	0

However, even more than in the case of forest plantation, it is clear that aggressiveness (root-colonizing ability) and competitiveness against wild symbionts are major criteria for selecting fungal symbionts to be utilized in urban plantations.

We are presently experimenting on inoculation timing in Paris, comparing the behaviour of *Corylus colurna* inoculated with the same fungal strains when outplanting or one year earlier in the nursery. The first results of this new series of trials are given in Table 2, showing clear difficulties for the introduced fungi to colonize the roots but better results in terms of symbiosis intensity when inoculation took place at the nursery stage.

Table 2: *Corylus colurna* planted along Avenue Boutroux in Paris. Inoculation with *Laccaria bicolor* S238N or *Paxillus involutus* BOUX took place either by trenching in the nursery one year before outplanting, or at planting. Figures given are the percentage of trees mycorrhizal by the introduced fungus, followed (in brackets) by the percentage, on the roots of these trees, of short roots mycorrhizal by the introduced fungus (out of a random sample of 200 short roots). Observations took place two years after inoculating.

Treatment	**Nursery inoculation**	**Outplanting inoculation**
Uninoculated	0 (0)	0 (0)
Laccaria bicolor	40 (19)	40 (11)
Paxillus involutus	20 (23)	20 (11)

In the USA, Smiley *et al.*, (1997) have proposed an alternative technique: instead of introducing the fungal inoculum in the nursery or at planting time, they tried to improve the health of declining old trees (pecans, willow-oaks and red oaks) by localizing inoculum of *Pisolithus tinctorius* in holes made in the soil in different places of the rooting zone. Four and seven months later, the treatment resulted in more abundant fine roots and a higher proportion of *P. tinctorius* mycorrhizas in the inoculated holes.

All these results are encouraging because they indicate that it is realistic to consider mastering the ectomycorrhizal status of urban trees as a tool for better performance.

7. Economical considerations

Commercial ectomycorrhizal inoculum is presently only available for forest applications where a low price is very decisive. But, as discussed above, we are not yet sure that he same fungal strains which are performant in forest plantations will do well in town under very different conditions. That is why, if controlled mycorrhization of urban trees is to develop, it is likely that special strains will have to be selected.

However, the cost of the inoculum is not so important in urban plantations; in the trials reported in Tables 1 and 2, it was only about FF 30 (Euro 5) per tree, which was marginal compared to the cost of planting such big trees. It would therefore be economically possible to use much higher doses of inoculum in order to improve mycorrhizal establishment.

8. Conclusion

The preliminary results discussed above encouragingly show that the management of ectomycorrhizas can be an environment-safe way of improving the quality of avenue plantations of ornamental trees in cities, either as an alternative to pesent techniques or as a complement. Further experimentation is presently taking place in Paris, but much remains to be done for selecting and mastering adapted fungal strains, due to the specificity and heterogeneity of urban ecosystems as compared with forest ones.

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Control measures against the horse chestnut leafminer, *Cameraria ohridella*

Introduction

The horse chestnut leafmining moth, *Cameraria ohridella* DESCHKA AND DIMIC (Lepidoptera; Gracillariidae), was first observed and detected on horse chestnut trees (*Aesculus hippocastanum* L.) in the surroundings of lake Ohrid in Macedonia in 1985 (DESCHKA AND DIMIC 1986). In Central Europe first records have been made in Upper Austria in 1989 (PUCHBERGER 1990). In the following years *C. ohridella* spread into the most Central and Western European countries and caused mass infestations. Until now, its distribution reaches from Bulgaria to the Netherlands and from Northern Italy to the North of Germany, and it is still expanding. The main reason for its expansion are different kinds of transport (such as train, car, ship) along main transport routes as it is well documented in Germany (BATHON 1999).

The leaves of attacked trees turn brown due to the feeding of the larvae and heavily infested trees are defoliated during summer.

This pest has not only reached much attention because of its rapid spread and spectacular damage to the trees, but also because the horse chestnut tree is one of the most popular ornamental trees in urban areas in Europe. Thus, there are great efforts in several countries to find effective control measures against *C. ohridella*. A survey of different control measures and experiences (and future aspects) against the horse chestnut leafmining moth is given in the present paper.

Control measures

- Cultural methods

  In Austria up to now two mechanical or cultural methods are applied to reduce the population of *C. ohridella*: the support of the vitality of the trees and the removal of dead leaves in autumn. Practical experience showed that watering and nutrient supply is an important measure to increase the tree's own defence mechanism, especially at dry periods in summer. Provision with water is very important for the horse chestnut trees because they need approximately 1000 mm precipitation per year in contrast to the amount of only 600 mm in Vienna and the Eastern regions of Austria. This can be explained by their place of origin in the mountains of Northern Greece, Albania and Bulgaria.

  In autumn the removal and destruction of dead leaves (e. g. burning or composting) containing overwintering pupae has proved to be an effective method (MARX 1997) to reduce the first generation of the moth in the next year (spring), especially on isolated places with horse chestnut trees, such as inner courts in cities, parks, private gardens or trees along streets and so on. In forest areas and great parks where a complete removal of the leaves is not possible, this method is unefficient.

- Chemical control

  Several chemical treatments have been tried or proposed, most with little success or applicability. For example, different experiments with tree-injections or tree-infusions seemed (very) promising using systemic insecticides, but problems appeared such as the application technique, an irregular dispension of the insecticide in the tree and the phytotoxicity of the solvent (FEEMERS 1997, KREHAN 1997).

  Insect growth regulators proved to be most effective and practicable. Trials with 3 different insect growth regulators have been carried out at the Institute of Phytomedicine (Federal Office and Research Centre for Agriculture) in Vienna. BLÜMEL AND HAUSDORF (1996) obtained best results with WP formulations of Alsystin Bayer (Triflumuron) and Dimilin (Diflubenzuron): 98% - 100% of the larvae were killed depending on the number of applications. In practice the application of Dimilin succeeded in getting used as general control possibility. Diflubenzuron acts by inhibition of chitin synthesis and interferes with the formation of the insect cuticle. Thus, this mode of action can result in larvicidal and ovicidal effects at the time of moulting of the larvae or at the hatching of the eggs. Due to the specific effect on developing insect stages the correct timing of application is decisive for the success. Therefore Dimilin has to be sprayed before or latest at time of oviposition on the upper surface of the leaves where are the moths‘ eggs. Thus, the leaves‘ parts which are covered with the spraying solution are also very important because Dimilin has only an effect by feeding or direct contact.

Diflubenzuron is effective at a concentration of 0,04 % against the horse chestnut leafmining moth. One single treatment per year – at the flight period of the first generation of the moth (between the mid and end of April, depending on climatic conditions) - with correct application is sufficient for an effective control of *C. ohridella*. In Austria each year the authorization of the use of Dimilin for the control of *C. ohridella* has to be renewed and is limited for a certain period of time (maximum 3 months).

- Biological control

Despite the successful control of *C. ohridella* with Dimilin chemical control is not regarded as a suitable solution for longer periods and therefore research is needed on topics such as mechanical and biological control measures. In Austria encouraging preliminary results were obtained with regard to the fauna of natural enemies. The species composition of the parasitoids, the most efficient natural enemies of the moth, has been determined on different localities in Austria during the last years. Besides studies on the biology of the most important parasitoid species have been conducted. A total of 22 species of parasitoids was found on *C. ohridella* (GRABENWEGER AND LETHMAYER 1999, STOLZ 1997). Most of them are Chalcidoidea (Hymenoptera) with the Eulophidae as the main component and only a few individuals belong to the Ichneumonoidea. All these parasitoids are polyphagous on different leafmining insects and none are specialists. The most abundant species were *Pnigalio agraules* WLK. and *Minotetrastichus frontalis* (NEES), which dominated the species spectrum in every sample. Another 5 species of Chalcidoidea were collected regularly: *Chrysocharis nephereus*, *Chrysocharis pentheus*, *Closterocerus trifasciatus*, *Cirrospilus vittatus* and *Pteromalus* cf. *semotus*. The remaining parasitoids occurred only very infrequently. Until now, the rate of parasitism is very low (about 5 % - 20 %, depending on the locality and the moth’s generation).

In the meantime investigations on the moth’s parasitoids have also been carried out from other European countries.

Further investigations and studies for biological control measures of *C. ohridella* are going on (not only in Austria), such as the conservation and augmentation of parasitoids, mass rearing of parasitoids, the search of the moth’s area of origin, and so on.

- Biotechnical control

After identification and synthesis of the special sex pheromone of *C. ohridella* this year (SVATOS et al. 1999) future studies will develop pheromone based monitoring and control methods.

Summary

During the last years intensive investigations on different possibilities to control the horse chestnut leafmining moth were carried out in several European countries, especially in Austria. Although there is successful chemical control against *C. ohridella*, this is not regarded as the definitive solution. Additionally, the moth’s mass occurrence and rapid spread is still not stopped. Thus, the development of sustainable and integrated pest management strategies in urban areas – incorporating different environmental friendly control methods, minimising or replacing the use of insecticides - is of great importance for the future. Furtheron, international cooperation will become much more important and necessary to find an integrated pest management system for urban areas.

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Creating landscapes that suppress insect pest outbreaks

Introduction

In natural habitats herbivorous insects seldom outbreak, whereas in disturbed or highly managed habitats, where ecological processes are disrupted, herbivores frequently outbreak. Elucidating factors that lead to insect outbreaks in disturbed habitats can help us to identify methods to restore some of the functional processes that prevent insect outbreaks. Many studies have attempted to describe and understand the relationships among various components of vegetational texture of both natural and managed habitats and the abundance of phytophagous insects (Tahvanainen and Root 1972, Root 1973, Cromartie 1975a and b, Raupp and Denno 1979, Bach 1980a and b, 1981, 1986, 1988, Risch 1980, 1981, Rausher 1981, Kareiva 1983, Elmstrom et al. 1988, Andow 1990, 1991, Denno and Roderick 1991) and natural enemies found there (Hatley and MacMahon 1980, Andow and Risch 1985, Sheehan 1986, Russell 1989, Letourneau 1990a and b, Hanks and Denno 1993, Marino and Landis 1996, Colunga-Garcia et al. 1997, Dyer and Landis 1997). This article discusses recent works examining the influence of vegetational texture on herbivore distribution and abundance in managed urban landscapes. These works are discussed in more detail by Shrewsbury and Raupp (in press) and Leddy (1996).

In urban landscapes, azalea lace bug, *Stephanitis pyrioides* (Scott) (Heteroptera: Tingidae) is the single most important pest of azaleas in Maryland (USA) (Raupp and Noland 1984). A thorough description of the bionomics of azaleas and azalea lace bug was presented by Trumbule et al. (1995). Azalea lace bug abundance varies dramatically in time and space (Raupp 1984, Trumbule et al. 1995). Understanding the relationship among components of vegetational texture and azalea lace bug abundance is important for at least two reasons. First, by identifying habitat factors that correlate with lace bug abundance, existing landscapes can be evaluated and assessed for the likelihood that lace bug outbreaks will occur. This has direct implications for designing integrated pest management programs for landscape managers (Ball 1987). Second, a more thorough understanding of the relationship between vegetational texture and pest abundance may allow landscape designers to create aesthetically appealing landscapes that are relatively refractory to pest outbreaks.

Previous studies correlated the degree of light exposure to patterns of lace bug injury and frequency of infestation of azaleas. Raupp (1984) found that the frequency with which azaleas were infested by azalea lace bug varied where azaleas in afternoon and all day sun were more frequently infested by lace bugs than azaleas receiving morning sun only. In a related study, Trumbule et al. (1995) identified four categories of azaleas damaged by azalea lace bug and discovered that the highest light intensities were recorded over azaleas in the highest damage category and the lowest light intensities were recorded over azaleas in the lowest damage category (Trumbule et al. 1995). Neither of these previous works directly measured the relationship between azalea lace bug abundance and light exposure. In addition, both studies were limited to examining only a single component of vegetational texture, light exposure.

In this study, we examined the relationship between azalea lace bug abundance and several components of vegetational texture in managed landscape habitats. We wanted to determine which component(s) best explained patterns in lace bug abundance. The components of vegetational texture examined were light exposure, plant species diversity, evenness, and richness, host patch size, and the structural complexity of the habitat. We hope that a better understanding of the relationship between herbivore abundance and vegetational texture will assist in designing low-input, sustainable landscapes.

Materials and Methods

To examine the relationships among azalea lace bug abundance and components of vegetational texture in managed landscape habitats, we selected 24 established home and municipal landscapes in Maryland (U.S.A.). Landscapes were selected that appeared to vary in light exposure, plant species diversity, evenness, and richness, host patch size, and the structural complexity. Within each site, we selected one azalea plant as the study plant. We then measured a 10 x 10 meter area, with the study plant at the center of the square, to use as the study area.

Azalea lace bug abundance was measured on each study plant within each site on ten dates from June to October. Lace bug abundance was measured using a standardized beating technique (described in Shrewsbury and Raupp *in press*). The number of lace bugs per square meter of leaf area was determined for each plant on each sampling date and then summed over time.

Components of vegetational texture measured at each landscape site were light exposure, plant species diversity, evenness, and richness, azalea patch size, and structural complexity. The amount of light exposure that each study plant received was measured using a light meter (Decagon Sunfleck Ceptometer) to determine photosynthetically active radiation (PAR - waveband 400-700 nanometers). Light sampling was performed in the morning and in the afternoon at each study site to determine if time of day influenced the relationship between light intensity and azalea lace bug abundance. The average of the morning and afternoon readings was also calculated. Within the 10 x 10 meter study area of each landscape site the taxa and number of each taxa of all plants were determined. From this data, plant species diversity, evenness, and richness were estimated using a Shannon Wiener Diversity Index (Zar 1974). Within the 10 x 10 meter study area, azalea patch size was measured as the area of contiguous azalea foliage inclusive of the study plant and all of its azalea neighbors.

A rating system, modified from Erdelen (1984), was developed to quantify the structural complexity of each landscape site. Structural complexity is an index of the structural intricacy of a landscape based on the amount or frequency of vegetation in the three dimensional space of the habitat. The vertical vegetational strata of the space consisted of five layers, a groundcover/turf layer, an annual/perennial layer, a shrub layer, an understory tree layer, and an overstory tree layer. The presence or absence of plant material in each square meter of the three-dimensional grid was scored (10x10 meters x 5 plant strata = 500 squares total). Each site's complexity rating was the total number of grid squares occupied by plant material. The contribution of each of the five vegetational strata to azalea lace bug abundance was examined to determine which vegetational strata explained the most variation in lace bug abundance.

Results

When azalea lace bug densities were summed across all sampling dates, there was a wide range in abundance among the 24 landscape sites (range = 1 – 3,122 lace bugs / m^2 leaf area). Similarly, there was a wide range in the measurements for components of vegetational texture in the landscape habitats (see Shrewsbury and Raupp *in press*).

When components of vegetational texture were examined simultaneously in a multivariate analysis, multicollinearity existed for one or more of the components of vegetational texture. Therefore, a multiple regression analysis was not performed. When testing for correlation between the components of vegetational texture, a strong negative linear association between structural complexity and light exposure (r^2 = -0.73) was found. Not surprisingly, there were strong positive linear associations between structural complexity and plant species richness (r^2 = 0.65) and between plant species richness and plant species diversity (r^2 = 0.77).

In examining how well each of the individual components of vegetational texture explained the variation in azalea lace bug abundance, the best habitat predictors of azalea lace bug abundance were structural complexity (r^2 = 0.54) and light exposure (r^2 = 0.53). In addition, three of the remaining four components were significantly related to lace bug abundance (Table 1). Plant species richness also explained a relatively large amount (41%) of the variation in lace bug abundance (Table 1).

Further examination of light exposure revealed that morning readings of light exposure explained less variation in lace bug abundance than afternoon readings (partial r^2 = 0.09, partial r^2 = 0.52, respectively). The use of both morning and afternoon readings explained only slightly more of the variation in lace bug abundance (r^2 = 0.61) than afternoon readings alone. These relationships were positive and indicated that as light exposure increased, azalea lace bug abundance increased. Of the five vegetational strata comprising structural complexity (groundcover/turf, annual/perennial, shrub, understory tree, and overstory tree) the combination of the overstory tree layer and the groundcover / turf layer explained 76% of the variation in lace bug abundance. These two factors were the best descriptors of azalea lace bug abundance. The overstory tree layer correlated negatively with lace bug abundance, indicating that the more overstory trees in a landscape, the fewer lace bugs. Alternatively, the ground cover / turf layer was positively correlated with lace bug abundance, indicating that as more ground cover / turf is found in a landscape, lace bug abundance is greater. This is not surprising since turf was more commonly found than any other ground cover and study areas with more turf had fewer trees. It was also interesting that the vegetational stratum containing azaleas contributed very little to the variance in lace bug abundance (partial $r^2 < 0.05$).

Table 1: Summary of regression analyses of azalea lace bug abundance[a] and components of vegetational texture from established urban landscapes in Maryland U.S.A.. Lace bug abundance was summed over 10 sampling periods in 1994.

Vegetational Component	**n**	***F***	***P***	r^2	**Model**	**SE for *b***
Structural complexity	24	20.83	0.0002	0.54	y = -0.007x + 2,87	0.0016
Light exposure	24	20.45	0.0003	0.53	y = 0.0007x + 0.79	0.0002
Plant species richness	24	12.64	0.0023	0.41	y = -0.1208x + 2.69	0.0339
Plant species diversity	24	5.87	0.0260	0.25	y = -1.0092x + 3.09	0.4159
Azalea patch size	24	5.41	0.0320	0.23	y = -0.0650x + 2.11	0.0279
Plant species evenness	24	0.66	0.4274	0.04	y = 1.3213x + 0.70	1.6270

[a] Azalea lace abundance was the $\log_{10}(x+1)$ transformation of the number of lace bugs per square meter of leaf

Discussion

This study identified two components of vegetational texture, landscape structure and light exposure, as the best predictors of azalea lace bug abundance, relative to host patch size and plant species diversity, evenness, and richness in managed landscapes. Our results are consistent with several studies that have demonstrated greater herbivore abundance and injury in sunny, exposed habitats (Collinge and Louda 1988, Moore et al. 1988, Cappuccino and Root 1992). Although, other studies do contrast these results (see Shrewsbury and Raupp *in press*).

Differences in structural diversity or complexity of a habitat has been shown to affect both herbivore and natural enemy abundances (Hatley and MacMahon 1980, Bach 1981, Letourneau 1990a, Riechert and Bishop 1990, Hanks and Denno 1993, Döbel and Denno 1994, Marino and Landis 1996, Colunga-Garcia et al. 1997, Dyer and Landis 1997). Although Hanks and Denno (1993) did not directly measure habitat complexity of their study sites, they found high populations of white peach scale on isolated mulberry trees in landscapes, whereas in more structurally complex wood lot settings, mulberry did not support high densities of white peach scale. They implicated differences in predation by natural enemies between habitats as a primary determinant of this pattern (Hanks and Denno 1993). In a similar study, Pinto (1980) found densities of obscure scale lower in wood lot settings. He argued that these differences were maintained in part because the primary parasitoid of obscure scale was three times more abundant on pin oaks in natural woodlot settings than in ornamental settings. Furthermore, Risch et al. (1983) reviewed 150 published accounts that examined the effect of varying vegetational diversity on herbivore abundance. They found of 198 species examined, 53% decreased in diversified habitats, 18% increased, 9% exhibited no change, and 20% were variable. Overall, these studies indicate a general pattern of herbivore abundance to be lower in both more diversified and shadier habitats. Our studies are in agreement with this pattern.

Regression coefficients indicated that as structural complexity of a landscape increased, lace bug abundance decreased and as light exposure increased, lace bug abundance increased. In addition, there was a strong negative correlation between structural complexity and light exposure. This is not surprising since of the five vegetational strata that comprise structural complexity, the overstory tree layer contributed more (71%) to explaining the variation in lace bug abundance than the groundcover / turf layer, annual / perennial layer, shrub layer, or understory layer. It is the overstory tree layer that would most greatly influence the level of light received by azaleas. The implication of this relationship is that the overstory tree layer of structural complexity is an indirect measure of light exposure. Furthermore, the overstory tree layer is a better predictor of lace bug abundance (71%) than light exposure readings taken in the afternoon (52%), morning (9%), or a combination thereof (61%).

Interestingly, Trumbule and Denno (1995) found that it was not the effect of light exposure per se on the plants that explained patterns of lace bug abundance. Studies in the greenhouse and outdoor nursery beds revealed that azalea lace bugs survived better, were more fecund, and preferred to feed and oviposit on shade grown azaleas rather than azaleas grown in full sun (Trumbule and Denno 1995). Lace bug fitness was positively associated with plant vigor (leaf-water relations, plant chemistry, or morphology) (Trumbule and Denno 1995). These findings contrast with this study and others that clearly indicate greater lace bug abundance with increasing light exposure (Raupp 1984, Trumbule et al. 1995). Trumbule and Denno (1995) examined this conundrum further and found that survivorship of uncaged lace bugs was lower on plants placed in shaded woodlots versus open-lawn habitats. Their results suggested higher levels of arthropod predation in shaded habitats as the mechanism for reduced lace bug survival in those habitats. Our results concur with the work of Trumbule and Denno (1995) and indicate that factors other than light exposure alone influences patterns of azalea lace bug abundance.

In conclusion, our findings demonstrate that two readily measured factors, structural complexity and light exposure, are strongly related to and predictive of lace bug abundance in landscapes. We provide a method to quantify structural complexity of landscapes based on the occurrence of vegetation in the three dimensional space of the habitat. Moreover, measuring the overstory tree layer only of structural complexity provides the most practical and highly accurate estimate of lace bug abundance, more so than total structural complexity or light readings recorded in the afternoon and/or morning. However, a two factor model that incorporates the overstory tree and groundcover strata provides the best predictor of azalea lace bug abundance in landscape habitats. Other components of vegetational texture, such as plant species diversity, evenness, and richness, and host patch size, that others have found important in explaining herbivore abundance patterns, were less important than structural complexity or light exposure in this system.

The mechanisms underlying greater abundance of azalea lace bug in simple, exposed landscape habitats relative to complex, shady ones were not elucidated in this study. However, in later studies we examined several ecological processes to determine why lace bugs are more abundant in structurally complex landscapes than simple one. We found that mechanisms such as host plant quality and herbivore immigration and emigration did not explain these patterns in lace bug abundance. However, differences in natural enemy taxa and abundance between simple and complex landscapes played a key role in relegating lace bug outbreaks to azaleas in simple landscapes (see Leddy 1996).

The implications of our findings for pest management are as follows. Landscape sites can be evaluated for susceptibility to lace bugs and perhaps other pests. Structural complexity and light exposure measurements can be used to predict relative levels of azalea lace bug abundance. More complex landscapes have fewer pest outbreaks than simple ones. Therefore, complex landscapes require less input in terms of monitoring time and application of control measures.

With respect to landscape design, the most important single factor limiting azalea lace bug abundance is the presence of an overstory tree layer. While it is difficult to add large overstory trees to existing landscapes, it is possible to add trees that will grow and provide overstory canopy as the landscape matures. Furthermore, azalea lace bug populations may be greatly reduced by planting azaleas beneath overstory trees. If azaleas must be planted in sunny exposed locations, then landscape managers and homeowners should be prepared to spend greater amounts of time and resources monitoring lace bug populations and intervening when lace bug populations reach unacceptable levels.

<u>Summary</u>

Ecological factors related to the distribution and abundance of azalea lace bug (*Stephanitis pyrioides* (Scott), Heteroptera: Tingidae), were examined in managed landscapes in the mid-Atlantic region of the U.S. Azalea lace bug is a key pest of azaleas and its abundance varies dramatically in time and space. The relationship between azalea lace bug abundance and components of vegetational texture were examined in managed landscapes to determine which component(s) best explained patterns in lace abundance. The components of vegetational texture examined were light exposure, plant species diversity, evenness, and richness, host patch size, and structural complexity of the landscape. The best habitat predictors of lace bug abundance were structural complexity and light exposure explaining 54 and 53 % of lace bug variation, respectively. Further examination of light exposure revealed that afternoon readings explained more of the

variation (52%) in lace bug abundance than morning readings (9%). Of the five vegetational strata that comprise structural complexity, the overstory tree layer and ground cover / turf layer (76%) were the best predictors of lace bug abundance. The implications of this work are that landscapes can be evaluated for susceptibility to lace bugs and perhaps other pests. It also provides information for designing landscapes that support fewer pest problems resulting in low-input sustainable landscapes.

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Sanitary aspects of oak species in the urban forest ecosystem

Introdction

The urban forest has by now become an established concept, and among those forest tree species that have always graced our cities must also be included the oaks. So far, however, it has proved difficult to plant oaks in an urban setting. The only exception has been *Quercus ilex*, planted commonly as a roadside tree and/or as clumps in squares or in green spaces designed for other uses. Nevertheless, some individuals of *Q. cerris*, *Q. pubescens* and *Q. robur* have been planted in suburban and sometimes urban parks ever since the end of the last and the start of the present century.

To determine the proportion of oaks in the total number of trees in cities and the proportions of the different oak species among each other, an investigation was carried out at Florence in 1992-1993 by the Società Botanica Italiana and Linnaea-Ambiente on behalf of the Settore Verde Pubblico Comunale under the direction of Prof. Paolo Grossoni of the University of Florence. From this it appeared that there were 2129 plane trees, the most common urban tree species, but only 317 *Q. ilex* trees. Other oak species, mainly *Q. robur* and *Q. rubra*, ranged in number from 12 to 1 individuals per species. These data reveal the existing ratio between oaks and other tree species, and that between the individual oak species themselves.

Aspects regarding the planting of *Quercus ilex* in the urban environment

Quercus ilex is an evergreen tree or sometimes shrub that may reach a height of 20 m. It has a dense globose crown and the leaves are elliptical with a tomentose underside. The bark is blackish tending to black, smooth on young trees but divided into scales on older trees. The root apparatus has a tap-root. It is an ombrophilous, rustic tree which can tolerate long periods of drought but not the submersion of the roots, and tolerates temperatures from -15 to -28°C.

When first planted it is a good idea to maintain a distance of 4-6 m between trees in rows, 1.5 -3 m in hedges. A safe distance from buildings is 8-12 m. It is easily pruned, as witness the very varied shapes it has in our cities. It is used in urban settings, on slopes, as visual and acoustic barriers, in parks and gardens. It adapts well to mixed planting with other species of oak and other forest trees.

Aspects regarding the planting of *Quercus cerris*, *Q. pubescens* and *Q. robur* in an urban environment

Quercus cerris is a deciduous, heliophilous tree with a life-span of 200 years and beyond, and a height of up to 30-35 m. Its crown varies from fastigiate to globose, the leaves are dentolobate and about 10-12 cm long. The root apparatus is with a tap-root. It is planted with a 14-18 m space between rows, 10-14 m in the case of hedges. It is used as visual and acoustic barriers, in parks and gardens. It should be planted 12-14 m away from buildings. It adapts well to mixed planting with other species of oak and other forest trees.

Quercus pubescens is a deciduous tree that grows to a height of 15-20 m. It has a globose crown and leaves that are tomentose on the underside. The bark is dark-grey with small plaques. Its main root is a taproot. It is a frugal species that can become some hundreds of years old and it is the least heliophilous among the deciduous trees. It should be planted 10-12 m apart in rows, 4-8 m apart in hedges. Its safe distance from buildings is 12-14 m. In an urban setting it is planted on slopes, in parks and gardens. It adapts well to mixed plantings with other species of oak and other tree species.

Quercus robur is a large deciduous tree that, when free-standing, may grow to a height of 40-50 m. It has an oval-globose crown, its leaves are obovate-lobate, 8-10 cm long and have a small peduncle. The bark is grey with short thin plaques. It has a life-span of up to 600 years. The root apparatus is rather shallow. It is tolerant of winter cold but requires high summer temperatures; it is among the most heliophilous tree species. It must be planted 14-20 m apart in rows, 8-12 m apart when planted in hedges, which rarely occurs. It is sometimes planted in city parks and gardens. It must be planted more than 14-16 m away from buildings. It adapts well to mixed planting with other species of oak and other tree species.

Health aspects

All the oaks mentioned, especially *Q. ilex*, suffer strong stress in transplanting. Once they have been successfully transplanted, their slow growth during the first few years makes them susceptible to nutritional deficiencies due to faulty planting. After their youthful phase (10 years), the rusticity of oaks protects them against functional destabilising factors, caused mainly by the soil. Because of their longevity they are subject to the ravages of time, but mainly they suffer from the urban environment as such, an important component of which is man himself.

Particular attention must be given to pruning since only *Q. ilex* can be frequently pruned, yet pruning is necessary to fit trees to the particular spaces where they are planted. The other oak species can be given nursery pruning after transplanting, but after that they can only be cut lightly, for health reasons.

Among abiotic agents that cause damage to trees in cities particular attention should be given to pollution. Alfani (1997) found that *Q. ilex* individuals growing in Naples had significantly higher deposits of N, S, Pb, Cr, Fe, Cu, Ni and Cd on their leaf surfaces than non-urban trees. Leaves were also smaller. Lorenzini *et al.* (1997), likewise, though on some other tree species, reported a negative effect of high ozone levels (200 ppb in 5 h).

As regards infective micro-organisms, it should be pointed out that many of these do not cause particular damage to the leaves. They are; for *Q. ilex*: *Cronartium quercuum, Elsinoë quercus-ilicis, Microsphaera alphitoides*, and *Phyllosticta ilicina;* and for the deciduous oaks: *Cronartium quercuum*, *Microsphaera alphitoides*, *Phyllosticta roboris* and *Taphrina coerulescens.* In a different category is *Apiognomonia quercina*, which causes severe leaf fall in some years. The branches too are destabilised by some canker agents which thus may put an oak population at risk. They include *Epidochium ilicinum* on *Q. ilex* and *Diplodia mutila* and *Nectria* spp. on the deciduous oaks. A very common bacterium on *Q. ilex* is *Agrobacterium tumefaciens.* Lastly, stromata of the ascomycetes *Hypoxylon mediterraneum* are also often observed through the large plaques on the stems of *Q. ilex* and deciduous oaks.

A different problem is that of rotting and root-rotting agents. The continuous stress and risk of wounding to which trees are subjected, and excessive pruning predispose the trees to attack from root-rot agents such as *Armillaria* spp. and *Rossellinia* spp., and from rotting agents such as *Condrostereum* sp., *Fistulina* sp., *Ganoderma* sp., *Laetiporus* sp., *Phellinus* sp., *Polyporus* sp. and *Trametes* sp. These agents can attack cellulose and lignin for long periods of time without showing signs on the outside. The great danger of these pathogens is in that they weaken the trunk and branches putting the tree at risk of falling from its own weight or as a result of climatic events.

It should also be noted that some less well-known mycetes have been becoming more common in the last few years: *Apiognomonia quercina; Diplodia mutila*, *Epidochium ilicinum* and *Hypoxylon mediterraneum.*

Apiognomonia quercina

This micro-organism, in the *Ascomycotina*, causes serious leaf-fall in more than usually rainy years. The twigs die before the buds break at the resumption of vegetative growth, and on these buds the acervuli differentiate. Infection occurs at temperatures of 20-26°C when the leaves remain covered for some hours by a film of water

Diplodia mutila

This micro-organism, in the *Deuteromycotina*, has been isolated in Italy from *Q. cerris* and *Q. robur* by Ragazzi and Mesturino (1987). It settles on apical twigs of 1-2-cm diameter, killing them, and on larger branches of 5-cm diameter, on which it causes elongated superficial cankers with mucilaginous bleeding. The cankers may girdle the branch, in which case it dies. It survives with its pycnidial fructifications, on twigs and cankers. The manner in which this pathogen is transmitted is unknown. It is very widespread and associated with declined and declining oaks of various species. It is thought to be involved in the oak decline that has occurred in Italy since the early eighties (Ragazzi *et al.*, 1986; Luisi *et al.*, 1991).

D. mutila can kill 3-5-year-old seedlings of *Q. cerris* and *Q. robur* (Ragazzi *et al.*, 1991), while on adult trees it will kill the apical twigs.

Epidochium ilicinum

This micro-organism, in the *Deuteromycotina*, is a wound parasite on pruning wounds and causes elongated cankers on *Q. ilex.* These cankers may girdle the branch and kill it. It survives with its fructifications on twigs near the cankers or in the cracks of the cankers. The cankers are weak points where branches may break easily and fall. It is not known how the pathogen spreads; presumably through pruning tools.

Hypoxylon mediterraneum

This micro-organism, in the *Ascomycotina*, has a black stroma consisting of perithecia appressed to each other. It was first reported by Biraghi (1955) and has more recently been found frequently on *Q. cerris*, *Q. ilex* and *Q. pubescens* in decline (Ragazzi *et al.*, 1986; Capretti and Mugnai, 1987). It has been reported on *Q. ilex* in many towns and cities in Tuscany, Umbria, Marche, and Lazio, especially at Livorno, Cecina, S. Vincenzo, Firenze, Lucca, Perugia, Terni, Senigallia, Pesaro, Latina, Terracina and Sabaudia. It is a parasite that profits from the weakness of plants under stress from high temperatures, drought and, in the case of forest trees, the passage of forest fires.

This is very similar to conditions in most urban and suburban parks, where trees find themselves under stress from high temperatures, as well as from factors such as excessive age, compaction of the soil, lack of water or water-logging, and recurrent anthropic effects. As a result deciduous oaks planted in cities become very susceptible to this micro-organism, which may trigger a decline that partly resembles the decline in oak forests. Since intervention here is difficult, city trees thus infected become sources of infection for other oak populations in the area.

Conclusions and precautionary measures

The sensitivity to transplanting of all the oak species here discussed makes it necessary to plant only trees with a stem diameter that exceeds 5 cm, and to plant them in holes whose depth is equal in size to the ball of earth holding the roots**.** The utmost care should be taken not to move the roots unless they have been damaged. If adequate watering is not possible it is advisable to thin the crown. The plant must be sheltered from the wind and supported with props that are put in place without damaging the stem or roots. Once the plants have taken root, the rusticity, already mentioned, of all oak species means that interventions must not be undertaken unless absolutely required, i.e. pruning only for crown thinning or to remove damaged and/or dried-up parts of trees, taking care to observe not only obvious cultural practices that are called for but also to disinfect all cuts with copper-based or benzimidazole compounds.

It will not normally be necessary to apply treatments for the control of foliar parasites which, with the exception of *A. quercina*, do not cause much damage in cities. On the other hand, sanitary measures are required on *Q. ilex* to remove any branches infected with cankers caused by *E. ilicinum*, to avoid the risk of the branches falling, and likewise on deciduous oaks to remove twigs on which *D. mutila* may settle, so that other trees in the park, especially nearby oaks, do not become infected.

As regards *Hypoxylon mediterraneum*, to reduce the amount of inoculum from this mycetes it is necessary to uproot trees killed by the infection and prune infected trees. The bark and branches must also be removed and burnt since the mycetes can survive for long periods on them as a saprophyte.

The preventive control of decay and root-rotting agents can be carried out by a regular programme of maintenance for urban green spaces, avoiding too drastic or too frequent pruning and thinning stands that are too dense. Existing decay can be treated surgically by cutting off infected wood and protecting healthy exposed wood with mastic and resins.

More generally, from the point of view of maintenance in a city environment it is desirable to mitigate the effects of stress on the trees: water deficiencies suffered by individual trees can be alleviated by controlled watering and loosening of the soil around them. This soil often becomes a layer impermeable to both rain and irrigation water. Soil loosening also improves soil aeration.

The loosened soil must be protected with suitable gratings. Trees must also be individually treated with fertiliser.

Appropriate pruning at the right time will help avoid competition for space and alleviate water stress. The removal of branches or parts of branches with signs of decay will keep decay problems within controllable limits.

New plantings must observe the recommended distances between trees. When it is absolutely necessary, parasites can be controlled with low-impact products that pose no hazard to the human population. Treatment application should be by direct injection into the trunk, or by sprayers that directly target the leaves and create air currents to distribute the compound throughout the foliar mass.

Summary

After a brief mention of the limited use of oak species in an urban setting, the main characteristics (crown shape, light, temperature and space requirements) and the major biotic and abiotic constraints of the most frequently employed species (Holm oak, Pedunculate oak, Pubescent oak and Turkey oak) are discussed. The most harmful fungal parasites of these species are also reviewed. In addition, suitable establishment and management methods are described, with special emphasis on the need for proper transplant of oaks, watering, pruning and sanitary measures.

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Proper nursery production - an imperative for healthy street trees

Introduction

Experience shows that there is direct correlation between the street trees' state of health and their actual functionality when transplanted in highly urbanized street environment. It is obvious that more pronounced negative effect of the street on newly planted tree individuals exists whenever nursery production conditions are poor, resulting in a poor quality of new transplants [1]. These facts are best evidenced in ecologically most difficult urban street conditions, especially the streets of large cities' central areas. Existing street tree lines on these sites are often in such a state that they demand thorough renewal. Thus, permanent production of high quality standard tree transplants must be provided in order to carry out successful reconstruction. On the other hand, systematic usage of carefully chosen, befitting tree species and persistence on their adequate age (older individuals than usually needed when other urban green spaces are concerned), result in establishment of good quality, functional street tree lines, even when for large cities so characteristic quite unfavorable street conditions are concerned. Whenever understorey plants from nearby forests are used to satisfy street tree lines' reconstruction needs, or when transplants purchased specially for so degraded environment are chosen without critical analysis of species characteristics and serious consideration to conditions in which these young tree individuals grew prior to transplanting (especially when they are brought from very distant nurseries with drastically different climatic and edaphic conditions), their failure to meet the expectations in new street tree lines is almost certain.

This otherwise fundamental perception of nursery produced stock, which applies to all ornamental plants used by landscape architects in urban greenscaping (trees, shrubs, flowers, vines, etc.), becomes the key moment which explains the very essence of permanent decline of this category of urban greenscape [5].

Actual state of street tree lines on Belgrade streets is evident confirmation of these facts. It may easily be seen that very young, small and twisted transplants with poorly developed crowns deteriorate much faster in streets of Belgrade than properly produced and trained shade tree individuals of the same species. It is also evident that the same low quality transplants perform much better and last much longer in less polluted streets or adjacent larger parks [3], only proving that busy central city streets burdened with heavy traffic are the most difficult environment for tree survival.

On the other hand, it is well known, especially in professional circles, that nursery production of large transplants for street tree lines barely exists in Belgrade (or in the country for that matter), especially during the last decades, due to low immediate, “instant” financial gain from such production and almost non existing long-term planning in present circumstances. That is the main motive for using suburban nearby forests as the primary source of shade tree transplants, despite the awareness that such individuals are too young, not resistant enough, and completely unaccustomed to harsh conditions in which they must continue to develop [2]. From time to time, when circumstances are somewhat better, imported transplants are used. Unfortunately, even then they are chosen and purchased almost solely on the basis of their low price, or just as a part of some compensation deal, and not on the basis of their high quality or any other essential professional reason.

Numerous consequences of such malpractice may be readily seen on all the streets of all Serbian settlements, especially Belgrade. It is very easy there, in actual street conditions, not only to confirm stated facts, but also to arrive to additional conclusion that in the long run the usage of non-quality tree transplants represents in fact more expensive and by every criterion far worse solution. The best proof of this statement is the fact that cheap and poor quality tree individuals decay very quickly, often need replacement only two or three years after planting, while overall functionality of such deteriorated, feeble and ailing street tree lines is far below every expectation concerning this category of urban greenscape. Obvious sub-quality of these transplants, their inadequate age, stunted growth, poorly developed crowns and roots, represent physiological, visual and ecological explanation of their very low functionality in street tree lines in general. It is also the main reason why most of these plants are very susceptible to numerous diseases and pests attacks. One more unpleasant fact must be added to these unfortunate circumstances: usual professional aftercare of Belgrade street lines practices just intermittent and very reduced maintenance, only symbolic protection from mechanical injuries induced by severe action of motor vehicles is applied, while other necessary maintenance measures are almost completely omitted. Even though actual state of some street tree lines raises the question whether intensive care of clearly poor street tree transplants is really worth the effort, and despite the fact that in the very essence of such state lies very difficult professional and financial situation in which domestic landscape architects act, it is obvious that the existence of functional street tree lines is simply not possible without proper maintenance, even when the highest quality nursery stock is concerned.

Method and Material

All street tree transplants with the diameter at breast height (dbh) under 8 cm were registered in ten central streets of Belgrade in order to support presented statements with objectively ascertained facts. The level of their functionality was evaluated on the basis of two collective grades: one for vitality and other for aesthetics. Vitality grade was based on the estimate of macroscopically apparent indications: the regularity of crown, evidence of epicormic growth, physical injuries of trunk and branches (bark tear, cleavage, various cavities and foreign objects in the stem, broken stalks and other traces of vandal behavior, specific mechanical injuries from motor vehicles), apparent decay of tree trunk and branches, broken branches, die back of particular branches or whole parts of tree crowns, as well as apparent diseases and pest attacks. On the basis of these indications every tree individual received a vitality grade on the scale from 1 (completely deteriorated) to 5 (in excellent condition). Tree transplants were evaluated on the basis of their aesthetic characteristics as well and likewise graded on the scale from 1 to 5 [1], which altogether provided the means for more complete estimation and perception of the overall functionality of street tree lines. Present state of tree transplants in researched street tree lines together with their collective grades are given in Table 1. Special attention was paid to individuals of *Acer platanoides*, since Belgrade street tree lines hold both forest transplants and nursery produced specimens of this species.

As a comparison to common situation, the same analysis was carried out in two Belgrade street tree lines which had been established in professionally more acceptable way, using very good quality transplants of domestic species (*Acer platanoides*), either produced in local nursery conditions or imported. Their present far better state, the age of around three decades and at the same time much higher vitality and aesthetics, clearly indicates the great importance, actually decisive effect that high quality nursery stock has on street tree line's functionality as a whole. All the results presented in this paper speak in favor of the statement from the title of this paper - proper nursery production is an imperative for healthy street trees.

Results and Discussion

Surveyed street tree lines of 10 central Belgrade streets revealed numerous facts in favor of the supposition that low quality of tree transplants in street tree lines is one of the key causes not only for their low functionality on given site, but their short existence as well. Most evident is the fact that from total of 1358 street trees in research area, precisely 424 (around 31 %) have dbh under than 8 cm at the present. And yet, only two decades ago the basic mass of Belgrade street tree lines was made of much older trees (different age for different species, but rarely under 65 years on average). Thus, it is easy to concluded that gradual replacement of old trees with so young transplants is a total miss, both in ecological and in aesthetic sense. How wrong this practice is proves the fact that the youngest transplants have dbh of only 2 cm (or even less), representing absolutely inadequate plant material for street tree lines. Furthermore, most of the transplants are taken from nearby suburban forest, and consequently posses too high a trunk and poorly developed crowns (often almost completely removed in the process of transplantation). That is why the size and shape of these trees' crowns is not only inappropriate for shade trees, but often incapable to develop even the minimal leaf mass in the first years after transplantation. The totality of these circumstances brings about rapid deterioration of numerous young tree individuals, which subsequently causes their early replacement, as soon as two or three years. Besides this, a large part of mechanically injured transplants, more than the half of their total number (229 specimens or 54 %) strongly confirms the presumption that too young tree individuals can not endure hard conditions of street environment, the one that calls for much larger and stronger trees.

Fig. 1: Under-aged tree transplants in Belgrade street environment

Table 1: Under-aged transplants in central street tree lines of Belgrade

STREET	TREE TOTAL	YOUNG (dbh < 8 cm)	MINIMAL dbh (cm)*	DAMAGE TOTAL	number of replaced during the first 3 years	still necessary to replace
Admiral Geprat St.	47	11	3	6	1	8
Beogradska St.	95	38	2	18	-	18
Kralja St. Aleksandra	133	8	2	5	2	5
Generala Zda-nova St.	156	15	2	11	2	13
Kneza Milosa St.	185	72	2	38	9	61
Kralja Milutina St.	154	26	2.5	15	2	15
Narodnog Fronta St.	86	32	3	14	1	21
Nemanjina St.	149	21	1	11	2	16
Njegoseva St.	84	21	2	13	-	13
Srpskih Vladara St.	269	180	1	98	17	72
TOTAL	1358	424		229	36	242

* During the last three years a total of 48 transplants had dbh < 2.0 cm, and 16 < 1.0 cm

The total of 242 transplants which need replacement due to their utterly low vitality and aesthetics (more than the half of the total number of young tree individuals present) also speaks very strongly of numerous disadvantages when too young and untrained street tree individuals are used in extremely difficult conditions of polluted street corridors. It is evident that actually more than a half of tree transplants must be replaced only one or two years after establishment. However, since this operation is done quite infrequently in Belgrade circumstances, numerous damaged young individuals remain on streets even after a complete die back of a whole tree. They are removed (but not always replaced) only when it becomes certain that dead plants are in question. It is evident that no one can experience any benefit from such street trees. On the contrary, their persistence in street surroundings may cause serious harm, especially in psychological sense. The basic rationalization of this pronouncedly negative psychological effect of dysfunctional street trees presence in urban environment lies in the fact that urban dweller's reflection concerning the causes of street trees' decline commonly commences with question how seriously or dramatically is the street environment truly endangered when even young shade trees can not survive in it for more than a couple of years.

Completely different picture, ecological as well as psychological, create street tree lines comprised of high quality tree transplants, though they grow and develop in the same unfavorable street conditions. Tree individuals of *Acer platanoides* in street tree lines of Cvijiceva St. and Hilandarska St. are quite good examples in this respect, since they represent high quality, properly produced and trained nursery transplants which held at the time of their transplantation all the necessary and by a certificate guaranteed qualities of proper street tree standard. Table 2 clearly shows that considerably higher present average grade of their vitality and esthetics completely confirms the importance of the initial quality of transplantation material. It should be also pointed out that average grades of these tree individuals during all the years of their existence on Belgrade streets were higher or equal to those presented in Table 2.

Table 2: Street tree individuals of *Acer platanoides* in Cvijiceva St. and Hilandarska St., and tree individuals of the same species in streets listed in Table 1.

STREET	TREE TOTAL	AVERAGE dbh (cm)	VITALITY GRADE	ESTHETICS GRADE
Hilandarska St.	38 (39)	18	4.3	4.5
Cvijiceva St.	271	27	3.9	4.3
10 streets from Table. 1.	197	29	2.8	2.9

Results presented in Table 2 confirm that the quality of tree transplants (from proper nursery production point of view) holds enormous, in fact crucial practical significance. Properly developed nursery production provides landscape profession with mature transplants of high standard, with sound and well developed crowns and adequate root system, completely healthy, without any mechanical injuries, and at the same time, of high esthetic value. Such plants undoubtedly have all the prerequisites to quickly and successfully adapt themselves to new conditions of street environment, which altogether exerts, as the ultimate urbanistic consequence, better quality street tree lines [4]. Average grades of vitality and esthetics of individuals in two qualitative Belgrade street tree lines, which are much higher than corresponding grades for specimens of the same species presented in Table 1, confirm above statements in the best possible way.

Conclusions

Presented facts concerning Belgrade street tree lines comprised of a large number of young individuals, offer sound grounds for the following conclusions:

Street tree transplants that have been used for replacement of old and establishment of new street tree lines are predominantly taken from nearby suburban forests. They are of very poor quality, both morphologically and physiologically, and as a rule, generally much younger than necessary. They do not posses well developed crowns nor appropriate root system. Having grown as a young canopy trees, these individuals are too high, and thus drastically lopped during the very transplantation process. Consequently, it is almost obligatory for these plants to have serious mechanical injuries even before establishment. Such tree transplants have almost no chance to develop in healthy and functional street trees, especially in the city's center, where extremely harsh environmental conditions prevail.

Poor vitality and low esthetics of too young transplants makes them very prone to further mechanical damaging, due to which they easily succumb to diseases or pest attacks. They deteriorate easily and readily, and have to be replaced after only two or three years. Since the new transplants are of the same quality, the circle closes, and the functionality of street tree lines becomes ever lower.

Distinct difference in the vitality and esthetics between nursery produced high standard street trees and transplants taken from forests clearly shows that only by using intentionally produced and properly trained nursery trees it is possible to preserve old and create new functional street tree lines in Belgrade environment.

Summary

Poor quality of tree transplants used for Belgrade street tree lines is the main reason why the functionality of this important urban greenscape category is becoming ever lower. These individuals do not present properly produced and nursery trained street trees, but mostly specimens taken from nearby suburban forests which are too young, damaged and of very low vitality. Systematic and persistent filling the empty spaces in existing Belgrade street tree lines with such plants only degrades and impoverishes street environment in the central part of the city, both ecologically and visually. Such state of affairs is in the essence of a strong recommendation to regard renewal of specialized nurseries for production and training of street tree transplants as one of the first professional tasks of Belgrade landscape architects.

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Poster Session

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Control measures to ensure seedling health of the mangrove *Avicennia marina*

Shora shrubs *(Avicennia marina)* are shown in Egypt along the Red Sea coast from Hurghada southward to Mersa Halaib. A number of their seedling couldn't develop as a result of seed borne disease infections. Shora seeds when subjected to health testing gave rise to a number of seed-borne microflora i.e. six genera of fungi and one genus of bacteria in different seed infection percentages. The greater portion of the microflora were detected from the seed pericarp. Among these microflora, three species of fungi belonging to the genus *Fusarium* i.e., *F. equiseti* ,*F.moniliforme* and *F. sambucinum* and to species of bacteria belonging to the genus *Pseudomonas* i.e., *P.syringae subsp . viridiflora* and *P. marginalis* were detected from seeds in the high relative majority as against other ones .

They brought out the same typical phenomena of seed rot, seedling die back, seedling mortalities, seedling disease symptoms and leaf lesions. Seed dressing chemical compounds when applied to seeds as a control measure often cause different kinds of seedling decline. This was ascribed to the severe influence of the chemicals to the seeds because of their wetness and their very high moisture content.

Soaking seeds in sea water before their planting contributed to get rid of their pericarps, the fact which reduced numbers of the associated seed -borne pathogens and then became as a mean of controlling measures.

Biological control process using *Trichoderma harzianum* and *T. koningii* as seed treatment proved to be of value in disease control and decreasing of seedling mortalities.

These two biological agents when applied to seeds after their soaking in sea water improved seedling health and their growth to a maximum.

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Results of a survey on the importance of plant protection in urban areas

Every year cities and municipalities invest large amounts of money in planning, planting and cultivating of public green areas. Numerous biotic and abiotic stress factors damage parc and street trees, beds and lawns, so the life expectancy of the plants is reduced in urban areas. Therefore the costs for support and reconstruction are very high.

A survey was carried out in Germany in 1997. The results show that

- only in big cities the official plant protection services are involved in these problems,
- in most cases inquiries will come from home gardeners, fewer from the fields of arboriculture, architecture and landscape-gardening,
- with regard to staff the official regional plant protection services are too small for intensive consultations,
- there are only few experiments for an improvement in plant health.

The cultivations in agriculture, forestry, horticulture and viticulture in most cases are optimized, plant protection is an integrated part of these productions. However, in arboriculture and in landscaping there are large lacks in quality. These are particularly due to:

- an insufficient planning of the stands,
- bad plant selections for the local position,
- little considerations of plant resistance to urban stress factors,
- a shortage in plant quality, for example infections with pathogens, low acclimatization,
- injuries caused during the transport,
- no long-sighted preparing of the stands, especially with respect to the ground,
- frequent mistakes in planting,
- no correct cultivations, for example inadequate plant protection measures.

The main cause of this situation can be observed in arboriculture and landscape-gardening, fewer in conservation and in the nursery. The public field is more problematical than the private one. There are no integrated systems in pest control, persistently trying to enhance plant health. This includes a better knowledge of the local situation, the possibility of optimizing the growth situation, the resistance and tolerance of the plants and their quality. Well-directed measures in plant protection have to complete this concept.

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Good horticultural practice in tree care

The city of Berlin strives on a far-sighted tree care to create healthy tree populations which present the character of a green town with 5.406 ha parc areas and 400.000 street trees. Optimal planning, professional preparing of the planting area, right trees for the location, using small plant heights (18-20), using roots without soil or with a corresponding ball, adequate planting distances and a regional cultivation of the plants decrease a negative evolution, damage and falling out of plants and guarantee favourable costs and a solid landscape. The final audit of plantings take place after 2-3 years, with the possibility to diagnose and to correct mistakes of cultivation and planting.

Integrated tree care leads off with a training of the tree-top to prepare traffic areas and visibility in an early stage, so there will be later no drastic measures and no undesirable reactions of the trees. Principally the lopping of branches is to do within the vegetation period on the line of branch-rings. Wound dressings are to use only on the sapwood. During the whole year dead pieces of wood should be taken out. The professional realization of essential cultivation measures (top-tree-training, watering, fertilizing, removing weeds, plant protection) has the effect of a well plant-evolution. This reduces the intensive and expensive stabilization of trees and areas which are widespread in the moment.

Gearing in roots and tree-tops is done in such a manner, that compartimentalization is very effective. The consequence of building activities are early measures for tree protection in the biological optimal time of tree reaction, for example root-curtains, lopping of branches and transplanting big trees. Rehabilitation of tree stands as removing coverings or substrates, fertilizing and mulching are only sometimes significant. Phytotoxic components (deicing salt, dog-urine, gas) are to decrease consequently or to repair. Beneficial organisms are to promote for biological control of pathogens.

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Virus diseases of trees from urban forested areas

Introduction

From the economic point of view one should be aware that virus diseased plants may increase production costs because of the possibly decreased growth of infected stock plants and that they may damage subsequent field performance. Virus infection alters plants predisposition and these trees become more susceptible to abiotic and biotic stress impact and may even lead to completely degenerating, dieing trees. Therefore tree seedlings with a long generation cycle planted in public gardens and forested areas should be virusfree and vital to overcome the changing stress impact for decades. Virus diseased trees are worldwide spread in forests as summerized by NIENHAUS and CASTELLO (1989). Our continued studies demonstrate the health status of deciduous trees of nurseries, public gardens and forest stands in urban areas focusing on virus infection.

Material and Methods

Leaf samples were taken from selected trees and seedlings in nurseries, forest stands and public gardens of different federal German states (Baden-Württemberg, Berlin, Hamburg, Nordrhein-Westfalen, Niedersachsen and Schleswig-Holstein). The seedlings and trees were grouped into three different age classes, up to 3 years, 3 to 7 years and older than 7 years. The studies refer to *Acer*, *Aesculus*, *Betula*, *Carpinus*, *Cornus*, *Fagus*, *Fraxinus*, *Populus*, *Prunus*, *Robinia*, *Sambucus*, *Sorbus*, *Tilia* and *Quercus* sp. For virus diagnosis serological (ELISA), molecularbiological (PCR, hybridization) and electronmicroscopical technics (negativ staining, ISEM, DEKO) were applied.

Results and Discussion

Referring to our investigations virusinfections occur dominant in nursery stands with intensive production as well as in extensivly used public gardens. The trees and seedlings showed infections by apple mosaic virus, aesculus mosaic virus, arabis mosaic virus, brome mosaic virus, cherry leafroll virus, prunus necrotic ringspot virus, poplar mosaic virus, robinia mosaic virus and the ringspot diesase of oak and mountain ash. Some tree species were be infected by two different viruses as there was *Prunus* (punus necrotic ringspot and cherry leafroll virus), *Fagus* (brome mosaic and cherryleafroll virus) and *Betula* sp. (apple mosaic virus and cherry leafroll virus). We registrated *Tilia* sp. as non infected. The degree of virus infected seedlings increased with the age of the plant independant of the tree species. This increasing infection status particular in nurseries, may be due to virus transmission by vectors or mechanically by cultivation technics.

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Optimizing plantings of perennials for public green areas

Urban greenspaces have to be resurrected as an important part of our urban environment. It must contain events that are attractive for a great part of the population. The current ground cover of these spaces was limited to the cultivation of individual species of shrubs or perennials. In the nature, species with a different cycle of vegetation interact, forming a closed ground cover. From our perspective, mixed plantings of perennials allow a better cover of these spaces, and increase the visual attraction during the Year too. They also allow the introduction of new methods of management, giving a really interesting alternative to the professional.

Perennials in mixed plantings

The project is beeing carried out in collaboration with several cities and universities in Switzerland and Germany. The ecological and economical aspects of these plantings are beeing studied simultaneously.

In 1999, more than 2000 metersquare have been planted with our mix of perennials.

Main characteristics of the project:

- High esthetical qualities
- Stability and durability
- Ecological qualities
- Management

Physiological and sociological characteristics of the plants, like for example dominance, propagation strength, growing forms, ecological strategy, growing cycles and life times are being taken into consideration when planning appropriate plant societies.

The attempt to understand planting as a dynamic system is fundamentally new in Horticultural design of public green. Different ecological aspects, especially plant community establishment and growing strategies, introduce a dynamic development (a succession) directed to a stabile plant community.

Goals

During the three years of this study, we want to observe the growing rates and the development of the plant communities. Six field observations per year during the growing season shall give us responses and information about the dynamical development and the propagating strategies in the plant communities. The time required for the management of planted areas will be assessed, too.

We also want to:

- Increase the aesthetic and ecology of public green areas
- Have answers on the real development of the chosen plants in the dynamical system
- Observe the Influence of diverse climatic conditions and of management systems on the growth
- Develop mixed perennials compositions for the practical application
- Develop and optimize of the management system

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Role of (V)AM fungi in revegetation: On the mycorrhization of deciduous trees

Introduction

Revegetation of disturbed soils should aim to reestablish a stable ecosystem with fully-functioning nutrient-cycling processes. Mycorrhizal fungi are likely to be important in helping to achieve that aim by increasing the nutrient uptake by plants and contributing to the restoration of natural soil structure. But most current operational revegetation practices ignore (V)AM-plant community dynamics and thus they have had limited success in establishing self-sustaining plant communities. The purpose of this study was, firstly, to investigate the endomycorrhization of some selected deciduous trees commonly used for revegetation in Germany and secondly, to study the influence of the inoculation with (V)AM fungi on the plant growth.

Material and Methods

- Selected plants: The one year old seedlings chosen for this study were: Acer platanoides, Alnus glutinosa, Alnus incana, Cotoneaster bullatus, Fraxinus excelsior, Prunus avium, Prunus spinosa, Sorbus aucuparia.
- Inoculum: expanded clay and small roots of *Tagetes erecta* infected with *Glomus intraradices* (substrate I) and with a mixture of *Glomus intraradices*, *G. etunicatum* and *G. mosseae* (substrate II).
- Soils: standard soil/sand = 7/3 (vol.) loamy sand from a brown coal mining site near Bitterfeld.

The inoculum (3 vol.%) was mixed with the soil and used for planting. The pot experiments took place under controlled greenhouse and field conditions. Heights and stem diameters were measured in the 14th and 26th week and 14 months after planting/inoculation. The presence of (V)AM infection was determined from root samples collected by the Phillips and Hayman procedure, except that trypan blue was used in place f chlooral hydrate.

Data were analyzed by Tukey's multiple comparison test ($P = 0.05$) and by comparison of two average values after the t-test.

Results and Discussion

Pot experiments under field conditions

Already 14 weeks after planting and inoculation the roots of inoculated *Acer platanoides*, *Fraxinus excelsior* and *Sorbus aucuparia* were well infected by the mycorrhizal fungi. After 26 weeks the same plants and *Prunus avium* roots are infected in both substrates. *Alnus incana* was infected only in the standard soil. The other plant species showed no infection at this time. After 14 months all plant species are infected by (V)AM fungi in both substrates.

Acer platanoides, *Prunus avium* and *Sorbus aucuparia* showed greater height and diameter growth than noninoculated control plants. Inoculated *Fraxinus excelsior* plants showed less high growth than that of the controls whereas the diameter growth was increased. These results indicate that the potential benefits from (V)AM fungi in nursery plant production are of such magnitude that in the cultural practice (V)AM fungi inoculum should be applied. The other species exhibited a non-uniform response to the inocula used in this study. For a better understanding of these results the investigation will be continued.

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Microbial control of the fall webworm (*Hyphantria cunea* Drury) in urban horticulture of the Black Sea Region of Georgia

Introduction

The urban horticulture takes the important place in the Black Sea coast of Georgia. The fall webworm, *Hyphantria cunea* Drury *(Lepidoptera: Arctiidae)* is distributed damaging many kind of plants (generally more than 600 species). The insect inhabits in the homesites, communities, suburban parks and places of mass restoring where by the viewpoint of sanitation-hygiene the using chemical pesticides are prohibited**.** The approach of this work is develop and refine suppression tactics appropriate to non-forest environments, including the use of entomopathogenic microorganisms (viruses, bacteria etc.) Due to the geographical location of Georgia there are the high temperature and UV radiation. It is advisable for search of environmentally safe the photostabilized microbial formulation for effective control to the fall webworm.

Material and Methods

The model trees of walnut (*Juglans* sp.*)* have selected with the middle and strong infestation by pest in Batumi (seacoast town) and Chokhatauri (West Georgia). Prof. Cohen submitted photostabilized bacterial complexes on the base of *Bacillus thuringiensis* var.*kurstaki* (*BT*) HD-l, *Bt*-AF, *Bt*-CW and *Bt* control under scientific agreement (USAID-Israel-Georgia). Bacterial suspension was used in 2% concentrations (267.000 unit/l) against lll-lV instar larvae. As a standard was served unstable *Bt* (264.000 unit/l). The treatment mortality caused by bacteriosis was corrected by Abbot's formula (Abbot, 1925). Biological effectiveness was calculated by using accepted methods in insect microbial control (Franz, 1968). Microscopic investigations were conducted by using methods accepted in insect pathology (Weiser, 1977).

Results

In results of laboratory experiments on the testing of *Bt* formulations have shown the perspectives of using the Bt photostabilized formulations against the fall webworm (Chkhubianisshvili, 1998). The summarized effectiveness of *Bt*-AF was 97,5%, Bt-CW - 98,6% and Bt - 69,8%. It should be noted that because of the high UV radiation in seacoast the biological effectiveness of Bt formulations is 5% lower than in localities situated at 350 m a.s.l. Entomocide activity of Bt-complexes is prolonged up 15 days, in this time Bt stops biological activity. In spite of that the pest is spread in mass, the development and density of colonization is high and the natural mortality is not registered. The introduction of Btu may take important place in the number regulation of pest in nature.

Conclusion

The preliminary results show that in the conditions of high UV radiation *Bt* formulations are characterized by the effective action on the fall webworm population. It gives the possibility of number regulation of pest insect and the bacterial protection will take the important place In integrated control system against *H. cunea* in the urban agro-ecosystems of Georgian Black Sea region that guarantees the high effectiveness and safety for environment.

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Low Frequency Currents Tomography for tree stability assessment

Introduction

Since the lignivorous fungi modify water content and density of wood, also the electric resistivity changes in case of decay. The resistivity could therefore be considered a diagnostic parameter for trunk investigation.

Tomographic processing allows to obtain an image of the electrical resistivity of a section of an investigated object, performing measurements just on the object borders. This technique is widely used both in medical testing and in underground geophysical investigation.

Both laboratory and field experiments have been carried out to assess the feasibility of electric tomography as a non invasive tool for wood decay.

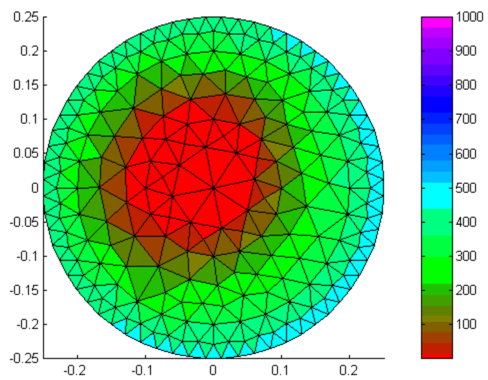
Materials and Methods

The field tests were carried out on living trees showing signs of internal decay, and that were later cut down. The laboratory tests were performed on wood disks extracted from the investigated trees as a check of the field results. The electric tomography device, used both for laboratory and field measurements, is a multi – electrodes georesistivimeter for geophysical surveying STING (AGI Ltd) on purpose modified to be used with electrodes suitable for resistivity measurements on trees. Measurements were performed with 16 equidistant electrodes for each investigated section and the data were processed with a software, based on quasi Newton algorithm, implemented in Matlab© for this specific application.

Results and Conclusion

The first results showed the reliability and the good resolution of the method for detecting the geometry and the characteristics of wood decays. A good correlation between resistivity anomalies and decays has in fact been obtained (as shown in the picture below).

At the same time, some technological and scientific improvements seem to be necessary in order to use the resistivity tomography as a routine tool for trees diagnosis: an on purpose designed device is being studied in order to perform reliable and fast measurements; many experiments are in progress to determine the best kind of electrodes to be used; the software is being improved to become less time consuming and more user friendly. Contemporary, a study has been started with the aim of collecting laboratory data on electric resistivity of wood in different decay conditions, as a help in the interpretation of the resistivity images.



In the picture a Plane wood disk (*Platanus hybrida*) with a decay and the relative resistivity tomographic image are presented.

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Ultrasonic Tomography for wood decay diagnosis

Introduction

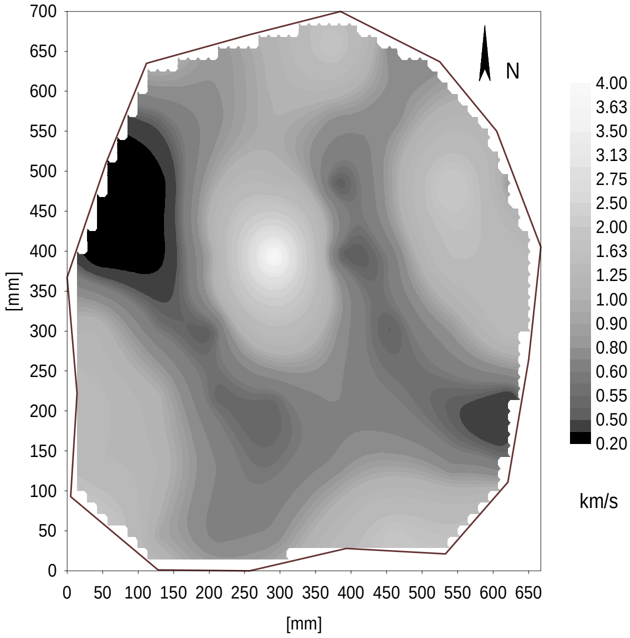
Both laboratory and *in situ* ultrasonic measurements have been carried out to assess the feasibility of ultrasonic tomography for non invasive testing on living trees, with the aim of detecting wood decay in the trunks. The lignivorous fungi modify the elastic characteristics of the wood and the ultrasonic spreading is function of this. It follows that velocity anomalies on the section and wood degradation are correlated. Tomography allows to obtain the image of the distribution of ultrasonic velocity for the investigated section of the trunk.

Material and Methods

The field tests were accomplished acquiring tomographic data on living trees which showed signs of internal decay and that were later cut down to extract wood disks and cubic samples in order to perform laboratory tests. The ultrasonic measuring device used both for laboratory and field measurements is a Pundit (Portable Ultrasonic Non-destructive Digital Indicating Tester) with operating frequency of 54 kHz.

Before performing tomography inversion, statistical pre-processing has been performed both on field and on laboratory results, allowing to define the reliability of the data, to optimise the tomographic processing and to carry on a correct interpretation of tomographic images. The pre-processing has contribute to point out some important aspects to be considered, in particular the problem of the signal attenuation (particularly strong in case of wood decay), that could affect the travel time detection; the problem of physical resolution, that determines the minimum size of the detectable anomalies; the problem of anisotropy (longitudinal, radial and tangential velocities are, in some cases, sensibly different) that has to be considered during the final interpretation.

Results



Many tomographic images have been obtained from different trees and the first results show that the developed methodology offers some advantages, both concerning reliability and information supplied, with regard to surveying methods commonly used.

In the figure is showed an example of tomographic imaging of an *Aesculus hippocastanum* showing low velocities zones related to decays.

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Early diagnosis on wood decay fungi by molecular approach

Introduction

A rapid identification of lignivorous Basidiomycota, even in absence of fruiting bodies, is an important aspect in urban tree management. In fact, the dangerousness and kind of decay is closely related with the causal agent. Classical methodologies for identification, mainly based on morphological features and biochemical analysis, is problematic and time consuming. Molecular approaches represent an interesting method for taxonomic identification of Basidiomycota. Among them, analysis of restriction fragment length polymorphism (RFLPs), based on enzymatic digestion of amplified rDNA regions, is known to be a reliable method (Fischer and Wagner, 1999). The aim of the present work is to set RFLPs patterns able to discriminate among species of lignivorous Basidiomycota cause of wood decay.

Materials and methods

Thirty-five isolates of Ganoderma lipsiense, G. lucidum, G. pfeifferi, Stereum hirsutum, S. rugosum, Chondrostereum purpureum, Schyzophillum commune, Armillaria mellea, A. tabescens, Heterobasidion annosum, Phellinus punctatus were used. DNA was extracted from fresh and dry lyophilised fruiting bodies and mycelia according to Cenis (1992). PCR was used to amplify rDNA comprised between ITS1 and ITS4B primers (Gardes and Bruns, 1993). The obtained products were purified by QIAquick PCR Purification Kit (QiaGen) and then restricted with endonucleases Taq I, Alu I, and EcoR I (Takara Biomedicals) according to the manufacturers' instructions. The restriction products were resolved on 1,5% Separide Agarose Gel (GibcoBRL).

Results

DNA was extracted successfully from all stocks. The size of amplified fragments ranged from 800 to 950 bp. RFLP's patterns obtained were able to discriminate among the isolates according to the species. Only *Ganoderma pfeifferi* and *G. lipsiense* were not reciprocally discriminated.

Discussion

The region considered in our studies appears to be useful for taxonomic classification at species level (Gardes *et al*., 1991). The possibility to identify Basidiomycota directly from fresh mycelium with DNA analysis greatly reduce the time need for diagnosis.

Furthermore, the method used could represent a useful tool for identification of these fungi directly from wood (Johannesson and Stenlid, 1999), and to clarify the aspects regarding the chain of micro-organisms involved in the decay.

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Increasing severity and spread of *Sphaeropsis sapinea* (FR.) DYKO AND SUTTON in Switzerland

Introduction

The fungus *Sphaeropsis sapinea* (Syn.: *Diplodia pinea* (DESM.) KICKX) belongs to the native fungal flora. It is an opportunistic pathogen worldwide of more than 20 pine species. It is killing current-years shoots, major branches, and ultimately entire trees. The fungus is most damaging to planted exotic and native pine species. The effects of this disease are most severe on landscape and park trees. The fungus is seldom found in natural pine stands. In the last decade the severity of the disease seemed to increase in Switzerland. We therefore made a survey to investigate the epidemiology of *Sphaeropsis* shoot blight.

Method

The data were collected between 1989 and 1998. Tree samples from obviously diseased pines sent to our diagnosticians by tree owners, respectively data from an annual questionnaire we sent to the 140 forest districts, as well as own observations were evaluated. All information was collected in a database (Oracle®) and epidemiological overviews for Switzerland were produced using Arc/Info®.

Results

The first serious disease outbreaks were observed 1989 in western Switzerland, in the regions of Lake Geneva. In the following years the disease has expanded to the east. Actually the disease front has reached the border of Lake Constance and the canton Ticino. Until 1994, only planted trees in parks and gardens were affected. In 1994 however the disease was found for the first time in one of the rare Austrian pine stands in the Swiss forest near Pruntrut (Jura). Four years later the fungus also seriously damaged a young Scots pine afforestation in the same region. Diseased trees were found in regions up to 800 m above sea level. Austrian pine (*Pinus nigra*) was always the most affected pine species and heavily infected trees often died. Scots (*P. sylvestris*) and Mugo pines (*P. mugo*) were also infected but normally they suffered much less from the disease.

Discussion

Different reasons may be responsible for the increasing spread and severity of the *Sphaeropsis* shoot blight of pines. Repeated summer drought that occurred between 1989 to 1992 caused water stress and increased disease severity. In addition the disease process might be promoted by increasing nitrogen deposition that is known to enhance infection by *Sphaeropsis sapinea*. Another explanation on the genetic level was given by the findings of Stanosz et al. (1997). They identified two morphotypes (A and B) of *Sphaeropsis sapinea* which differ clearly in their aggressiveness against different pine species. The A morphotype is much more aggressive and is able to attack European larch (*Larix decidua*) as well as pines. There is some indication that the two morphotypes are already present in France (Morelet and Chandelier, 1993). The morphotypes of the Swiss population of the fungus have not been identified yet. It remains to be seen weather the aggressive A morphotype is responsible for the increasing severity of *Sphaeropsis sapinea*.

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Control of woody plants as weeds in urban areas

Woody plants spreading out in nature and countryside are not an enrichment of the naturally structure. The collective term „problematical woody plant“ describes non-native ones as well as such who put down the local flora through their characteristics. Most of these species are important. They have good spreading possibilities to get a compact thicket. Often they are planted for getting green of slopes, dumps, industrial fallows, for structuring the border of forests and others. In Germany these are for example *Acer negundo*, *Robinia pseudoacacia*, *Symphoricarpos albus laevigatus*, *Rubus fruticosus*, *Prunus serotina*. Without regulation they are spreading out in the countryside, forest and in nature reserve. They are able to prevent trees and other shrubs in growth. The characteristics of the problematic woody plants are to displace and to put down the typical flora.

Prunus serotina Erhr. is known as a very problematic woody plant for the natural forestry. It is very difficult to stem a plant like this. *Prunus serotina* Erhr. was introduced to Germany in the second part of the 18th century. The aesthetic and the assumption that it is possible to produce value wood on stands in minimal nutrients compared to the native country were the reasons for planting. Good cultivation requirements leaded to a wide spread and often to a supression of the local flora as a result of their characteristics. So it was not possible to reach the intention of forestry. Preserving and developping the local natural flora and timber stand are not able to reach for supporting the regeneration of nature. A lot of workers are necessary for the control with mechanic methods like to pull up, to take off the trunks a.o. Furthermore it follows in a formation of shoots. Without new attentions many trees fruit again in a very short time. It is possible to use selective methods with herbicides with weakning or dieing effects, which prevent fruiting and shooting.

This special method is the application of stems after notching in the field. In late summer the active substances Glyphosate, Triclopyr, 2,4 D were applied in two concentrations (5, 10%) in notches, one for each 5 cm stem diameter. The reactions - the abscense of blossoms and seeds, discoloration and dieing of leaves, leafless of the crown, small or not any sprouting of shoots – were seen in the next vegetation periode. All active substances in the concentration of 10% have a better effect than the 5 %. Glyphosat in a concentration of 10% was very effective, after a time the lower concentration (5%) and the herbicide 2,4 D, too.

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Potential usefulness of mycorrhizal fungi for the management of urban green areas in Braunschweig (Germany)

Urban green areas of Braunschweig can be classified into forests, parks, river banks, orchards resp. farmers gardens („Bauerngärten“), ornamental gardens, cemetaries, farm land, street edges, sport and play grounds, communal green, building areas and slag heaps. Some of these urban greens are exposed to great stresses like immissions etc. and vitality of the plants is low. High costs appear for the communities to replant these sensible areas.

Approximately 90 % of all plants in natural stands build a beneficial symbioses with arbuscular mycorrhizal fungi (AMF). More than 200 higher plant species occuring in Braunschweig were proofed for their mycorrhizal status. Nearly 30% of the urban greens show a lack of symbionts. Especially plants of areas with high frequency or intensity of disturbance showed low colonization rates by AMF.

Because of the beneficial effects of mycorrhizal symbioses to increase plant growth and stress tolerance of their hosts the introduction of adequate fungi is recommended. The AMF can already be applied during production of the plants for urban greens. The application of mycorrhizal inoculum will also benefit the growth of annual and perennial plants in balconies and private gardens. The symbioses of higher plants with AMF increases the vitality of the plants and thus lowers costs.

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Polypores on fruit trees in urban and suburban areas of Slovakia

There are known about 50 species of higher basidiomycetes causing mycosis of fruit trees in Slovakia. It is possible to divide the diseases of fruit trees caused by these fungi into 4 groups according to the families (taxonomic groups) of originators: stereoses, hydnoses, agaricoses and polyporoses. Polyporoses are caused by numerous fungi species, which belong to *Polyporales s. l.* Practically all fruit trees suffer from them in various rate. Polyporoses occur on trunks as well as on branches.

The data presented here come from many resources. In the 50´s Kotlaba (1962) has been inquiring into occurrence of wood–destroying fungi. During 10 years of studies in the former Czechoslovakia territory he has found occurrence of 32 fytopatologically significant polypore species. Generally, the most attacked woody plant was *Malus sp*. (20 finds). He explains it by unfavourable influence of long time cultivation on resistance of this species. The second most attacked and by greatest number of species attacked was *Juglans regia L*. (12 finds). It is out of its native distribution area and suffers often by frost (frost injuries), what supports the infection. Very often attacked was *Cerasus sp*. (19 finds). The most seldom attacked was Pyrus sp. Among polypores the most wide-spread were *Inonotus hispidus (Bull.) P. Karst. a*nd *Phellinus igniarius (L.) Quél*. on *Malus sp*. in orchards, gardens and avenues. The presented data were obtained from the research in the former Czechoslovakia territory and are applicable for territory of Czech and Slovakia as a whole.

The recent data from Slovakia come from research of polypores on woody plants in urban and suburban areas made by Gáper (1996 a, b, 1997) in 1982 –1989. Among other species there were investigated fruit trees, too. On 8 fruit tree species there were found 23 polypores species in all. Most often occurred *Inonotus hispidus (Bull.) P. Karst*. (5 finds) and *Phellinus pomaceus (Pers.) Maire* (4 finds – on genus *Prunus*). *Juglans regia L.* (13 species) and *Prunus sp*. (10 species) were attacked by richest polypore species spectrum. On *Malus sp*. there were found only 4 polypore species. There are differences in occurrence and diffusion of single polypore species according to the size of seat – the larger the size is, the more species is present. One of the causes of this state is the influence of more stress factors (mechanical injuries) on woody plants in larger towns, what reduces tree resistance. The results are influenced by unequal number of visits in the seats, too.

The specific type of environment, where the fruit trees are grown, are orchards. There is more then 90 000 ha of orchards in Slovakia. Complex data on polypores and other wood–destroying fungi occurrence from orchards in Slovakia are missing. The only available results are partial results from author's research in 1999. Except from all wood–destroying fungi only polypores *Trametes hirsuta (Wulfen) Pilát* and *Trametes versicolor (L.) Pilát* were found on 11 195 trees of 4 fruit species. The highest ratio of the attacked trees to the healthy trees had *Malus domestica Borkh. (Golden delicious* – 0.99 %, and *Jonathan* – 0.58 %) – 32 years old. No polypores were found on *Malus domestica Borkh*. (*Spartan* – 15 years old), *Juglans regia L*., and *Cerasus vulgaris Mill.*

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Radar investigation on wood decay and roots.

Introduction

Thanks to the development of non invasive methodology already used in the fields of medicine, archaeology and engineering, non invasive diagnostic tools can be used for tree stability assessment as well. Causing no damage to plant tissue, data can be collected on the entire section under study using sonic, ultrasonic and electrical tomography. A tree's stability depends on both a healthy trunk as well as roots and the techniques mentioned above cannot be used for detecting root rot or verifying the structural anomalies of the roots which can weaken the tree's stability. For instance, of the 65,000 ornamental trees in Turin, checked in the last years using the V.T.A. technique, most of the fallen trees were uprooted. For this reason, the development and the application of non invasive techniques on the plants could be of significant practical importance. Georadar could be used for detecting the root system underground in addition to diagnosing wood decay in the trunk. The aim of the present work is to verify the effectiveness of the acquisition criterions and the reliability of both the data processing and the georadar data images on both laboratory models and plants in the open field.

A model for data acquisition.

A preliminary test was conducted using a laboratory model made from a cylindric tank (ϕ 0.4 m), filled with water. A plastic tube (PVC) 2 cm in diameter was immersed inside the tank. The georadar data acquisition was carried out before and after the positioning of the tube in the tank, according to the following procedures: 1) single reflection measurements using antenna with main frequency of 1,000 MHz and 1,500 MHz; 2) measurements for transparency using a 1,000 MHz and 1,500 MHz receiver.

The data processing of the single reflection measurements involved both a pre-processing data filtering and the application of a transform in polar form of coordinates that better represents the circular geometry of the object. The best results were obtained from the single reflection acquisition which enabled to locate the tube's position with high accuracy and good resolution.

Georadar on the trunk.

The technique was applied on a trunk of horse chestnut with an internal cavity. The position of the cavity was accurately assessed in the transformed image of radar data in polar coordinates.

A controlled experiment on the georadar application for roots was carried out using a previously extracted stump, subsequently reburied in undisturbed soil conditions. The data acquisition was carried out in a single reflection operating mode, using a 900 MHz antenna. The data were acquired along parallel and perpendicular profiles, in an area of 5m x 5m with a 0.25 mesh. Data were processed in order to obtain maps of the distribution of the reflected signal amplitude at constant timeslices. These timeslices ranged between 4 ns to 24 ns, using single windows of 2 ns. In the selected time range the survey depth ranged approximately between 0.2 and 1.5 m. A good correspondence between the actual geometry of the near surface radical apparatus and the radar image is clearly evident, but the quality of the georadar images decreases at greater depths.

Discussion

The georadar investigation for wood decay diagnosis has proven to be a quick to use technique with very effective results and the times of data acquisition are relatively short. The georadar application to the ground needs some improvement for an extensive application in the field: *i)* the acquisition schemes that foresee a dense mesh of profiles for the correct elaboration of the timeslices might be difficult to use in the city where the spaces do not always allow for adequate arrangements of profiles on the ground; *ii)* the timeslices could better define the extension of the root system rather than to accurately delineate the sizes of the primary roots; *iii)* the development of new algorithms for the data processing could be used to study more complex radical apparatus as well as analyse the root geometry in depth.

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Use of composted organic wastes of urban households for phytosanitary purposes in peri-urban agriculture - a concept for waste and plant health management in West Africa

With the increasing urbanisation in Western Africa urban households produce more and more organic waste which arrives at its greatest part at wild disposal sites creating serious hygienic problems. At the same time, peri-urban agriculture is gaining more and more importance. There exist endeavours to use the growing quantities of organic household waste for purposes of plant nutrition, but another central problem of peri-urban agriculture remains unresolved: the aspect of plant protection. Yield losses caused by diseases and pests are an important constraint in developing countries agriculture. Therefore the use of chemical pesticides is the normal strategy to avoid losses. But a lot of farmers are not able to buy these chemicals due to their low income. Additionally chemicals could have some disadvantages, such as development of resistant pest strains and risks for user, consumer and environment.

To overcome these problems a research project was created which has the aims to understand the conditions for promoting the collection of compostable organic material in urban areas. The organic waste will then be transformed into compost and the potential of this compost or of compost extracts to control plant diseases will be examined.. A suppressive effect of composts against soil borne pathogens, such as *Pythium* spp., *Phytophthora* spp. and *Fusarium* spp. was reported by several investigators (e.g. Ben-Yephet and Nelson 1999; Erhart et al. 1999). The application of suppressive composts to the rooting substrate could be a very important measure to avoid early infection of seedlings by dangerous pathogens.

The use of compost or compost extracts to control pathogens of leafs, shots or fruits has not been studied to a great extent so far. Nevertheless, the few investigations carried out showed some very promising results. Different leave pathogens such as *Plasmopara viticola*, *Botrytis cinerea*, *Erysiphe graminis* and *Bremia lactucae* were effectively controlled by compost extract applications (e.g. Dittmer et al. 1990). The mode of action of the compost extracts were described as induced resistance and direct suppression of the pathogens. Based on the identification of suppresive composts the further objective of the project is the implementation of compost products as an alternative control method into existing production systems and the understanding of the conditions under which peri-urban farmers will adopt this strategy.

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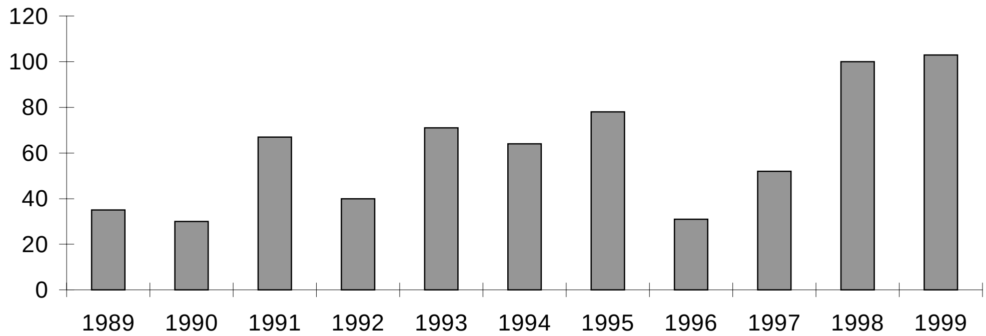
Plant health in private urban gardens in Scotland.

Introduction

The Royal Botanic Garden Edinburgh provides a free plant identification and advisory service to the public. This includes a service to identify plant health problems. Advice on recommended pest and disease control strategies is also given. This service is not advertised. In the past ten years a moderate number of individuals made use of this service, with an average of 61 enquiries per year (Fig. 1). Some of these yielded multiple data as a number of specimens were submitted.

Fig. 1: Enquiries



Materials and methods

Relevant data from the enquiries were entered into a database and analysed for the following fea-tures: plant identity and type (e.g. woody, herbaceous etc.); problem identity and type (e.g. pests, fungal disease etc.); recommended control and type of control (e.g. chemical, cultural etc.).

Results

Host plants: The majority of enquiries was concerned with tree problems, followed by fruit problems and ornamental plants. Problem causes: Fungi ranked highest in the problem causes. Arthropod pests and physiological conditions came second and third, respectively (Fig. 2). Recommended control: Cultural control was most frequently recommended, followed by chemical control and integrated approaches. No control was necessary or possible in 27% of cases.

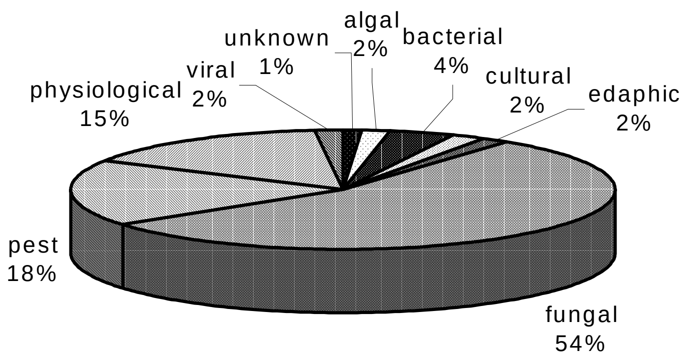


Fig. 2: plant problems by cause

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Scale insects on urban trees in Switzerland

A survey of the scale insect fauna of Switzerland showed that quite a number of species can be found on trees and shrubs in urban areas (KOZ·R et al., 1994). Nearly all of these species occur in low densities and lead a hidden life. Therefore, people normally do not notice them. In the 90ís, however, outbreaks of two introduced species were observed in the city of Zurich: the mulberry scale, *Pseudaulacaspis pentagona* (Targioni-Tozzetti) on *Sophora* sp. (MANI et al., 1997) and the horse chestnut scale, *Pulvinaria regalis* Canard on lime and horse chestnut trees (HIPPE and FREY, in press).

P. pentagona is of Asian origin and has become a pest in Southern Europe, e.g. on mulberry and peach trees. In recent years the species spread northwards. In Switzerland, an increase in urban infestations by this polyphagous diaspidid was not only noted in Zurich but also reported from Nyon (BAGGIOLINI et al., 1993). The mulberry scale has two generations in our region. Adult females overwinter and can lay up to 200 eggs.

The univoltine coccid *P. regalis* is known to predominantly infest its host plants within towns and cities. Trees already suffering from stress symptoms are preferred and show the highest infestation levels. A single female can lay up to 3000 eggs (SPEIGHT, 1994). The species presumably has its origin in the Far East but has been found in Europe only so far. While heavy infestations may have an impact on the growth of the trees (SPEIGHT, 1991), the primary problem caused by the horse chestnut scale seems to be a cosmetic one: The conspicuous white ovisacs of the females cover the stem and the main branches of the tree and are often mistaken for an unsightly fungal disease by the public. Amenity trees, however, are supposed to look nice. Infestations in other cities (e.g. London, Paris, Bonn) subsided after some years. The reasons for this decline are unknown. Natural enemies do not seem to have a decisive impact on the populations of the horse chestnut scale in urban areas.

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Requirements for the registration of plant protection products for non professional use in home and garden

According to §15 of the German Plant Protection Act of May 14th 1998, the Federal Research Centre for Agriculture and Forestry (BBA) decides on the suitability of a plant protection product for use in home and garden (amateur gardening) in agreement with the Federal Institute for Health Protection of Consumers and Veterinary Medicine as well with the Federal Environmental Office. The legislator assumes that the amateur gardener is not always well-informed to use plant protection products safely. Therefore, the following criteria are particularly taken into consideration when evaluating a plant protection product intended for use in home and garden (KOHSIEK 1999):

1 Properties of active substances and plant protection products

a) Generally not suitable for use in home and garden are plant protection products which according to the Regulation of Dangerous Goods have to be classified as T+ (very toxic), C (caustic), T (toxic, provided that this classification is necessary on the basis of carcinogenic, mutagenic or reproduction toxic properties).

b) Plant protection products which according to the Regulation of Dangerous Goods have to be classified as T (toxic, provided that this classification does not apply on the basis of the reasons mentioned before), Xn (detrimental to health) or Xi (irritating), or which show a particularly hazardous potential regarding the natural balance and groundwater, may be suitable for amateur gardening (examination of individual cases), if it is ensured that the type of formulation, dosing equipment, packaging and manner of application, when used properly and as directed or as a result of such a use, a risk for human being, animals, natural balance and groundwater is excluded.

c) If a plant protection product for amateur gardening is intended for indoor uses it must be ensured that a lasting negative effect on the air in the interior cannot occur.

2 Dosing ability

a) For all plant protection products formulations which are not ready-to-use a dosing precision of ±10 % must be ensured.

b) The dosing system for the production of a ready-to-use product (e.g. spray liquid) for amateur gardening, must be such that the user cannot be harmed when the product is used properly and as directed.

3 Packaging size

In order to be suitable for a plant protection product for amateur gardening, a maximum packaging size shall not be exceeded. The calculation of the maximum packaging sizes is based on a single treatment of an area of 500 m^2. If only one packaging size is intended for the treatment of an area of 400-500m^2, at least one further packaging size has to be offered for treating smaller areas. Moreover, the packaging size can be individually assessed if, for instance, a calculation is not possible or makes no sense (e.g. aerosol cans, plant protection sticks).

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Biological plant protection in indoor areas

In a city as Berlin the cultivation of indoor plants is a new service and an important part to the income of horticulture. In future the importance will increase, because many institutions (business centres, hospitals, kindergartens, hotels, banks and so on) have more interest on indoor plants. The arrangement of indoor plants is very different and there are tropical and subtropical plants or trees. Architects considered esthetical factors and fashion trends. That is the reason why often the conditions in the building are not conform with the growthfactors of the plants (light, humidity, temperature and ventilation). This could be the reason, that plants get pests and diseases.

The plants originate from different regions of the world and often there isn't much time for acclimatization in practise. The main pests are Pseudococcidae, *Tetranychus urticae*, Coccidae, Diaspididae, Thysanoptera.

The application of chemical pesticides in rooms is sometimes critical, the use of biological methods is the alternative. In many institutions antagonists of pests are introduced with good results. The application in rooms is very effective and advantageous to chemical methods.

The know-how of service is the basic for good results; knowledge about plants, assessment of climate conditions in rooms and the biological parameters of antagonists are main factors for an effective biological plant protection in rooms.

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Stethorus punctillum – an important antagonist of spidermites in the city*

Stethorus punctillum Weise was reported to be one of the predators responsible for decline of tetranychid mite populations in many parts of the world (e.g. BODENHEIMER, 1951; BÖHM, 1960; PLAUT, 1965; PUTMAN and HERNE, 1966; CHAKUROV, 1968; GAMBARO, 1974; MORI and VIANELLO, 1979; PASQUALINI, 1980). Adults as well as larvae of ladybird beetles *S. punctillum* are highly specialized predators of different kinds of tetranychid mites.

In the study about beneficial organisms in the public green the role of adults and larvae of *S. punctillum* were analysed on plants and trees in urban areas in Berlin. Aim of the investigation is to determine the efficiency of the predator on urban trees, as *Tilia* spec. and *Quercus* spec..

Development of *S. punctillum* includes 6 immature stages: the egg, 4 larval stages and the pupa. The duration of the development under laboratory conditions (21 °C) is 20 to 23 days. The eggs are elongated ovals and they are generally of a pale creamy colour. They are laid singly on the leaf or on the bark, often in the midst of mite colonies. The colour of the larvae varies with the age from pale cream to dark grey. Larvae at all stages of their development can crawl along the webbing of mites, but the first and second larval instars seem frequently handicapped by dense webbing on trichous host plants. The larvae suck their prey, liquefying the body contents by extra-oral digestion. The pupa is dark coloured; setae are scarce and wax secretion exists. The adult is black. They can fly actively and aggregate on mite colonies. The total progeny is 197 – 1290 eggs. *S. punctillum* consumed during development 239 *Tetranychus urticae* .

It was necessary to carry out a laboratory rearing. Adults are collected on *Tilia* spec. und are taken into a glass (2000 ml) with a gauze top. As feeding fresh leafs with *T. urticae* are taken into a smaller glass (250 ml) with a gauze and this is taken into the big glass. Mites leave the glass as feeding for S. *punctillum.* Adult beetles lay their eggs on the gauze. Three times of the week the gauze with eggs is taken from the glass in a petridish. After hatching from the egg the larvae are kept in small boxes (15 ml) with mites. Three time of the week the larvae are fed with mites until development of the pupa. The rearing conditions are 20 – 25 °C, 16 h light and 60-75 % R. H. .

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Biological control of the lily leaf beetle, *Lilioceris lilii,* in North America, using parasitoids from Europe

The lily leaf beetle, *Lilioceris lilii* Scopoli (Col. : Chrysomelidae) is a Palearctic species that recently invaded North America and quickly became a serious pest of native and cultivated lilies in New England and Ontario. No natural enemy was known from this beetle before we started to investigate its parasitoid complex in western and central Europe. Surveys were made in various climatic and ecological regions, on both wild and cultivated lilies. Six primary parasitoids, and one hyperparasitoid were found. Eggs were sometimes found parasitized by a mymarid, *Anaphes* sp., and larvae were heavily attacked by a complex of five species, the ichneumonids *Diaparsis jucundus* (Holmgren), *Lemophagus errabundus* (Gravenhorst) and *L. pulcher* (Szepligeti), the gregarious eulophid *Tetrastichus setifer* Thomson and the tachinid fly *Meigenia* sp. *Lemophagus* spp. were found to be parasitized by a *Mesochorus* sp. *D. jucundus*, *T. setifer* and *L. pulcher* were particularly important in regions, such as the Jura mountains, where wild lilies occur naturally. In these regions, parasitism rates were often above 50% on cultivated lilies and above 70% on wild populations of *Lilium martagon*. In regions where no native lilies occur, such as western France and northern Europe, the parasitoid complex was largely dominated by the eulophid *T. setifer*. In most parts of Europe, larval parasitism undoubtedly plays an important role in keeping the pest at an acceptable level of tolerance, suggesting that European parasitoids have a high potential for the biological control of *L. lilii* in North America.

We are presently investigating the biology and ecology of the main parasitoids, and evaluating their potential as biological control agents. Of particular importance is the assessment of host specificity. Ecological studies and screening tests in Europe and USA tend to show that *T. setifer*, *L. pulcher* and *D. jucundus* are specific at species level or, at most, at genus level, whereas no congeneric host species occur in North America. *T. setifer* is presently released in New England and its establishment evaluated. The release of an ichneumonid species is considered. The selection of the species to release should be made according to their specificity, host synchronisation, habitat preference, distribution in Europe and competitive interactions with *T. setifer*.

Biological control could be envisaged also in regions in Europe where *L. lilii* is considered a serious pest, e.g. in Holland or UK. As preliminary observations suggested that, in these regions, only *T. setifer* is present, ichneumonids could be introduced from Central Europe. As an alternative, an augmentative biological control programme could be developed using the native egg parasitoid *Anaphes* sp.

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Neem pesticides in public green areas

Test applications under use of NeemAzal -T/S have been carried out in tree avenues, urban tree stocks in squares and on solitary trees for leaf destroying caterpillars in the Land Brandenburg. Besides the employment of ground-based machines the efficacy of trunk-painting and infusions into the trunk were tested to control the target organisms *Thaumetopoea processionea* on *Quercus petraea*, *Yponomeuta malinellus* and tortricides (*Olethreutes variegana*, *Hedia nubiferana* and *Spilonota ocellana*) on apple trees, *Phyllonorycter leucographella* in *Pyracantha coccinea*, *Lymantria dispar* on *Quercus rubra* and other large trees and *Euproctis chrysorrhoea* on several deciduous trees.

Results of NeemAzal tests in 1995 ... 1999

Target organism	mode of application	NeemAzal concentration in water	NeemAzal formulation	efficacy in %
Lymantria dispar	spraying	0,5%	T/S	50 ... 60%
Lymantria dispar	trunk-painting	50% in 100 ml each tree	T/S	15%
Lymantria dispar	infusion	3 grammes in 300 ml each tree	conc. active substance	15%
Euproctis chrysorrhoea	spraying	0,5%	T/S	50 ... 60%
Yponomeuta malinellus	spraying	0,5%	T/S	73 ... 94% *
Tortricides	spraying	0,5%	T/S	80%
Thaumet. processionea	spraying	0,5%	T/S	0 ... 67% *
Thaumet.processionea	trunk-painting	10%	T/S	67 ... 70%*
Thaumet.processionea	spraying	1,0%	T/S	33 ... 87%*
Phyllon. leucographella	spraying	0,5%	T/S	> 90%

Annotation: * depending on the mode of evaluation: for instance number of infested trees, degree of defoliation, number of surviving target organisms.

The effects were compared to other, chemical or biological, insecticides registered for use on ornamental plants or ornamental trees and forestries. The efficacy was satisfactory and nearly as high as compared insecticides.

The favourable effect of NeemAzal was a detectable low risk to beneficial arthropods (spiders, hymenopteres, beetles) and non-target insects, low smell pollution and low hazard to humans and water (Kleeberg, 1999). The slow impact to the target organisms, a small available period of development of the insects (in maximum first larval stage and beginning second stage), no long lasting effect and some effect uncertainties are disadvantageous. The application of NeemAzal takes a higher degree of intelligence to the user than other comparable insecticedes.

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Analysis of the arthropod fauna in different urban vegetation in North Italy: street trees, urban parks and woody areas

Introduction

The aim of the work is to study the different kinds of urban public green in order to know the role and the importance of each kind of green typology. In particular it has been studied the differences in arthropod communities living on the three main types of urban green.

Material and methods

All the most important green areas in Como were studied. Samples were taken by all the most widespread trees during a two years period. Mainly leaves was picked up, till a height of 8 meters, in many points of the foliage. The collected material was subdivided in two parts. One has been utilised to collect the arthropods. The other was put in a climatic chamber in order to obtain adult parasitoids and predators.

Results

There are three kinds of arthropod fauna on public green areas in Como: trees, parks and woody areas. The first area contains 57 species of insects and mites, the second 55 and there are only 33 in the third. As reported in previous work many are beneficials (Sawyer and Casagrande, 1982; Rigamonti and Lozzia, 1999). Some of these species are found in all three areas but others are particular to one area. Differently from what was expected, the woody area is poorer in terms of arthropods with respect to the urban area. This poverty could be due to the fewer tree species that can be found. The parks are slightly different because there are more different species of trees or because the plants in such an environment attract more arthropods, such as for plane-trees (Lozzia, 1996; 1999).

The distribution of the species on the same type of vegetation but in different environments has given interesting information on the different arthropods. The hazel-nut tree, for example, hosts *Tetranycopsis horridus* (Can. and Fanz.) both in the parks and in the woody areas, but in the first place it is predated on by the phytoseiid *Kampimodromus aberrans* (Oud.) and in the second the *Phytoseius macropilis* (Banks) is more active. In urban parks the aphid of the hazel-nut tree is *Myzocallis carpini* (Koch), which is a victim of *Praon dorsale* (Haliday), while in woody areas the antagonist is *Trioxys pallidus* (Haliday).

There are three species of *Trioxys* who are parasitoids on the linden tree on avenues, only one in the gardens (*Trioxys tenuicaudatus* Starý), while in the woods the aphid was not attacked by parasitoids, also due to the low density of the population.

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Predation of *Aphis gossypii* Glov. on *Catalpa bignonioides* Walt. by polyphagous predators

Indian Bean Tree (*Catalpa bignonioides* Walt., Bignoniaceae), originating from North America, is also grown in urban areas of Slovenia. In our country, it is usually planted as a solitaire or in rows, enclosing buildings or surrounded by asphalt pavements; it was not long ago that phytophagous organisms were detected here on these species.

In 1997, numerous populations of aphids were observed on the trees exposed to the sun, near the main railway station in Ljubljana (the capital of Slovenia). According to the literature available, this pest belonging to *Aphis gossypii* complex has not been found on *Catalpa bignonioides* Walt. in Europe yet, though the species is a well known winter host of cotton aphid in America. The attacked leaves are deformed because of many aphids being on. The attack normally begins in a lower quarter of the tree crown, gradually covering the leaves in honey dew and sooty mold fungi. Aphids spread then also to the higher parts of trees, still remaining lower in the crowns. Each leaf is attacked by several hundreds of wingless aphids; being densely covered with the pests. From June on, *Adalia bipunctata* L. (imagos, eggs, larvae, pupae) is also found.

In 1998 and 1999, the Indian Bean Trees growing in Ljubljana and its surroundings were being inspected throughout the vegetation periods. In spring of both the years, fundatrices of *Aphis gossypii* were detected on the above mentioned location, and also some kilometres away. New generations of parthenogenetic aphids emerged, migrating later to the plants growing under. On both the locations, the trees were planted in rows along the asphalt pavement. No aphids were found on solitaire plants growing on grassy surface. Besides *Adalia bipunctata*, which was the prevailing predator all the year round, predators of the genera *Scymnus* spp. and *Orius* spp. were detected from August till the first colder autumn days. According to visual evaluation of the Indian Bean Tree crowns (deformation and early shedding of the leaves, poor and very late blossoming), the rate of yearly damage caused by aphid attacks was over 25%.

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Phyllosticta crataegicola Sacc. and *Entomosporium mespili* (DC ex Duby) Sacc. – two diseases on *Crataegus spp*. in public green are spreading

Introduction

Leaf spots caused by Entomosporium mespili (DC. ex Duby) Sacc. is a persistent and destructive disease of many species of Rosaceae (e.g. Amelanchier, Aronia, Crataegus, Cydonia, Malus, Mespilus, Photinia, Pyracantha, Pyrus, Sorbus, etc.). E. mespili is distributed worldwide in temperate to tropic climates. Entomosporium leaf spot is particularly damaging to plants and difficult to control during periods of frequent rainfall, and heavy infection may defoliate plants. Phyllosticta crataegicola Sacc. is a rare pathogen on Crataegus spp. Only one record could be found for the last decades (ZEINALOV and KANYGINA, 1988).

Background

In July 1999 both pathogens, *Entomosporium mespili* and *Phyllosticta crataegicola*, could be found on *Crataegus spp. E. mespili* caused severe damage on *Crataegus spp*. in public greens in Vienna and other parts of Austria. Heavy infestations of *Phyllosticta crataegicola* on leaves from *Crataegus spp*. could be found in public greens in Eferding (Upper Austria). Such severe infestations by both pathogens were never recorded previously.

The pathogens

Entomosporium mespili (Teleomorph *Diplocarpon maculatum* [Atk.] Jørstad) causes red and purple pinpoint dots to black spots, 1-3 mm in diameter, 4 – 7 days after inoculation (VAN DER ZWET and STROO, 1985). The optimal temperature for infection is between 20 and 25°C and the shortest wetness period is 8 hours. In the centre of these spots are darkbrown subcuticular acervuli, 100 – 200 µm in diameter. The overwintering of this fungus occurs on infected twigs (primary infection next spring by conidia) or on fallen leaves (infection next spring by conidia or ascospores). The transmission occurs by splash-dispersed conidia; ascospores appear to be of minor importance. Conidia can infect both upper and lower surfaces of leaves. The pathogen penetrates young leaves directly. Older leaves are infected through the stomata (BAUDOIN, 1986).

The hyaline conidia measure 15 – 23 x 6 – 9 µm and have 4 – 6 cells. They have two larger cells, one upon the other, and two or more smaller cells lateral. Apical setae, 7 – 15 µm long, are located on the upper and lateral cells.

Phyllosticta crataegicola causes round and grey leaf spots. Pycnidia are developed on both sides of the leaves. The pycnidia measure 60 – 100 µm in diameter. The one-celled ellipsoidal conidia measure 2 – 3 x 0,5 – 1,5 µm.

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Preliminary studies on declines of some ornamental tree species in Rome

Ornamental trees, grown in urban environment, suffer many biotic and abiotic stresses, able to trigger the syndrome of decline (Manion and Lachance, 1992). Rome environment offers severe growth conditions for woody plants and, in this context, fungi play an important role in complex diseases. A study is in progress, since 1996, to characterize symptomatic features, and the associated mycoflora, on declining leguminous tree species widely cultivated in Rome: *Robinia pseudoacacia*, *Acacia dealbata*, *Sophora japonica*, *Albizia julibrissin*. In fact, plants very often have dead branches and sparse foliage and show, year after year, a progressive decline of their vegetative vigour. Besides, fruitbodies of basidiomycetes associated to wood decay processes (especially *Inonotus hispidus* on *S. japonica* and *Ganoderma adspersum*, *Laetiporus sulphureus*, *Phellinus punctatus* and *Perenniporia fraxinea* on *R. pseudoacacia*) are frequently observed.

Moreover, all the four species above cited show, both in old and young branches, brownings in the wood, ranging from small black points to long and thick streaks; longitudinal sections of branches reveal that such brownings usually arise from the insertion of dead bud or sprouts or from little wounds. In particular, in *R. pseudoacacia* the alteration of wood can be associated, in hot summer, with withering of leaves and death of branches. On the other hand, in young green twigs of *S. japonica* and *A. dealbata* necroses interest also the bark, that becomes rough and yellowish in the first species, while it becomes black in the second one.

Isolations, conducted on 54 symptomatic plants (23 plants of *R. pseudoacacia*, 10 of *S. japonica*, 9 of *A. dealbata* and 12 of *A. julibrissin*) revealed a strict association with *Phomopsis* spp. About 65 isolates of *Phomopsis* spp. are under study for colony morphology, production of alfa and beta conidia and growth rate on artificial media, in order to attain their specific identification: preliminary results indicate an interesting scenario of variability among isolates from different species, or from different trees of the same species and also among isolates from the same tree.

The presence of *Phomopsis* spp. in leguminous trees is well-known, but their importance as pathogenic agents is not always defined. *P. mendax* was reported in 1879 in Italy on *A. julibrissin*, while on *A. dealbata*, *P. acaciicola* was reported in 1898 in Germany (Uecker, 1988). More recently, in Italy, *P. oncostoma* was reported as the causal agent of decline of *R. pseudoacacia*, showing bark and wood necrosis and blight (Ribaldi, 1954; Sidoti et al. 1998), and attacks of *P. sophorae* were also reported on *S. japonica* in nurseries (Frisullo et al. 1994). It is evident that the relationships between *Phomopsis* spp. and the different leguminous species still need to be explored. As a consequence, pathogenicity tests are in progress to assess the role of *Phomopsis* spp. in the decline and to establish the degree of specificity of the isolates, through heterologous host-parasite combinations. Moreover, use of molecular tools will help in clarifying this tricky *Phomopsis* group.

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Cercospora microsora Sacc. a disease, which gains in significance, on *Tilia* spp. in Southern Austria

Introduction

In the summer of 1999 severe problems were caused by a leaf spot disease which occurred on *Tilia* spp. Above all a newly planted lime hedge was infected. The plants came from different tree nurseries in Germany and Austria. Many small (1-3 mm in diameter), brownish black, glossy spots with dark margins appeared on the leaves of the infected plants. When already the stalks of the leaves were infected, a premature and massive leaf-fall occurred, so that the trees were leafless in September. This disease could be diagnosed as *Cercospora*-leaf spot disease caused by *Cercospora microsora* Sacc.

Causal organism

Cercospora microsora has long been known as a pathogen of lime-trees, but in the last year it seems to have increased significance, so that it has become one of the most common fungal diseases on lime-trees, and can cause severe problems especially in tree nurseries.

In most cases the microscopically diagnose is easy. At the beginning of July typical conidia appear. C. *microsora* sporulates mainly on lower leaf surfaces in dense fascicles of conidia. They are between 35 and 90 µ long and 3 to 4 µ wide, with several septa and light olive coloured. It can be difficult to diagnose correctly when the fungus occurs mainly in its sterile stage. This phenomena was described by BUTIN AND KEHR (1999) for the northern regions of Germany. In the southern parts of Germany and in Austria there was no lack of conidia. Besides the leaf and stalk infections, cancer-like symptoms on the twigs of the lime-trees can occur. These infections formerly were blamed on *Cercospora exitiosa* H.andP. Sydow. These necroses are ideal places for the fungus to overwinter and consequently they are starting places for new infections in spring.

The teleomorph to *Cercospora microsora* was found by KLEBAHN in 1912 and was identified as *Mycosphaerella millegrana* (Cook) Schroeter (syn. *M. microsora* Syd.). *Mycosphaerella millegrana* can be found easily because it occurs only in the area of the spots caused by *Cercospora microsora* and can de differentiated from the wider-spread species *M. punctiformis* (Pers.: Fr.) Schroeter by the larger ascospores.

Control

In most cases infections of *C. microsora* can be tolerated without control measures Control might become necessary only in tree nurseries or new plantings. To prevent severe infections infected leaves should be removed in autumn and necrosis on the twigs controlled by cutting.

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New services for pest monitoring in future in urban green space

Introduction

Early in this century, we will have to deal with the global climatic warming and higher pollution, especially in our crowded cities. Coming from the East and the South, some new pests will probably threat our parks. The dispersal behaviour of such well known pests as *Cameraria ohridella* , *Corythucha ciliata* and *Metcalfa pruinosa* will seriously emphasize the need to take redeployed management programs based and implemented from Integrated Pest Management in agriculture. So far, whilst considerable effort has been devoted to pest control in agriculture and horticulture (Simon et *al.*,1998; Rieux, Simon et Defrance, 1999) very few attempts have been implemented for urban forest pest control in Europe. Such an obvious factor as productivity, which mainly sustains IPM programs elsewhere, is rather absent from urban forest management. Therefore, aesthetic injuries seem to slip away the durability of the stressed trees themselves. Before a large phenomena of depressed and depleted urban forests occurs, we should quickly set up highly specific packages of technologies and know-how, both being usually too disconnected from each others for our concern.

New tools and services

From the mixing of new and advanced technologies with traditional and ecological practices (Cottu, 1999) can emerge potential strategies which will meet the requirements of urban sustainable development and urban biodiversity as well. So, we may and should extensively apply :

information and communication technologies - remote technologies with Radio Frequency Identification Systems –successfully employed for the urban forest in Paris (Jeanne-Beylot, 1999), Geographical Information System and multimedia- in order to collect and process biological or physical data with the greatest confidence

Advanced tracking technologies associated with conventional monitoring and targeting technologies may offer us one of the uppermost mean for pest control

Biosensors coupled with neural nets can be an invaluable tool and can meet some very specific achievements needed for pest control (Kauffman, 1999)

Also, utilization of radionucleids for autocide control can be of strategic importance for pest control programs as well as new projections in mycopesticides studies

Finally, we can take into consideration some technical innovations made for efficient and practical pest control in agriculture.

Conclusion

New and advanced technologies may increase the accuracy and speed of assessment of pests and host plants status in known climatic conditions in towns. This means that we are now able to anticipate and predict pest behaviour. Some important recommendations linked with urban gardens management have also to take place amongst gardeners.

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PICUS Sonic Tomograph – a new device for nondestructive timber testing

Municipalities and private tree owners are held responsible for damages caused by their trees. Most often trees are broken or thrown because of decay caused by fungal infections. To avoid risks the safety of trees has to be assessed on a regular basis.

Old-fashioned methods and devices need several years of experience, inspect only small parts of the trunk, or cause severe injuries (i. e. increment borers). Their range of application is therefor rather limited.

The PICUS Sonic Tomograph is a new device to assess the stability of trees and timber objectively and nondestructively. It is easy to apply and yields precise results.

Application:

The sensors are evenly spaces around the circumference of the trunk. They detect stress waves induced by manual impact and propagated through the wood. Time-of-sound transmissions are used to generate two-dimensional pictures that document decay and cavities.

Within 15 – 20 min a tomogram is attained as follows:

2. Coupling of the sensors to the tree
3. Recording of the geometry of the tree's cross-section – in most cases two perpendicular measurements with a calliper suffice. Where necessary, the software provides for a more detailed description of the geometry
4. Induction of stress waves: a slight tap on each sensor
5. All data are recorded automatically
6. On-site graphical presentation of results
7. Documentation: all results can be copied into standard office software

System specification

- Can be used for trees even larger than 1.5 m in diameter
- Integrated power supply - System can be operated for several hours
- Resolution depends on tree size and number of sensors, standard version is sufficient for most practical applications
- Can be operated with a notebook computer (WIN95/98) or a PalmSizePC

The poster presents the application of sonic tomography and results obtained for some of the most important urban tree species.

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Impact of ozone on virus-infected *Betula pendula* – determined by selected physiological parameters

Material and Methods

Cherry leaf roll virus (CLRV) - infected and uninfected one-year-old birch seedlings (*Betula pendula* Roth.) were treated with near to ambient ozone concentrations for five days (150ppb ozone, 8h daily). Symptom development was observed twice a day. As biophysical parameter, chlorophyll fluorescence and as biochemical parameter the activity of pathogenesis-related proteins (chitinase and ß-1,3-glucanase, Fink et al., 1989) and peroxidase (Lagrimini and Rothstein, 1987) were measured.

Results and Discussion

No symptoms were visible in CLRV-infected plants. Necrotic local lesions were formed after ozone treatment only in CLRV-infected birch seedlings while healthy seedlings did not show any visible symptoms after ozone treatment. Chlorophyll fluorescence measurements showed that the photosynthetic potential of the infected plants was better than that of the uninfected plants. A decrease of the steady-state quantum yield was observed in uninfected trees after 15 h of ozone treatment, while the quantum yield was not affected in infected plants.

No remarkable differences in enzymatic activites were observed between infected and uninfected trees. The increase in the activity of ß-1,3-glucanase after ozone treatment was more prominent in infected trees compared with uninfected trees. It increased after three days of ozone treatment and decreased to initital levels after three days of cultivation under ozone-free conditions. Chitinase activity increased after one day of ozone treatment in infected and uninfected trees and kept elevated for three days after the end of ozone treatment. Peroxidase activity did not react to ozone treatment. Infection of ozone-treated trees (3d, 150ppb ozone for 8h daily) did not show any effect.

After treatment with ozone as a second stressor, infected birch trees showed a stronger increase in plant defense reactions (activity of pathogenesis-related proteins) up to the development of visible symptoms. The virus-infected plants seemed to be sensitized against a second stressor.

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The monetary value of street trees in cities as for example Berlin

Public green is accepted from broad sections of the population in cities, because the citizens know and notice the positive functions of trees. Whereas the public green gets a constant high regard in the society the budgets for new plantations and their preservation go down rapidly. In a period of an economic way of looking at things the administrations are required to check their properties and their possessions with regard to profitability. At first a check of economic viability has to examine the costs for production, support and renovation of a subject. Costs for support of 0,5 – 1,0 % of the purchase are usual by long living things, that means for trees, shrubs, parks, public green, too.

The calculation of the costs for the installation of street trees (method KOCH) results in a price of 2 540,- DM for a planted and growing tree. This includes the plantation of the tree (size 3xv, 18/20), the replacement of substrate, the cultivation for three years and a risk for growth of 10 %. The following time of growth (time span of establishment) for a) 10 years, b) 20 years, c) 30 years and the annual costs for cultivation of 50,- DM results in a monetary value in dependence of the age of a tree a) young tree: 4 360,- DM, b) middle age tree: 7 052,- DM and c) older tree: 11 034,- DM. Strength of a subtraction of 5 %, 20 % and 40 % for the age the 400 956 street trees of Berlin have a monetary value of 2,182 thousand million DM (Tab. 1).

Table 1: Number of street trees and their monetary value in Berlin

age of the tree	number in 1998	value / tree	total amount
< 15 years	132 859 (31,1 %)	4 360,- DM	- 5 %: 549 039 820,- DM
15 – 40 years	141 613 (35,3 %)	7 052,- DM	- 20 %: 798 697 320,- DM
> 40 years	126 493 (31,5 %)	11 034,- DM	- 40 %: 834 853 800,- DM
total	400 956 (100 %)		2 182 590 940,- DM

For maintenance of the functions of street trees it is necessary to care for the plants. Therefore the 400 965 trees in Berlin costs about 5 to 30 million DM and 13,- to 74,- DM each tree respectively depends on the way of looking at things (Tabl. 2). Mostly the real budgets in cities are to low, so it seems that the owners of the trees have no necessary circumspection and no economic prudence. The consequences of low investments in tree care are the loss of the functions of the trees and the properties will run wild.

Table 2: Annual costs of support for the 400 956 street trees of Berlin by different percentages

	DM	0,5 % / DM each tree	1 % / DM each tree
purchase I [1]	1 018 451 100,-	5 092 226,- / 12,70 DM	10 184 511,- / 25,40 DM
purchase II [2]	2 967 731 300,-	14 838 656,- / 37,00 DM	29 677 313,- / 74,00 DM
monetary value	2 182 590 940,-	10 912 954,- / 27,20 DM	21 825 909,- / 54,44 DM

[1] costs of installation
[2] costs of installation and subsequent time span of establishment

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Integrated methods for healing of urban trees

On the example of care and treating work conducted on relic plane trees (*Platanus acerifolia*), which grow in Kolobrzeg, the most important integrated methods of urban trees healing were presented.

These tasks were completed in June 1995 on 15 trees, which were chosen from 74 other trees growing in three raws at Łopuskiego street. They suffered most from damages caused by biotic and abiotic factors. Having considered the exeptional natural value of the trees, as well as ornamental and environmental aspects of their presence, the plane trees were taken under strict protection and included into the special category of urban alleys. The age of the trees is approximately 150 years. The stressful conditions of a city caused visible variety in the size of plane trees, and the diameters of the stems measured at the height of 130 cm oscillated between 150 to 350 cm.

About one year before the actual treatment and care work the health and sanitary condition of the trees was very precisely estimated. On the basis of this expertise the 15 most heavily injured trees were selected. They were poorly developed, showing serious damages caused by pathogenic fungi and injured mechanicaly.

The integrated methods consist of modern biological and chemical ways of trees protection including the complex root system intervention. The basic rule of the task was to establish the individual range of methods, kinds of biological and chemical preparations for each tree. The amounts of the preparations depended on the health condition of a treated tree.

To conclude, the following treatments and care works were applied:

- Dried branches and shoots from the crowns were removed, the crowns were formed. Wounds and holes in the branches, boughs and stems were cleaned and preserved.
- Interventions into the root systems through the root injection, under the crown cover with the usage of organic-mineral and biological nutrients; exchange of the substratum around root collars.
- Application of implants prepared on the basis of the saprophytic *Trichoderma* sp. fungus and on systemic fungicides and insecticides.

It has to be stressed that the health reviews conducted in the following years proved an improvement in vitality of the treated trees, as well as regeneration of the injured tissues and their continuous development.

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Management and marketing for urban greening

Municipal park administrations have been affected by reduced financial support for maintenance and care of public open spaces. This leads to changes in quality of urban greening. In order to support them dealing with this situation the objective of this research project was to develop strategies for the management and marketing of urban greening, which would create a balance between the requirements of an urban landscape and the available resources like property, nature potential, manpower, technology and money. The task is to create as much well-being as possible for people living in an urban region. The basis of this research is from ongoing consulting projects in German and Swiss private and municipal park administrations.

The management-process for urban greening has three dimensions, which are linked closely together. The strategic dimension sets priorities for developing types of urban landscape which seems to be the best for integrating all the demands with adequate input of resources. The operative dimension organises an ongoing process of performance-review in order to reduce costs and the marketing dimensions develops strategies to convince politicians to give adequate financial support and to illustrate the consequences of cut backs.

Part of management is the well-organised process of care for public greening with its integrals features of setting objectives, developing concepts of care, planning the work and evaluation. Lack of planning, organisation and co-ordination leads to wrong decisions and causes unnecessary costs. The process has to be controlled so that the input-outcome-relation can always be measured. Special techniques of organisation have been developed for it. The marketing dimension presents 5 levels of quality for public open spaces, records these levels with photographs, calculates follow-up-costs to maintain these levels and classifies all public open spaces according to these levels of quality. The direct marketing presents the levels to politicians and lets them choose the quality they want to pay for. In addition it looks after private-partnership (e.g. „city-marketing“). The indirect marketing give incentives to citizens and organisations to realise the objectives for the development of urban landscape. Management and marketing of urban greening should be seen as an integral part of city planning. For that purpose, the co-operation of the planning bodies with the communal and private park administrators is essential. To provide basic research management of urban greening should be defined as a separate research field.

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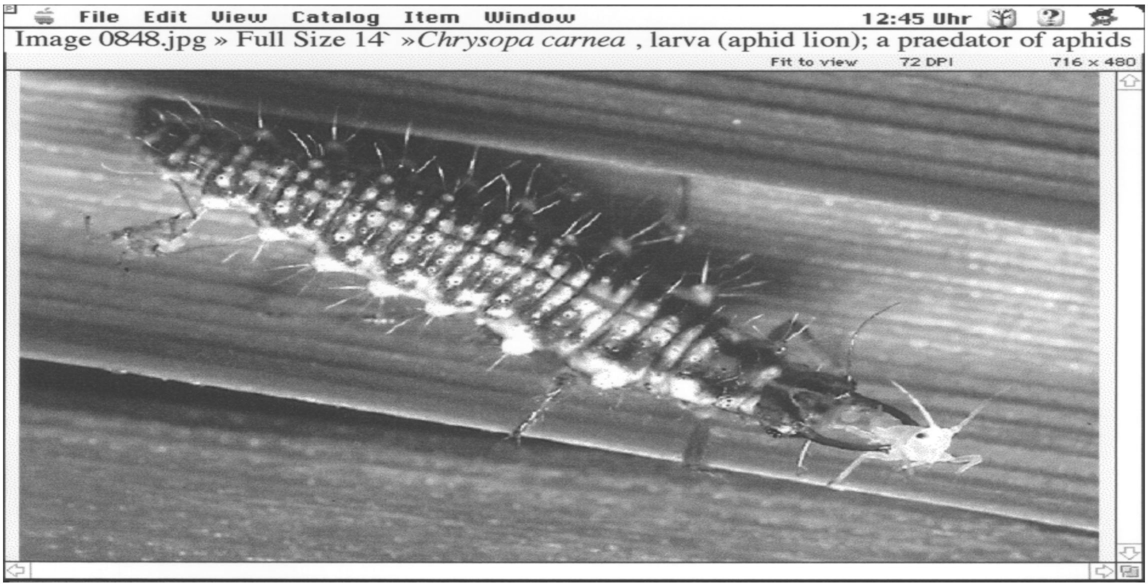
Image digitization in entomology – digital databases for research, teaching, and extension

The rapid development of image digitization for storage and display on personal computers offers and greatly enhances entomological research and teaching through the development of digital databases. One example of digitized images stored electronically on a CD ROM is „Plant Parasitic Arthropoda and Antgonists, Vol. 1 (1999), A Journal of Entomological Images“ edited by U. Zunke and J. D. Eisenback (ISBN 1-893961-05-2). More than 1000 images from the first author and contributors in Entomology are stored on one CD ROM together with an Index of the Images – sorted systematically – and a slideshow (200 images) for use within research, teaching, and advisory services. The photographs and micrographs are easily searched and accessed for ease of use. The pictures are stable and not subject to degradation such as fading, scratching, staining, etc. that are common with photographic images. The images are useful for observation directly on the computer screen or they can be printed on paper, overhead transparencies, or even photographic film. The images can be used for presentations with a digital projector or overhead projector panel connected directly to a computer or powerbook (Windows 95; Apple Macintosh MacOS). The equipment and steps for the development and use of digitized images are presented in a diagram.



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