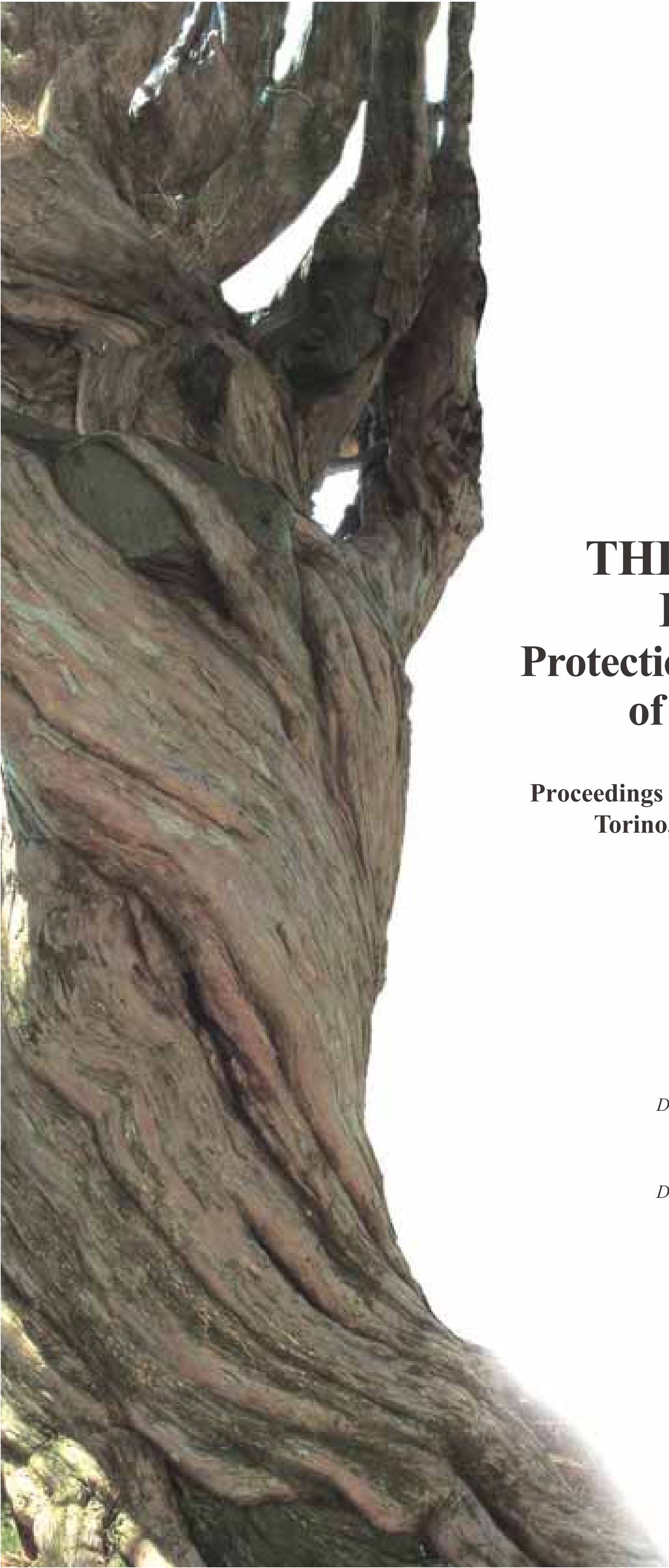

REGIONE PIEMONTE

Università di Torino

THE TREES OF HISTORY
Protection and exploitation of veteran trees

Proceedings of the International Congress
Torino, Italy, April 1st-2nd, 2004

Edited by

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DI.VA.P.R.A. Plant Pathology

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MONUMENTAL TREES IN HISTORICAL PARKS AND GARDENS AND MONUMENTALITY SIGNIFICANCE

R. Caramiello[1] and P. Grossoni[2]

[1] *Università di Torino Dipartimento di Biologia Vegetale - Torino*
[2] *Università di Firenze, Dipartimento di Biologia vegetale - Firenze*

Reference to trees is present in all cultures and in all ages as a cosmic symbol and one of regeneration and resurrection and more in general of life, in its various stages: from the biblical tree of knowledge of good and evil to that of the garden of Hesperides, from the tree of liberty to that of fevers which summed up medical knowledge in the first half of the eighteenth century on the fever which afflicts mankind in a wide range of diseases.

Despite these cultural values the protection of trees and woods in general has undergone over time periods of more or less marked decline. These have been linked both to a variety of reasons: a diminished sense of the sacred, reduced control over royal and community forests, changes in the use of the various species, and finally, to the different importance given to the question of the landscape.

However, the might of a tree has always caught man's attention and the species which could more easily reach considerable dimensions or age often acquired a religious meaning or a social role (for example, the oaks dedicated to Jupiter or Yggdrasil, the huge ash tree which according to Germanic-Scandinavian cosmogony had given rise to the universe and from which, after the disappearance of the world and gods, a new universe would be born or, to cite other examples, the cypress trees linked to the cult of St. Francis, the lime trees of mediaeval central Europe were often the place where justice was administered, etc.).

Conservation and protection in the past were therefore derived essentially from the respect of beliefs and traditions which saw in certain trees the symbol of a guarantee, including a supernatural one, of the daily activities of survival but which, often, were also a fundamental moment in human activity (trees for fruit production for food and/or for propagation, trees for shelter, trees as signs or boundary markers and so forth).

A first sign of defence of the territory and tree heritage can be found, for unified Italy, in the forestry law of 1877 and in 1939 tree heritage was finally considered in several laws which regarded historical and artistic heritage, at least as far as gardens and parks are concerned and the whole aspect of "… panoramic beauty spots considered as natural pictures" without better defining the characteristics. In the last few decades the cultural debate has led to the drawing up of national and regional legislation which include "trees" in programmes which promote the knowledge and protection of such assets.

Furthermore, many of the trees which at present are indicated as monuments are part of historical parks and gardens, although the practice of safeguarding and allowing trees to grow in gardens is a relatively recent cultivation technique. In the mediaeval garden and in formal gardens (in so-called Italian and French gardens) trees of particular size were not envisaged (it is sufficient to read the theories of Alberti, Colonna, Serlio, Del Riccio, Ferrari or Dezallier D'Argenville, etc.) although the presence of a majestic tree could form an unusual and striking architectural motif such as Castello's and Pratolino's oak (…*una Quercia di smisurata grandezza nella cui cima si sale per due scalle coperte dalle foglie ove sopra vi è uno spatio di 16 braccia di circuito cinto di lochi da sedere con una tavola nel cui mezzo sgorga un fonte chiarissimo* [... an Oak of huge size to the top of which one can go up by two stairways cloaked by leaves where above there is a space of 16 braccio in circumference, about 10 m, surrounded by places to sit with a table in the middle of which gurgles the lightest of fountains.]. AVR, Cod. Barb. lat., n. 5341, c. 210 r., 1588. In Zangheri, 1979).

For romantics, beauty is not closed in perfection: beautiful is any subject where it is possible to read the free flow of nature and history. Thus wonder for the unusualness of a tree (for size, shape, blossom, rarity, location, etc.) becomes a typical artifice of the romantic garden which is amply recommended by the theoreticians of the period because it exalts the very meaning of Nature, permanence and resistance: "*A tree, alone and isolated, may be noteworthy for its own nature: it can attract attention with its immense stature, with its fine canopy, and also with its branches, and with its leaves and fruits. The more isolated the tree is, the less the eye is distracted …… However the gardener artist will not offer too frequently a solitary tree, unless it merits particular regard"* (Silva, 1813).

Certainly sustained and fostered by Romantic aesthetic reasons, admiration for the unusual tree rapidly acquires momentum, as a motif of exceptionalness, whether the tree is unusual in itself, or in habit, in colour, in growth. In the woods of our continent, where, in certain zones, man's action has been uninterrupted for thousands of years, the monumental tree is not so much one which reaches the maximum dimensions as such but rather one which, for the reasons mentioned above, has been able to exceed the time limits (generally reduced) which man puts on the life of trees and thus it appears to be "outsize" compared to the standards of our cultural models.

It is the tree which lives longer than normal which surprises us for its dimensions and already Horace Walpole in 1771 wrote that one does not often see a really old tree because the sense of landscape and government inspectors are two incompatible things. Walpole was certainly not what we would call today an angry environmentalist, so much so that shortly later he also wrote that in a garden, at Petworth, there are several two-hundred-year-old oaks. According to him, if there is a shortcoming in such a noble, skilfully improved fragment of nature, it is that the large size of the trees is out of proportion to shrubs and bushes.

Factors Which Influence The Monumentality

A tree which for age, habit, size, rarity, cultural, historical or geographical value or for a specific connection with decorative or structural features (buildings, statues, fountains, etc.) has an intrinsic value which may be defined as a *very noticeable plant* (Grossoni, 2002). The *monumentality* of a tree brings immediately to mind the idea of exceptional dimensions (correctly speaking, *monumentality* qualifies the very grandeur of a specific monument); in this sense it is strictly connected to the definition of noticeable plant and it refers both to specimens of species which, potentially, may reach particular values regarding height, width of canopy and/or trunk diameter and to trees which are exceptionally "outside the norm" for species which are usually of modest size. The factors which can foster a "monumental" habit of a determined tree are multiple. They may be intrinsic (in the genome), correlated to cultivation methods or to environmental conditions.

1) Genotype. Given that a tree which reaches exceptional dimensions for its species is a clear expression of diversity, obviously the first condition is represented by the characteristics of that determined genome. The information contained in a genome is seen not only as a cause/effect relationship (i.e. genes that regulate a superior phenotype) but also as genes which induce the potentiality to grow very old by determining resistance to otherwise fatal diseases.

2) Age. It would seem obvious to state that the more a tree ages the greater it can grow in dimensions until it reaches a monumental value. Actually cultivation practices (in the woods) and maintenance, restoration or restructuring works (in an urban environment or in gardens) tend to sharply reduce the life expectancy of a tree.

3) Economic value. For centuries (and, in the Mediterranean area, for thousands of years) the woods of most of Europe (especially western Europe) have seen constant use, a fact which necessarily has limited the life of their trees and which defines periods of growth that are lower or much lower than their biological lifespan. The life expectancy of these trees has always been tied to the economics of felling. There are several examples but they regard essentially (more or less sporadic) species whose felling, until the advent of suitable tools (chain-saws), was particularly difficult and expensive (for example, juniper, yew and Cornelian cherry) or species whose wood is in little demand (e.g. *Pinus heldreichii* on Monte Pollino) or, finally, individual trees or clusters of trees growing in areas which are difficult to exploit (for example, the beech wood of the *Riserva Integrale di Sasso Fratino* in the *Parco Nazionale delle Foreste Casentinesi*). Likewise, individual trees were conserved when their products or exploitation determined an economic advantage (examples can easily be found throughout Italy among chestnuts and oaks with edible acorns) or had a social function (parks and hunting reserves, but also individual beeches, sycamores, cypresses or holm-oaks, linked to forms of veneration or used for shelter or protection). However, it should be pointed out that in the last few years, for both social and economic reasons, this rule of cutting any wood has started to give way to the advantage of protectionist choices (hydrogeological defence, conservation, etc.) Very recently the regulation for applying the Tuscan forestry law (Regional Law n. 39/2000), sub-section 12 (point 6) orders that "In all felling operations regarding a surface area of one hectare or more, at least one tree per hectare must be left to destine to indefinite aging for every hectare of wood cut. The specimens to be left uncut are those with the greatest diameter present in the felling area." (Regione Toscana, Decree of the President of the Regional Government 48/R, 08.08.03).

4) Planned historical parklands. In the specific case of historical organised green spaces (historical gardens and green areas) the existence of monumental trees is mainly closely linked to the kind of arboricultural cares: trees which have not undergone drastic or periodic pruning are at a strong advantage not only for their dimensions but, above all, for their life

expectancy. In this context, historical botanic gardens, for their very aim of conservation, have undoubtedly played a role in fostering the growth of trees which today have been qualified for their "monumental" status.

5) Environmental factors.

(a) location: it is easier to find that an isolated tree is identified and selected as monumental because the accentuated tapering of the trunk and the greater width and depth of the canopy make it particularly majestic and hence more easily identifiable.

(b) site conditions (climatic and soil): obviously, environmental conditions which are conducive to growth favour reaching advanced age and considerable dimensions. Often isolated trees used as midday shelter for animals have enjoyed the advantage of a constant supply of fertilizers. Neveertheless, it should be remembered that trees grown in environments which are more favourable than the natural environment could show greater growth rates, rapidly reaching considerable dimensions, but they are more open to attack by wood-eating organisms (fungi and insects).

(c) site conditions (pollution): widespread pollution is a recent factor linked to industrialisation and motor vehicle traffic. This complex factor is to be considered a negative element which limits the growth of veteran trees and acts as a debilitating agent which fosters the successive attack by pathogens. Moreover, the activity of certain pollutants (greenhouse effect) is attributed as being a cause of global climate change whose negative action is already clearly visible on many monumental (and ageing) trees.

(d) arboricultural techniques: arboricultural techniques regard especially trees in planned historical green spaces. They can constitute an advantageous factor in the expression of genetic potentiality but can have marked negative effects, as in the case of pruning (cfr. point 4) and the application of fertilizers and irrigation which by extending the vegetative period can make the trees more open to attack by pathogens. In any case, arboricultural techniques can be advantageous for the conservation of existing veteran trees.

6) Elements for enhancing monumentality. The acquisition or enhancement of the monumental aspect may be due also to mostly casual factors, which foster the development of particular growth features. These are frequently due to the fusion of several trunks, to the rooting of lower branches and to and to the emission of aerial roots.

(a) fusion of trunks: various trunks (suckers, branches or trunks growing closely together) "fuse" and graft; in this way trunks of particular dimensions and shapes are created (for example, the legendary Etnean chestnut known as the "Chestnut of one hundred horses" and the *Taxodium mucronatum* Ten. of Santa Maria del Tule with a diameter of 12 m, etc.).

(b) rooting of drooping branches at the base: rooting of branches of lower crown leads to the formation of a cluster of boles which can reach monumentality dimensions.

(c) aerial roots and buttressing: the emission of aerial roots and the development of buttressed roots are features which can exalt the sense of monumentality of a tree (e.g., in Palermo the *Ficus magnolioides* of Piazza Marina and of the Botanic Gardens).

Further factors which intervene in the concept of monumentality and are included in the definition cited at the beginning of the treatise refer to cultural and historical values which, very frequently, but not always, accompany the extraordinary dimensions and age of certain specimens. Indeed some have a precise historical motivation that connates them as monuments: for example, the Goethe palm in Padua, the date of planting is known (1585) as is the origin of the name, which dates to 1786 when, almost two centuries later, Goethe admired it and studied it, drawing inspiration for his evolutionary intuition expressed in the essay "The metamorphosis of plants". Other great trees, even in a historical garden, may not be accompanied by such a well known written history that documents when the tree was planted or the reason for the choice or that connects it with personalities and events. Certainly for this reason the Corpo Forestale dello Stato (National Forestry Service - CFS) lists that are today available, albeit rich, should be integrated with information that can come from herbarium or archive studies conducted in Botanic Gardens and similar cultural and historical contexts.

Monumentability And Botanical Species

It is not easy to make an analysis of the taxa to which Italian monumental trees belong in that a general official census that is representative of our country has never been performed. The only inventory on a national scale, decided and performed by an authoritative and representative organisation, is that conducted by the Corpo Forestale dello Stato which started in 1982. It is on the basis of this study that a selection was published in the early 1990s (Alessandrini *et al*., 1990-91) and is available on the official Corpo Forestale dello Stato website.

Most Italian regions have drawn up inventories for their own territories; similar initiatives have been undertaken and implemented also by individual provinces and municipalities. Therefore there are lists which are more or less comprehensive and more or less correct; however, even today there is no list that is exhaustive and authoritatively reliable. In fact the CFS inventory has given relative importance to historical urban and out of town public green spaces. It is not even possible to complete this list using regional, provincial and municipal lists in that the criteria of evaluation are different as the fundamental factor in the decision of giving a tree the title "monumental" still remains a subjective one linked above all to the emotion that a certain tree creates in the observer. Moreover the discriminatory threshold between ordinariness and monumentality tends to be also in function of the surface area of the territory in hand.

The "task" of our report is to examine certain aspects of the most common taxa represented in so-called *monumental trees*. For this reason our starting place was the only national list available. Actually, as the list published on the Corpo Forestale dello Stato website is more comprehensive than that published in the two volumes by Alessandrini and co-workers (1990-91), we refer to the web version. The inventory has covered 1255 trees belonging to 143 taxa (species, subspecies, cultivars and hybrids) belonging to 76 genera (21 Pinophyta and 55 Magnoliophyta). Of the 143 taxa 65 are included in Italian flora and 78 are exotic.

In addition to the use, in some cases, of now obsolete nomenclature, the analysis of this inventory brings up some justifable doubts on the correct taxonomic attribution of some of the recognised specimens. We refer, for example, to the numerous specimens of *Cedrus libani* A. Rich. (58) and *Platanus orientalis* L. (37) which are a little too abundant compared to the systematically nearest taxa (*Cedrus atlantica* Carr. (19), *C. deodara* G. Don f. (22) and especially, *Platanus x acerifolia* (Ait.) Willd. (3).

Quercus pubescens Willd. is the most represented species (211 records); far behind in second place is *Fagus sylvatica* L, which is mentioned 98 times (the value would rise to 113 if ornamental varieties were included). There are 99 cedars but 58.6% of these are cedars of Lebanon; among the other oaks the main species are fairly well represented (holm-oak, with 52 specimens, sessile oak with 50, turkey oak with 43 and the pedunculate oak with 36). All native deciduous oaks amount to 346 (27.6% of the total): this is certainly linked to the significance that these species had in the countryside as well as of course, to their longevity and growth capacity (it is highly probable that there have been errors in taxonomic attribution between sessile oak and downy oak). Obviously there are quite a few specimens of plane trees and giant sequoias, while we find the presence, but not in abundance, of two species which have a considerable importance in the coastal and hill landscapes of our peninsula: *Pinus pinea* L. and *Cupressus sempervirens* L. (the latter is particularly linked to episodes of devotion and religious tradition) were included in the inventory 22 and 25 times respectively. Naturally, it is given for granted that certain species are present mainly, or exclusively, in certain geographical areas; this is due to their chorology or to the fact that the climatic environmental are such as to prevent or discourage their growth in other regions. The parameters most used in defining a certain tree as *monumental* were undoubtedly the dimensions (height and/or circumference); however, also age, bearing, rarity and cultural values (historical, social, landscape) are all well represented. Not all the specimens included in the census are necessarily of exceptional size and several species are represented by shrubs or arborescent specimens.

In order to check what the most representative taxa were, we had used some other inventories for comparison/confirmation purposes. As mentioned earlier, we used the inventory of the Corpo Forestale dello Stato and, for the sake of comparison/completion, a geographically defined sample, among the other existing lists. For the sake of simplification, we examined some surveys made in Tuscany, the region where one of the authors lives.

In addition to the CFS inventory (Alessandrini *et al*., 1991), for the monumental trees of Tuscany we consulted some surveys made by the Lucca Botanic gardens (Poli *et al*.; 1992), Regione Toscana (2001) and a review made by Capodarca (2003). We then examined also the results of a survey conducted on the territory of the province of Lucca (Giambastiani, 1996). The number of specimens included in the censuses ranged from 176 (Alessandrini *et al*., 1991) to 347 (Capodarca, 2003; this author, however, also reports the results for Tuscany of the national census). In all, 82 taxa were reported in this region; 10 other taxa are records which have been surveyed by Giambastiani (1996) only in the province of Lucca.

Compared to the taxa identified in the CFS inventory and excluding the province of Lucca, 37 more taxa have been reported while 7 are missing. On the same tree there are differences between the inventories and, in some cases, also very considerable ones both for the dimensions reported and especially for the discordant taxonomic classifications in the genus but also (cfr. the case of *Washingtonia/Jubaea*) between genera. The distribution of Tuscan vegetation ranges from a dry Mediterranean to a montane environment, "summing up" in a certain sense most Italian forest climatic conditions. Likewise, the frequency trend for species of monumental trees presents many similarities with the national trend: deciduous oaks (downy oak, sessile oak, turkey oak, etc.) are the predominant species followed by cedars, beech and chestnut. Above national average we find holm-oak, cypress and stone pine in that these species are particularly used in this region as ornamental plants (historical gardens, etc.), so much so that they characterise much of Tuscan landscapes.

For Piedmont the regional law which governs the census and successive protection of monumental trees is Law 50 (1995). The Corpo Forestale dello Stato inventory cites 102 monumental trees in Piedmont, of which about twenty are highlighted as specimens of exceptional value. The data are being updated as part of a wide-scale census and monitoring operation throughout the region, which has brought about, as a first step, the official "baptism" and inclusion in the appropriate regional list of five monumental trees: the Napoleon Plane in Alessandria, the Mergozzo elm (VB), the Macugnaga lime (VB), the Zelkova in the Park of Racconigi Castle (CN) and the Moncenisio ash (TO). The last two specimens have not been cited in the previous lists. The works of the Commission are obviously continuing and other reports will be arriving, including from the Turin Botanic Gardens, on some specimens which so far had not been included in the census. In the Aosta Valley 10 monumental trees have been mentioned, 4 of which particularly noteworthy. They are made up of species such as *Tilia cordata* Mill. in Aosta, *Picea abies* Karst. at Courmayeur, *Aesculus ippocastanum* L. at Donnas and *Larix decidua* Mill. at Morgex. On the other hand, in Liguria, where 18 trees have been classified as monumental, there is a predominance of exotic species, introduced into parks and gardens, including *Araucaria bidwillii* Hook. f. at Villa Groppallo and *Jubaea chilensis* Baill. at Villa Serra in the city of Genoa and *Sequoiadendron giganteum* (lindl.) Buchholz at Montoggio (GE).

The list for Lombardy reports some 192 specimens and among these we may mention, at least for a sense of affection, that of the Scopoli Plane, planted in the Botanic Gardens of Pavia by Giovanni Antonio Scopoli, a man of great scientific repute, who the previous year had been appointed director of the Gardens. From a brief look at the lists of other regions, these too need revising, one can observe that all in all species can, if left to grow freely without the restrictions of management or maintenance, reach such dimensions that undoubtedly many of them could be classified as monumental trees. Even if we limit our inquiry to only native species, we could include conifers such as fir, spruce, larch, some pines and broad-leafed trees such as all Fagaceae (with the exception of kermes oak and a few others), elms, the nettle-tree, the sycamore maple, limes and the common ash (although the monumentality of the last two groups is perhaps more tied to Central European culture than to that of the Mediterranean).

Loudon (1835-39) wrote that thanks to the extreme variability of climatic conditions in Italy every species on the planet could be grown. The claim is certainly excessive but it gives a good idea of the possibilities of growth and development of numerous exotic species in our country which have been able to reach dimensions which justify including them among monumental trees. Among the Gymnospermae the genera which are most represented and representative of the very concept of monumentality are undoubtedly *Cedrus, Sequoia* and *Sequoiadendron*; however, we should not forget *Ginkgo* and *Cupressus* (*Cupressus semprevirens*). The latter is noteworthy not only for the dimensions of certain species but also for the landscape value which it has in certain regions and in certain climatic environments (for example, the southern Alpine lakes). Moreover, in general we should remember some other genera of the Cupressaceae family such as *Calocedrus, Thuja* and *Chamaecyparis* which, although less frequently, are also present with noteworthy specimens. Albeit less frequent, we should note Arauciariaceae and Taxodiaceae (for example, *Araucaria columnaris* (Forster) Hook. and *Taxodium distichum* in the Reggia park in Caserta).

Tulip trees, planes, ornamental forms of beech, *Ficus magnolioides* Borzi, *Sophora japonica* L. and *Carya* are exotic Magnoliophyta which can produce specimens of exceptional dimension.

For these taxa we outline some useful aspects for understanding their salient features.

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TAXON	NUMEROUSNESS					
	ITALY (Alessandrini et al., 1991)		TUSCANY (Alessandrini et al., 1991)		TUSCANY (Poli et al., 1992)	
	N	%	N	%	N	%
Quercus pubescens	211	16.81	27	15.34	23	9.27
Fagus sylvatica	98	7.81	14	7.95	21	8.47
Cedrus libani	58	4.62	9	5.11	20	8.06
Castanea sativa	52	4.14	11	6.25	21	8.47
Quercus ilex	52	4.14	21	11.93	29	11.69
Quercus petraea	50	3.98	11	6.25	8	3.23
Quercus cerris	43	3.43	9	5.11	17	6.85
Sequoiadendron giganteum	40	3.19	4	2.27	4	1.61
Platanus orientalis	37	2.95	3	1.70	0	0
Quercus robur	36	2.87	2	1.14	3	1.21
Cupressus sempervirens	25	1.99	8	4.54	6	2.42
Cedrus deodara	22	1.75	1	0.6	1	0.40
Pinus pinea	22	1.75	5	2.84	8	3.23
Abies alba	19	1.51	5	2.84	4	1.61
Cedrus atlantica	19	1.51	5	2.84	7	2.82
Tilia cordata	18	1.43	0	0	0	0
Acer pseudoplatanus	17	1.35	1	0.6	1	0.40
Sequoia sempervirens	15	1.20	5	2.84	4	1.61
Ulmus minor	15	1.20	0	0	0	0
Celtis australis	14	1.16	2	1.14	2	0.81
Taxus baccata	14	1.16	0	0	5	2.02
Olea europaea	11	0.88	2	1.14	5	2.02
Calocedrus decurrens	7	0.56	2	1.14	5	2.02
Platanus x acerifolia	3	0.24	0	0	4	1.61

Absolute frequency and percentage of the most represented monumental trees in Italy and Tuscany (several sources)

		Alessandrini et al. (1990-91)		Poli et al. (1992)		Ciambastiani (1996)		Regione (2001)		Capodarca (2003)	
		height (m)	circum (m)	height (m)	circum (m)	height (m)	circum (m)	height (m)	circum (m)	height (m)	circum (m)
AR	Poppi	19.0	8.80	19.0	8.80					19.0	8.45
		Castanea sativa		*Castanea sativa*						*Castanea sativa*	
FI	Florence	24.0	7.60	24.0	7.60			27.0	7.50		
		Cedrus libani		*Cedrus libani*				*Cedrus libani*			
	Vinci	19.0	5.20	19.0	5.20			11.0	4.60	16.0	5.13
		Quercus ilex		*Quercus ilex*				*Quercus ilex*		*Quercus ilex*	
	Montaione	13.0	4.00	13.0	4.00			12.0	3.90		
		Washingtonia filifera		*Washingtonia filifera*				*Jubaea chilensis*			
LI	Campiglia M.ma	22.0	5.90	22.0	5.90			18.0	4.00	22.0	6.25
		Quercus petraea		*Quercus petraea*				*Quercus robur*		quercia	
LU	Capannori	25.0	5.50[1]	25.0	5.50	28.0	6.20				
		Liriodendron tulipifera		*Liriodendron tulipifera*		*Liriodendron tulipifera*					
	Massarosa	8.0	3.77	8.0	11.00	8.0	12.88			9.0	10.60
		Olea europaea[2]		*Olea europaea*		*Olea europaea*				*Olea europaea*	
	Camporgiano	20.0	4.80	20.0	4.80	24.5	5.20			-	4.90
		Quercus petraea		*Quercus petraea*		*Quercus petraea*				*Quercus pubescens*	
	Capannori	22.0	4.00	15.0	4.00	16.0	4.15			20.0	4.21
		Quercus robur		*Quercus pubescens*		*Quercus pubescens*				Ibrido. Forse *Quercus cerris*	
PT	San Marcello	30.0	6.00	28.0	6.00					23.0	6.06
		Quercus cerris		*Quercus cerris*						*Quercus cerris*	
	Lamporecchio	20.0	4.30	25.0	4.40			30.0	4.45	22.0	4.50
		Quercus pubescens		*Quercus pubescens*				*Quercus pubescens*		*Quercus pubescens*	
SI	San Gimignano	25.0	4.70	25.0	4.70					21.0	5.74
		Celtis australis		*Celtis australis*						*Celtis australis*	

Comparison between various inventories referring to Tuscany and the Province of Lucca (various sources)

[1] in the CFS website list it is indicated as 5.65 m
[2] this specimen is not reported in the list on the CFS website

EVOLUTION OF TREE LANDSCAPING IN HISTORICAL PARKS AND GARDENS

M. Devecchi
Dipartimento di Agronomia, Selvicoltura e Gestione del Territorio. Università di Torino

1.Foreword

Since the origins of history, man has developed the need to organize and mould the surrounding space, in both amusing-recreational and utilitarian terms, transforming and changing it in a pleasantly livable environment. A garden is a space that symbolizes Eden, where we were born, but from which we were driven away. A garden represents the myth of the "*sacred wood*", i.e. of the *magical place* or enchanted and remote microcosm, where everything is possible and achievable. The tree, as a primary component of the garden, has always represented the symbol of stability and is associated with the concepts of growth, development, protection, longevity, radication, and age. Planting a tree has always been an act full of spiritual meaning, as it is a faithful mirror of man's existence. The big tree invites to meditation and induces respect and wonder that turned to a deep religious feeling in many peoples and civilizations. "*The garden art*" emerges naturally from this religious thought, linked to the idea of creation and organization of the natural element in an anthropical vision, i.e. in a landscape arranged according to a rational criterion. A garden has, thus, the primacy of being the aesthetical, historical, and cultural identity of a place. Not only a garden, but the very landscape appears as a metaphor of human deeds, that modify it continuously following his demands and needs. Each tree, group of plants, avenue, thicket and spontaneous hedge, as well as the heritage of urban green and country green, holds a landscaping function of extraordinary importance. A tree characterizes, carves, and determines the colour and often the shape of landscape. In particular, the trees of monumental interest, as elements that participate strongly in the characterization of places, represent elements able to "resist" to an increasing landscape banalisation and simplification. It is renowned how the rural landscape even in the Piedmontese reality, has found in the trees the characteristic features that can be referred to well identifiable plantation and exploitation models. An example of this are, for instance, the trees around farms, the rows and single specimens placed to mark the borders between holdings or along water courses and ditches. Old prints or paintings are of great interest for this purpose, as they depict the landscapes of some centuries ago, where one can see the frequency with which oaks are illustrated for the majestic architecture of their trunk and branches. Landscape safeguard and exploitation can be addressed also towards a field until now not sufficiently explored as that of the tree heritage, considering the importance of such elements in the characterization of the landscape, besides of parks and gardens. In a view that does not end only in the aesthetical-perceptive consideration of landscape, another aspect of the trees of extraordinary importance is the fact that they are the result of a whole series of environmental adaptations and of the capacity to respond to external conditionings that make them the depositary of a remarkable heritage of scientific knowledge.

2.The use of trees in ancient times

Under the word garden, we usually mean a piece of ground in which ornamental plants and flowers are grown. Really, the oldest descriptions talk of a garden as a vegetable garden, or an "orchard", thus having utilitarian scopes. In the mythological imagination, Persian paradises are enclosures and places where tame animals, that do not attack man, are kept as signs, symbols, and memory of the old "***sacred wood***". In the **Egyptian civilisation**, the garden was conceived both as a place of relaxation and as a productive place for growing grapevines, date palms and vegetables and so, with the typical feature of the "***orchard-vegetable garden***". The Egyptian garden, known through many paintings found inside tombs, was characterized by a strictly planned design: around a rectangular basin, or even more pools, herbaceous and shrubby plants were placed, followed by the tall trees. Among the evidence found, remarkably important are the paintings on the walls of the temple of Tuthmosis III at Karnak, illustrating 256 different species, that underline the particular interest of the Egyptian culture for the study of botany. Among the most common plants grown there are trees of productive and ornamental interest, such as palms (*Phoenix dactylifera*), tamarisks (*Tamerix gallica*), fig trees (*Ficus carica*), pomegranate trees (*Punica granatum*), olive trees (*Olea europaea*), almond trees (*Prunus amigdalus*) and grapevines (*Vitis vinifera*). In the civilisation of **ancient Greece**, the garden was not considered as a real kind of art, it was characterized instead in a functional and productive way. The old garden of the literary tradition, handed on from the Greek world, is described in the 7th book of the Odyssey, where Ulysses arrives when he approaches the town of the Phaeacians and is hosted in the royal palace of Alcinous. It is a meticulously arranged garden, as often this image of the Greek world is, like a mixture between garden and orchard. It is a fructiferous place, sprayed with crystal water and decorative elements. Greek mythology refers to the *locus amoenus*: a magic place where the *genius loci* reigns and where one searches the harmony between man and landscape, inherent in nature. Such were the woods close to the sanctuaries, where plane trees (*Platanus orientalis*), elms (*Ulmus minor*), alders (*Alnus glutinosa*), and cypresses (*C. sempervirens*) are grown, as well as fruit trees. The woods in the neighbourhoods of the towns were instead different, they were planted in regular rows. In Athen's agora, for example, in correspondence with the temple of Hephaestus, there was a geometrical garden, in which the rows of small trees repeated the setting of the temple's columns.

The **Romans** had the custom to name a certain tree species to the divinities, that they believed were born from trees or under trees, symbolizing with them their attributes; so the oak (*Quercus robur*), as the expression of strength and vigour, was consecrated to Jupiter for its majesty and superiority over the trees of the forests; the holm oak (*Q. ilex*) was consecrated to Pan and with this tree the ancients forecasted the deeds of heaven (also the Etruscans considered the holm oak divining and, with its branches shaken towards the sky, they called for the rain to make the seed grow); the elm (*U. minor*) was dedicated to Morpheus, as it invites to relax, because under its shadow sleeping is sweet; the ash tree (*Fraxinus excelsior*) was linked to Mars, as it was useful to make lances; the cypress (*Cupressus sempervirens*) was dedicated to Pluto and was put on the front door as a funeral sign; the white poplar (*Populus alba*) was connected to the Muses and to Hercules; the black poplar (*Populus nigra*) was joined to the Heliades in memory of Phaeton, their brother; the weeping willow (*Salix babylonica*) was consecrated to Juno, because she was born and brought up among these melancholy trees; and finally the laurel (*Laurus nobilis*) that, as a symbol of triumph, health, cheerfulness and also safety, was dedicated to Tiberius. In Italy at the time of the Romans there was no spring, river, famous place, and forking of a public road that had not its sacrarium with a tree; The most solemn acts of the life of peoples or of the individuals were made in the shade of big trees. Around certain consecrated trees a fence was built in which not everybody could enter; the enclosed space became sacred and the ground a religious place (AA.VV., 1990). Especially starting from the Augustan age, the gardens in Rome reached the highest forms of artistic expression, also as a consequence of the fact that the vegetation became architecture, through the practice of the *ars topiaria*. The specialists of the *ars topiaria* tried to make the garden habitat lively, operating not much with the colours, but with the shapes of the plants (Grimal, 1990). So these were pruned in the most curious shapes and placed so as to create diverse shades of green of the foliage of trees and shrubs (Fariello, 1967). The remaining decorativity came from fruit trees, thanks to their abundant blossoming, such as in the peach trees, a tree imported from Orient by Lucullus, together with local species, such as cherry and apple trees. Fundamental is the information handed on to us by Pliny the Elder in *Naturalis Historia* about the commonly used plants: oak (*Q. robur*), holm oak (*Q. ilex*), and pine (*Pinus pinea*) were used in big parks; the cypress was used to make protective curtains in gardens; linden (*T. cordata*), plane tree and palm were instead employed mostly in the city; laurel, box (*Buxus sempervirens*), myrtle (*Myrtus communis*) were preferred, because easily shaped; but there was space also for alder, oleander (*Nerium oleander*), ivy (*Hedera helix*), fruit trees and flowers: roses (*Rosa* spp.), violets (*Viola odorata*), anemones (*Anemone nemorosa*), hyacinths (*Hyacinthus orientalis*), and other flower species.

3. The tree in the medieval and Arab garden

In the Middle Ages, the garden called *Hortus conclusus* became a place of meditation and spiritual retreat. Among the most useful literary sources for the comprehension of the medieval garden, fundamental is the treatise of agriculture *De Ruralium Commodorum*, written in 1305 by Pietro De' Crescenzi, a jurist of Bologna, close to the Angevin court of Naples. In this work one can understand how the garden, divided geometrically by beds separated by alleys covered with pergolas, was often marked by the presence of the "*Pomarium*", composed of fruit trees set in rows. In the *Hortus conclusus* there was place for flowers and fruits full of symbolic meanings, such as the rose, the Virgin's flower, the lily, symbol of purity and poverty; the pomegranate (*P. granatum*), a metaphor of the unity of the church, and, among the trees, the palm (*P. dactylifera* and *Chamaerops humilis*), symbol of justice, the fig tree (*F. carica*), a metaphor of sweetness, the olive tree (*O. europaea*), symbol of mercy, and even clover (*Trifolium* spp.), a direct recall of the dogma of trinity. In the **Arab garden**, water represented the main element of its composition, as it was present in fountains, pools and canals. Among the trees, above all the cypresses (*C. sempervirens*) were grown in large numbers, as they were mentioned in the Koran as symbols of eternity and female beauty. Among the most beautiful creations of Arab gardens, there are the Hispano-Arabic ones of Alhambra in Granada. Generalife and Alhambra are connected by a very valuable avenue of cypresses.

4. The tree in Renaissance, Baroque, and English gardens.

In order to fully understand the different elements characterizing the garden of the Renaissance and, consequently, the peculiar use of trees in the architectonic design, a great importance is held by the work entitled *Hypnerotomachia Poliphili*, by the Dominican Francesco Colonna (Tagliolini, 1991). It describes the love dream of Polyphilus and Polia, transported to the island of Citera. The arrangement of the island and the setting of the plants, strictly managed by perfect harmonical and geometrical rules and relations, constitute the example of the garden during Humanism. The amphitheatre of Venus, placed in the middle of the island astonishes Polyphilus, since on the top of the steps, instead of a colonnade, like in the classical theatre, there are "trees geometrized" by the topiary art and cypresses that create interlaced arches of a vague islamic taste.

The perfection of Renaissance gardens and their strong character of permanence derived from a recurring use of evergreen trees and shrubs, such as cypresses, holm oaks, pines, boxes, and citrus trees grown mostly in vase with an ornamental aim. A great fame was acquired by the "*Garden of Hesperides*" where the golden pomes and the fruits bestowing eternal youth and immortality were kept. A contribution to the cultivation of new tree and shrub species arrived during the XVIth century from the development of botanical sciences that led to the birth of tree and shrub collections inside botanical gardens, among which the Garden of Pisa, founded in 1543, and that of Padua and Florence created in 1545 and 1550, respectively. The studies of agronomy permitted to improve new short growth habits for fruit trees, such as apple, pear and apricot trees (Pozzana, 1990). A precious witness of the fashion prevailing at that time to prune the fruit trees in a dwarf shape is contained in the work by the scholar Agostino del Riccio entitled "*Del giardino di un Re*": "*Now I have in front the garden of dwarf fruit trees, and one may say unmistakably that it is the pleasure of the ladies and their young daughters, who often go into a small garden with dwarf trees for their retreat and amusement, and they enjoy themselves indeed, especially when the small fruit trees are full of their pomes of different kinds, and sometimes with great taste they take them with their soft hands white like snow and pleasantly offer one to the other. None the less pleasure has the King, when also he enters such a garden for his recreation and walk. But in order to make these dwarf fruit trees be more desired by everyone and to enable them to make them, I will describe them lovingly and nobody will overcome me, unless with a good description in excellent style*".

Also during the XVIIth century the scientific literature on botanical themes acquired a remarkable importance thanks to several Authors who gave a precious contribution to the knowledge of tree species, as in the case of the scholar Francesco Pona. The XVIIth century garden did not abandon the axial composition ruled by geometric and mathematic principles, but it widened, almost assuming the feature of a "*park–wood*", joining ideally with the surrounding land also because of the lack of a precise definition of its perimeter. The great season of the Baroque garden had its major bloom in France after the first half of the XVIIth century. Parterres, orchard theatres, plants reduced to geometrical shapes, and large arboreous masses, with an evocative chromatic effect, composed the typical scenery of the French garden (Mosser and Teyssot, 1990). Compared with the Italian one, there was a greater presence of woods and thickets, made of medium and tall trees, with principal and secondary avenues having a simple or double set of planting. Plant architecture achieved, in the design of the XVIIIth century garden, a kind of micro-urbanistic complex, characterized by a dedalus of walks and spaces, next to wide walls of green obtained with yews, cypresses and laurels (Vercelloni, 1990). Besides such evergreen species, typical of the topiary tradition, the French garden employed also a considerable variety of wide canopy deciduous trees, such as hornbeams (*Carpinus betulus*), elms (*Ulmus campestris*), beeches (*Fagus sylvatica*), maples (*Acer campestre*), lindens (*Tilia cordata*), plane trees (*Platanus x acerifolia*) and horse chestnut trees (*Aesculus hippocastanum*). The palisades were created mostly with beeches and maples, while the thickets were made mainly by oaks (*Q. robur*), beeches and lindens. Box remained the shrub species preferred for the parterres.

During the XVIIIth century, the transition took place from the garden of strictness and discipline of geometrical shapes, pertaining to the classical typology, to more various and free settings, that led to the birth of the landscape garden. The trend towards an always more romantic and open expansion of the natural element reached its highest expression in the work of two famous landscapists, Lancelot Brown (1715-1783) and Humphrey Repton (1752-1818). Compared with the rigid planning of arbored avenues and of symmetry axes and with the neat definition of the garden limits, the use of tree and shrub species in more disengaged shapes and groupings was promoted, as well as meandering and irregular walks and the abolition of the garden margin with the aim of a total integration of it with the surrounding landscape. In Italy, at the beginning of the XIXth century, Count Ercole Silva, an expert botanist, revisited the Italian tradition according to the general lines of the English school and published his renowned treatise "*Dell'arte dei giardini inglesi*": a work that influenced considerably Italian designers during the whole century. In the course of the XIXth century the interest towards exotic species grew remarkably; many of them were trees, that enriched European and English gardens, in particular, with shapes and colours, thanks to the collecting work in all explored continents by the famous "plant hunters", who were active above all in the United Kingdom.

5. The tree in town avenues and parks

After the appearance of new requests linked to the phenomenon of urban expansion during the XIXth century, the concept of urban green established itself gradually. In the Viennese reality, thanks to the demolishment of the walls, the rings could be built: arbored avenues that could recreate the continuity between the historical centre and the town in expansion. Also the city of Lucca, following the cultural models of the time, effected the transformation of town walls from a defensive purpose to a place of walks with the vast realization of arbored avenues. In France, thanks to Napoleon IIIrd, a broad establishment of parks and green public areas in the towns had begun. In Paris, in particular, through the demolition of the historical city, the great boulevards were created: arbored avenues able to connect the greatest celebrative points of the city, planned for walking. They were composed of two rows of trees, mostly plane trees (*Platanus x acerifolia*), next to a zone for pedestrians in the middle (with kiosks and areas for music) and the route for carriages.

The realization of great parks received, furthermore, a meaningful impetus from beyond the ocean, the most famous example of which is represented by Central Park in New York designed by Frederick Law Olmsted, following the principle of "naturalization" of the city, thanks to broad plantings of trees, aiming at a recreating a kind of urban wood. Such a project criterion, conceived for the urban green, assumed the dignity of a real scientific discipline in Anglosaxon countries, known as ***urban forestry***, so to indicate that some green areas can be proposed like oases of rurality inside urban habitats.

6. The tree in Piedmontese parks

In Piedmont the most important realizations until the middle of the XIXth century were represented by the gardens of the royal palaces, followed by far, by size and care, by those pertaining to villas and palaces of the nobility, influenced by court gardens and often made by the same creators. The long season of the garden in Piedmont found an important reference point in the two famous figures of André Le Nôtre and Michel Benard. Le Nôtre, the celebrated designer of Vaux-le-Vicomte, Versailles, and Chantilly, was called in 1669 and then in 1697 to give a new shape to the Savoyard gardens. The first plan, designed after a visit to the site, was required by Savoia Carignano for the park of the castle of Racconigi (Roggero Bardelli *et al*., 1990). The project drawn by Le Nôtre was characterized by a green setting according to geometric modules in which, on a slightly degrading plain around the castle, flower beds, grassy parterres, and water pools are displayed. At the end of the median axis of the park, Le Nôtre placed a wide circular basin and behind it a continuous row of trees, so to underline an arrangement of the space to infinity. Still today several of the entrances of Piedmontese noble villas are characterized by the presence of great shady alleys of poplars (*P. nigra* L.), elms or hornbeams, creating high green side walls (Accati and Devecchi, 1996). In the middle of the XVIIIth century the French taste had settled down and Charles Emanuel IIIrd entrusted Michel Benard with the management of the crown's gardens; he was immediately engaged with the realization of the park of Stupinigi, inside the perimeter already defined by Juvarra. The great axis of the entrance, as a major axis, with a strong value in the design of the territory, permitted to join firmly the Palace to Turin. A great importance was, In particular, the use of Lombardy poplars (*Populus nigra* var. *Italica*) was of great importance to underline the design on the land thanks to the roads around the Palace complex. A precious testimony of this is provided by the drawing by Ludovico Bo "*Pianta* *della fabbrica da costruersi in contorno delle albere pine […]* " of 1779 (Mondini *et al.,* 2003).The diffusion of the landscaping style in Piedmont was due to Giacomo Pregliasco, a scene painter and urbanist who started the first transformations of Racconigi since 1787, with interesting insertions in a picturesque style. The complete transformations according to the romantic taste of the age was accomplished by the famous German landscapist Xavier Kurten, the author of the renewal of taste in the great number of Piedmontese gardens of the first half of the XIXth century (Devecchi, 1999). Kurten's work had as main points the "**isolated tree**", shrub masses and thickets, groups of trees in circle, the lake with irregular sides and a small island, the big lawn, the small hill, and sometimes a small temple. In his several gardens the perspectives can be easily identified and represent the fundamental elements of the theory of the landscape garden and of the picturesque garden fashionable at the beginning of 1800 in Italy and in Europe. At Racconigi, thanks to Kurten's work, the park received a remarkable enrichment of vegetation, also of trees, so to comprehend many specimens of plane trees, maples, horse chestnut trees, birches, hornbeams, next to elms of the Caucasus, Judas tree, liriodendron, etc. The perspective of arbored avenues and long extents of lawns was a common feature also in Kurten's projects for the gardens of the numerous Piedmontese noble residences, such as those of San Martino Alfieri (Accati and Devecchi,1994; Accati *et al.*, 1999), Sambuy, Monticello, Pralormo, Santena, Villa Il Torrione, Sommariva Perno, Sansalvà, Castagneto Po (Salina Camerana,1994). At Pralormo, in particular, he took the starting point from the natural scenery of the Alpine chain to propose wise cuts between the trees so to enjoy some preferential views during the walks in the park.

The ideal route among the most representative figures who worked in Piedmont cannot exclude the most renowned Italian landscapist of the past century: Pietro Porcinai (1910-1986). The modernity of Porcinai's project solutions had a point of force in the attention towards themes of ecology, in the research of a privileged relation with nature, through a constant use of vegetation, but also of natural materials, such as wood, stone, and water to mask the artificiality of architectonic manufacts. The simple and linear design of Porcinai's gardens found a cue also in the choice of the plant species with a preference for evergreens, such as olive trees *O. europaea*, cypresses (*C. sempervirens)* and holm oaks (*Quercus ilex). Rhus typhina* was a beloved species much used by Porcinai, who exploited the sculptorial and sinuous aspect of its trunk and the particular projection of the canopy that always hides possible constructive elements. In a writing by Porcinai of the '50s, starting from correct considerations of a phytosociological kind, he confirmed the concept of harmonic exaltation of shapes and colours of the trees: "*It has been discovered that when the plants live together in full associative harmony (botanical harmony) also their habitus and their shape express a harmonic perfection: and such a harmony involves of course also their colour. The most perfect chromatic relations are attained, therefore, with plants that are botanically in harmony*". Porcinai understood the importance to propose gardens, not only as places of aesthetical enjoyment of nature, but as realities where to prove the pleasure of the knowledge of plants and the meaning of the different agronomic practices. Interesting examples to this regard are the "orchards" rich of decorative elements and full of a thousand year old agronomic culture, that were proposed on several occasions by Porcinai, such as Villa Maggia on the hills of Turin. The fruition of gardens was encouraged by Porcinai also thanks to decoration elements, such as a pool, a gazebo, a barbecue, and tennis and bowls courts, included tactfully in the garden's structure, often screened with hedges of cypresses *C. sempervirens*, hollies *Ilex aquifolium*, laurels *L. nobilis*, oleasters *Elaeagnus pungens*, hawthorns *Crataegus spp.*, etc., and groups of shrubs, among which, for instance, butterbushes *Pittosporum tobira*, and boxes *B. sempervirens* (Accati e Devecchi, 2000). A further remarkable example is represented by the garden of Cà Gianin at Trivero in the province of Biella, that assumed, according to Porcinai's and the owner's idea, the meaning of a botanical collection, where interesting tree species are required, having pleasant shapes, colours and seasonality of blossomings. For example, besides the specimens of local or naturalized species of that area, such as beech, sweet chestnut, and birch, a broad use of evergreen species was made, such as *Chamecyparis lawsoniana*, together with different species, sometimes poorly known, of the genera *Picea*, *Abies*, *Juniperus*, and *Thuja*. These were planted with a great number of shrubs, above all acidophilous species, such as azaleas, rhododendrons, *Pieris*, and hydrangeas, that Porcinai requested expressly, probably after having seen them in full vigour in the Burcina Park.

7. Conclusions

Since ancient times the tree has held multiple meanings, also ritual and religious ones. Its presence in a garden has always represented an element of capital importance for the arrangement of a green area design, even if having diverse shapes and purposes. Therefore, both plant architectures and monumental trees of a park and a garden, as they are in the landscape, must be considered a precious historical and cultural heritage. So an always greater attention and sensibilization of people is more and more needed as far as the importance of safeguarding trees and defining correct management terms are concerned, above all referring to the specimens of monumental interest, with the aim to prevent the loss of a patrimony of exceptional value and not only naturalistic value.

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Fig. 1 – An interesting example of the use of trees for creating avenues orienting the views on the most valuable architectonic elements of the garden [Sans Souci Palace – Potsdam]


2a


2b


2c


2c

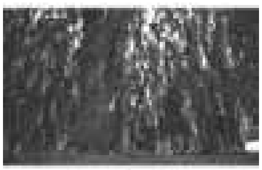
Fig.2 - The use of garden trees in an architectonic shape constitutes an element of great value and recurrent interest in the history of garden art [(2a) SchÖnbrunn Castle - Vienna; (2b) Het Loo Castle – Apeldoorn; (2c) Sans Souci Palace – Potsdam; (2d) Hidcote Manor garden – Gloucestershire]

Fig. 3 – View of a XIXth century print depicting a monumental oak in the park of the Castle of Villastellone, the monumentality of which represented at that time one of the most important attractions of the park


4a


4b

Fig. 4 – Trees represent a precious opportunity of putting colours inside a park and a garden, coming from the foliage and, even if more transient, from the blooming [(4a) *Prunus pissardii*; (4b) *Liquidambar stiracyflua*]


5a


5b

Fig. 5 – The very wide range of shapes and architectures of tree canopies has always been exploited by park and garden designers to evoke different and particular sensations and moods in the observer [(5a) *Fagus sylvatica* cv 'Pendula'; (5b) *Salix babylonica*]

THE TREES OF THE BOTANICAL GARDEN OF PADUA UNIVERSITY

P. Giulini
National Committee for the Historical Garden of the Ministry of Arts and Cultural Property

Introduction

The Botanical Garden of Padua (till 1591 was called *Hortus Medicinalis*) can boast of being the most ancient university botanical garden in the world. It is still in the same place and has the same functions: didactic, of research and of acclimatization of the plants, the latter ordered by the University, just for the commercial advantages which the Republic could derive from the botanical knowledge guaranteed by the garden.

To understand the importance of its foundation, preceded chronologically only by Matteo Selvatico's medicinal garden of the Medical School of Salerno (Giulini, 1992) and by the one of Pisa, we need to immerse ourselves in medieval knowledge when the Church catechized that just God, during the creation, had granted to natural matters the capacities of treating the body diseases, induced by those of the soul: sins. As a consequence of the Confession, therefore, the sinner's body was healed thanks to the medicinal herbs received from the priest and had, only then, the certainty of having been absolved even in Heaven from the sins committed.

From the threshold of the second millennium the treatment of the body and that of the soul were progressively separated. The Padua School gravitated under the strong and attentive leadership of the Venetian Republic and under the flag of Saint Mark, while the power of the Church was definitely limited. As a result the Scholars, only in a very small part Venetians, streamed into the Padua Athenaeum especially from Central Europe and from the Balkans where for many years that contention the Church called "heresy", and elsewhere was called "Reformation", had been spreading more intensely.

Next to the "*Tacuina sanitatis*" from the end of the fourteenth century the herbarium manuscripts made by the amanuensis became more and more frequent as did the treatises of the preparation of medicinal herbs not only in Latin after the invention of the printing movable types. The same iconography had a strong evolution leaving more and more the fantastic and superstitious aspects of the plants to look for, instead, the real and salient details, to promote their identification. Thus, the time was ripe to deal with the teaching of the simples (*Lectura simplicium*), that is medicaments of natural origin (prevalently vegetals) and so called because from the union of the properties of each one, the compound was extracted. Padua had its first professorship in 1533 with Francesco Bonafede from Padua. He gave his lessons "*ex cathedra*" in Latin, so all the Scholars understood, despite the different languages of provenance. However he realized how difficult it was to be able to understand each other about the plants because already in Latin it was difficult to identify every species with a unique European name and, above all, know what it interfered in the absence of a sample. Therefore he sent a request to the Venetian Republic on behalf of the Professors and Scholars to grant permission to create a "*Horto Medicinale*" near which lessons of "*Ostensio simplicium*" could be held, taking the Scholars directly to the heart of the subject. After a three-year wait the government of the Venetian Republic adopted the request on 29th July 1545. By 1546 the Garden was ready for its activity, rich in vegetals that in those times according to tradition, had healing powers. Science, however, was already ready for the interpretation, the verification and discussion of the ancient Authors' authority.

The space destined to the garden was loaded with history and traditions both Roman and monastic; just outside the medieval ring of walls, it was for some years surrounded in the bastioned ring of walls. Its creation was charged to the builder Andrea Moroni from Bergamo, who in those times was completing the most important public and religious buildings of the Renaissance town. The project, said to be conceived even before July 1545 by Daniele Barbaro and Pietro from Noale (Guazzo, 1546), was a "*summa*" of architectonic perfection in the spirit of the "*Hortus conclusus*" of the medieval tradition and whose size depended only on the available shape and space. The collaboration between the rising Garden and the adjacent Benedictine Monastery, former owner of the land, was at the beginning so strong that the Head typesetter of Saint Giustina was free with his advice and information.

The ligneous plants

Recently studies have been carried out on some drawings dating back to the decades following the foundation (Terwen-Dionisius, 1994); in them the names of the plants are quoted in their first position. Thanks to these lists, brought up to date in the botanical nomenclature by Andrea Ubrizsy Savoia (1995), we can assert for sure that, already some years after the foundation, numerous shrubby and arboreal plants, nowadays considered autochthonous, but prevalently coming from areas commercially influenced by the Venetian Republic, had been placed inside the *Hortus conclusus*. Among these: the silver fire (*Abies alba* Mill.), the Italian cypress (*Cupressus sempervirens* L.), the maritime pine (*P. pinaster* Ait.), the savin and prickly juniper (*Juniperus Sabina* L., end *J. oxycedrus* L.), the true laurel (*Laurus nobilis* L.), the mulberry (more probably *Morus alba* L.), some oleanders (*Nerium oleander* L.), the cork oak (*Quercus suber* L.), the wild service tree [*Sorbus torminalis*(L.) Crantz], the common spindle tree (*Euonymus europaeus* L.), the bladdernut (*Staphylea pinnata* L.), the white poplar (*Populus alba* L.), the golden chain (*Laburnum anagyroides* Med.), the lote tree (*Celtis australis* L.), the chinaberry (*Melia azedarch* L.), the date plam (*Diospyros lutus* L.), and several fruit-bearing trees as pear and plam trees (*Prunus L.* sp.pl.). Few plants are not mentioned and many others, even exotic, are added in the list of those cultivated in 1591 (Cortuso), list commented and identified according to the present nomenclature by Elsa M. Cappelletti(1995). For instance, among the arboreous trees there are planted out numerous conifers [*Juniperus communis* L., *Picea abies* (L.) Karst., *Larix decidua* Mill., *Taxus baccata* L., *Pinus pinea* L.), the oak-trees (*Quercus ilex* L., Q. *robur* L., Q. *macrolepis Kotschy*, Q. *coccifera* L., Q. *petraea* (Matuschka) Liebl.], other poplar-trees (*Populus nigra* L., *P. tremula* L.), the ash-trees (*Fraxinus ornus* L., *F. excelsior* L.), the maple-trees (*Acer platanoides* L., *A. campestre* L.), the European field elm (*Ulmus carpinifolia* Rupp. ex Suckow.) and other fruit-bearing trees enrich the list.

To the two lists, mentioned as the most ancient, reporting the trees planted in the *Hortus cinctus*, successively 13 more followed up to 1842. From that date until 1938, there followed other 45 *indices seminum* (Gola, 1947) and later 21 more from 1947 to 2004 (Botanical Garden's Library Archives). These catalogues are the list of the species whose seeds are proposed for exchange with other botanical Institutions. However the *indices* don't represent the list of all the trees growing in the Garden at a certain date, but only of those offered for seeds exchange. For more than ten years the *indices* also have included the seeds of dying out species, not only those picked up in the Garden but also in the surrounding areas. After four centuries no trace remains of the above-mentioned shrubby and arboreal plants. However we can't leave out two worth mentioning plants which date back to that time. Northward, outside, but close to the boundary wall, there lived till 1984 a white-flowered, well grown-up chaste-tree (*Vitex agnus-castus* L.) with large foliage and vast bloom. After 1975, unfortunately, a fungus infection to the conductive vessels little by little made it die. The documentation which names it in 1550, the anomalous position in which it lived and the suspected aphrodisiac properties marking this species make many scholars conclude that this tree pre-existed the Garden's foundation and it could possibly be a *trait-d'union* with the medicinal Benedictine Garden. The rests of this chaste-tree are still preserved in stores, expecting to be shown soon.

Nowadays in the Garden, the oldest living tree is a dwarf palm or European palm-tree [*Chamaerops humilis* L. var. *arborescens* (Pers.) Steud.] which dates back to 1585. This palm, already bicentenary, was seen and studied by Johan Wolfgang von Goethe, during his journey in Italy on 27th September 1786. The hypotheses obtained from this research were published later in 1790 in *Die Pflanzen Methamorphose* thanks to which our palm-tree was celebrated through the following centuries by the visit of thousands of Germans, as if going on a cultural pilgrimage, so much so that it was no longer the dwarf palm tree of the Botanic Garden but Goethe's palm tree.

For centuries, in winter, it was protected by the movable store wooden structures in order to avoid that this specimen, which had much grown and become historical not only because of its age, might succumb to an exceptionally severe winter. In 1874 it was protected by a larch greenhouse built *ad hoc* and replaced between 1935 and 1936 by another structure of reinforced concrete. As the palm tree has always lived in a a favourable climate, it is still very luxuriant and is provided with many stems, some of which are eight metres high. The tree doesn't suffer from any pathology. Relatively nearer to us in order of time, since 1680, outside the round enclosure, there has been living a western huge trunked largely hollowed plane tree (*Platanus orientalis* L.). On the basis of a XIX century water-colour we learn that, at the date of the picture, the trunk was still healthy and solid but had a large scar crossing it through from top to bottom. The wound cause can be traced back to a thunder-bolt, however a rot [*Ganoderma applanatum* (Fries ex Persoon) Pat.] hollowed the trunk out within a century. In spite of the impressive cavity, the tree, regularly pruned in order to avoid an excessive growth of its foliage and to grant a better stability, is living quite well and, thanks to the treatments dating back to about 40 years of "carbolineum" diluted in petroleum paintings, its infection has receded so much as not to have produced any more fruitful bodies for almost 15 years. Two more over centenarian trees live inside the enclosure. A male maidenhair tree (*Ginkgo biloba* L.) planted out near the corner of the fourth part North west (Spaldo as it was called in old times) now called "Quarto del Ginkgo" dates back to 1750. It is therefore the oldest specimen of this species still living in Europe. Half century ago in one of its low branches was grafted a female branch which every year produces quite a lot of fertile semen. This fragile wooded living fossil has lost for over one hundred years its straight bole owing to the crashes caused by violent rain storms, yet its scars are quite healthy with a large healed callus. A bull bay (*Magnolia grandiflora* L.) is living near the centre of the fourth part in the South west side. Some sources date it back to 1756 while others to 1786. Anyhow we are dealing with one of the oldest plants in Europe which, owing to its position, has never been able to develop itself properly and has shown recently important foliage thinness and a less flower blooming.

The radical apparatus is superficial because the soil is very heavy and asphyctic. This very situation must be the main cause of its limited growth. It is one of the first plants in the Garden infected by the honey fungus (*Armillaria* sp.) two decades ago at least. Various areas of ceased growth and of consequent decortications such as, on the other hand, mushroom clusters are present, late in Summer, on the infected roots. On the margins of decorticated areas the reaction callus is always very limited, in spite of that, the whole plant is still alive. Up to now no drastic intervention has been made partly because it is justly believed that inside the *Hortus conclusus* arboreal species are not to be planted out, partly because to cure this plant all the arrangement of the Fourth part which is entitled to this magnolia, should be entirely upset, and thirdly because the intervention has seemed to us to be *in extremis*. Outside the surrounding wall a very tall black pine (*Pinus nigra* Arn.) dating back to 1772 is still perfectly luxuriant. It is the only plant still living which surely was part of the *Arboretum*, conceived, carried out and corrected by Giovanni Marsili (1727-1795, Prefect of the Garden from 1760 to 1794). This particular *Arboretum*, few years later, was largely imitated by many other Botanic Gardens. The certainty about the age of the plant doesn't come only from XVIII and XIX cartographic documents but also from a check through a dendrochronological study (Zennaro, 1996-97) made on numerous healthy subjects present in the site. Again in the *Arboretum* context there lives a holm hoak (*Quercus ilex* L.) dating back to the first lay-out.

Unfortunately an old devastating caries has transformed it into an empty trunk united to the ground through stilts which prevents us from ascertaining its age. As to Marsili's plan it had a short life, both because the Holm hoak was planted a order of a fixed plantation and also owing to a terrific hail storm on August 26th, 1834 which destroyed the whole Garden and its greenhouses [de Visiani (in Paganelli, 1995) relates that Bonato, at that time already very old, almost died of broken heart]. Only few more competitive and strong subjects survived and little by little they were substituted by other Prefects who come later and who planted out new trees according to the growth size of any single species following Marsili's specific indications: especially Giuseppe Antonio Bonato 1753-1836, Prefect between 1794 and 1835 and Roberto de Visiani 1800-1878, Prefect from 1836 to 1878.

Just from the beginning of the XXth century the *Arboretum* around the walled Garden has extended and renewed itself, but above all, it has filled with new arboreous trees whose seeds came from the Far East and America. Some deciduous plants are important for the date of their arrival: plants such as *Magnolia* L., various walnut-trees as *Juglans* L. & *Carya* Nutt, two bull bays at the entrance of the Garden which date back to 1801 and have always exercised a great effect on visitors. Even the landscape of this vast area changes according to the fashion of the English Garden with no longer rectilinear tracks and with the raising at the South east edge of the Garden of a panoramic hill overlooking the surrounding gardens, kitchen-gardens and the orchards. In 1828, close to the panoramic hill, the first deadar [*Cedrus deodara* (D. Don) G. Don] was planted from seed in Europe. This date, reported in literature, is the true one attesting the arrival of this species in Europe (Maniero, 2000). On the western Garden edge, along the bank of Alicorno canal, near the border, a row of bald cypress (*Taxodium distichum* (L.) Rich.) was planted. They are still living but have been brutally cut on two following occasions owing to wrong interventions of the neighbouring Jesuits (from dendrochronological researches all the trees present very deep hart rots). In the second half of the nineteenth century, also some species of Japanese cedar (*Criptomeria japonica* D. Don) and California redwood [*Sequoia sempervirens* (D.Don) Endl.] were planted out. Certainly they hadn't a good growth owing to the soil nature and climate, nevertheless this plant is still alive and thriving notwithstanding its stability problems.

The preservation of historical species

The preservation of species of particularly historical importance create many problems of maintenance, especially for large plants in such a narrow space (the Garden of Padua has had till now an area of little more than 2,2 hectares). Moreover the urban, more and more polluted climate and the building "siege" all around cause serious problems during the summer down-pours.

The exemplars bent by the wind or by crashes of fallen trees are steadily anchored to close plants or plinths on the ground. A similar thing executed on some branches of large size. The anchoraging grants not only an elastic support to the protected subject but also avoids that a sudden crash may cause damages to the people working there (technicians) and visitors. Therefore besides curative pruning on crashes and disinfection of wounds, necessary to grant the health of our plants, we must also operate on contraction pruning carried out with the utmost care and attention so as to lengthen these specimens' lives, which are often in a natural phase of aging but above all in an ecologically anomalous environment as to their original climate.

Tree climbing modern technique helps us greatly especially in our space where the extensible jibbed cranes have an overwhelming impact on the ground owing to their weight and the scarce manoeuvrability of the cab among the foliage. Dendrosurgery is rarely used because constant checks allow us to-day to intervene promptly on the saprophyte attacks.

In the past the use of "carbolineum" solved many problems, yet the results have not always been positive in fact we have lost quite a lot of specimens, exotic for the most part, owing to a basal stem rot (the empty spaces are not noticed by visitors, but for those who have always worked there and lived in and for the Garden for a long time, they are and will always be open wounds). Over ten years ago the news that a residential building, bordering the Garden, was being built against any legal orders and breaking the low, spread far and wide throughout the world.

For four months the surface water-bearing stratum was dried up, upsetting, in so doing, the whole site where an underground garage 10.000 m^2 large was built.

The opinions on the real responsibility of this crime for the damages caused to the Garden are still much debated and perhaps almost impossible to demonstrate owing to timely interventions. I myself am a strenuous supporter of the intransigent wing and believe that the root rot which was modestly present in the past, is now the consequence to the present hydro-derangement.

The University Committee promptly built an irrigation plant-system at their own expense. However the going up and going down of the water are two physiologic situations quite different if referred to plants with a physiologic precarious balance.

Since 1996 University Botanic Pathologists have planned a research with a view to limiting the root rot diseases by removing less valuable vegetable subjects, especially those more struck down by this illness and taking away the most infected soil and treating the rest with fumigations. The two bull bays which stand at the entrance have been firmly anchorated by strong supports. Their main roots have been laid bare, the soil has been substituted with expended clay and *Trichoderma* sp. has been inoculated as a powerful antagonistic to *Armillaria* sp. drug (Zuccoli Bergoni 2002-2003).

Conclusions

From what has been said the importance of historic tree conservation is evident. Historic trees are the witnesses of man's life and of his landscape. Saving them depends almost always on few expert's responsibility. Destroying them has always depended on many people's interests and profits.

For a Botanic Garden the choice lies on the engagement to protect all subjects to postpone their death which is unavoidable anyhow.

As to Historic Gardens, besides fighting in favour of their preservation, we must accept the conscious choice of a renewing life because priority utterly concerns the vegetable world as a whole.

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AGING PROCESSES IN TREES AND THEIR RELATIONSHIPS WITH DECAY FUNGI

D. Lonsdale
33 Kings Road, Alton, Hampshire UK
formerly of Forest Research - Alice Holt Research Station

Abstract

The development of physiological dysfunction within the central wood of old trees is a major feature of the aging process, together with a tendency to become unable to maintain a complete outer shell of functional tissues. Species-related differences in the durability of the dysfunctional wood are of key importance in the ability of trees to live to a great age. Due to the differing abilities of various decay fungi to colonise functional and dysfunctional wood and to cause its degradation, the longevity of a particular tree depends partly on the particular fungal species which colonise it.

Introduction

The developmental characteristics of a particular species play a major role in determining its aging processes. Most tree species have an indefinite pattern of growth, as they produce new shoots, roots and radial increments of wood and bark throughout their lives. On the other hand, organisms with a definite growth pattern (e.g. coelomate animals) usually have a far more limited potential for growth after reaching maturity. Thereafter, their growth usually involves only the repair and replacement of worn out or damaged cells, although some species may gradually increase in size throughout life. The repair of existing body parts cannot indefinitely maintain full function, so that aging and death eventually occur. In contrast, the ability of most tree species to form a new 'living outer shell' in each growing season could in theory be regarded as allowing some potential for immortality. In practice, however, a tree tends to have a life-span which, although less pre-determined than that of a human being, falls within a range typical of its species.

Although trees are fundamentally different to organisms with a definite growth pattern, they share some processes of aging with them. These involve the aging of cells that normally survive for a number of growing seasons, and perhaps also the accumulation of 'errors' within the genome of meristematic cells. Despite some indications that such aging may have physiological effects on the newly formed tissue of old trees of some species, there is no reason to believe that it limits their longevity. Instead, the main processes that limit longevity are related to the accumulation of old, dead tissues within the tree. In particular, the older layers of sapwood lose their water-conductivity and their parenchyma cells eventually die. They are then described as being physiologically dysfunctional (or just 'dysfunctional' for short) even though they remain structurally functional.

The reasons why an increasingly large core of dysfunctional wood tends to limit the lifespan of a tree include the following:

1. the progressive thinning and attenuation of the radial increments of new wood and bark around a core of increasingly large girth;
2. the development of decay within the increasingly large and decay-prone dysfunctional core of the tree, with two possible consequences: (a) the physical break-up of the tree and/or (b) the killing of sapwood and bark by decay fungal species with an ability to overcome the defences of functional tissues;
3. the alteration of the tree's growing conditions due to its continued growth, including (a) the depletion of mineral nutrients locked up in its wood and (2) alterations in the moisture content and aeration of the soil beneath an increasingly large and dense rootplate.

The above three factors will now be considered. Additionally, the maintenance of functional tissue within the main stem will be considered in relation to the retention and growth of branches.

Change in ring width with age

During its early life, a tree colonises the space available to it, both above and below ground (Raimbault, 1995), as determined by the environmental conditions and the tree's inherent physiological characteristics and growth potential. During this formative or 'exploratory' phase, the volume of successive radial increments tends to increase, because the crown volume and hence the photosynthetic capacity of the tree is increasing (White, 1998). Eventually, however, the crown approaches its maximum size, at which stage the tree is regarded as having reached maturity. On this basis, White (*loc. cit.*) recognises three phases in the life of a tree: formative, mature and 'senescent', although it should be noted that the term senescence is perhaps unsuitable to describe an organism that still has considerable vitality and thus shows re-iterative growth in between episodes dieback (Raimbault 1995). Also, it should be noted that Raimbault (*loc. cit.*) has recognised a number of intermediate stages, according to changes in the crown architecture.

The increase in diameter of the woody cylinder during the mature phase causes the increments of new wood to become progressively narrower. This happens because the crown of a tree reaches a maximum size in maturity and for a long period thereafter tends to produce the same average amount of photosynthate each year, albeit with fluctuations due to weather and defoliation events. The radial increments of new wood and bark therefore have about the same volume in successive growing seasons, but are spread out over an increasing girth (White, 1998).

White (*loc. cit.*) suggested that radial increments can continue to form, despite becoming progressively narrower, until as many as 20 xylem increments make up one centimetre of radial growth; i.e. the average incremental width is 0.5 mm. On the basis of White's model, a specimen of *Quercus robur* or *Q. petraea*, growing under the most optimal conditions available in Britain, could theoretically maintain a complete outer 'shell' of new sapwood and bark until beyond the age of 4000 years (Fig. 1), by which time its stem would be almost 8 m in diameter. On the same basis, a specimen within a woodland would reach this stage at about 1100 years of age, when its diameter would be nearly 2 m.

Although radial increments could in theory continue to form for centuries or even millennia, it can be postulated that this process will eventually be perturbed because the increments will become so narrow and attenuated as to have insufficient conductive and storage capacity to maintain a full crown. It can further be postulated that a process of negative feedback will then ensue; in other words the dieback of the crown, due to insufficient physiological support from the vascular and storage system, leads to a reduction in the supply of photosynthate to the cambium, which in turn leads to an acceleration in the narrowing of new radial increments; more than would be expected purely because of the geometrical effect of increasing girth. When a tree enters such a state, it shows characteristics (especially episodes of dieback) which are regarded as typical of the declining phase of its life.

Loss of continuity in the outer shell of functional tissue

Observations of ancient and veteran trees show that discontinuities eventually tend to develop within the outer shell of living sapwood and bark. These usually take the form of dead strips of tissue, subtended by individual branches or roots which have died back or broken. In some cases, such strips may occupy a greater proportion of the tree's girth than the adjacent living tissue (Fig. 2). It is well known that the death, breakage or severance of branches or roots can lead to the dieback of strips of associated cambium within the main stem, but it is also possible that dieback could be initiated within the cambium, leading to a situation in which a branch or root becomes deprived of a connection with new sapwood and phloem and then declines. Although the exposure of dead tissue at the surface may increase the rate of decay, the restriction of cambial growth to discrete strips around the circumference of the stem may be seen as a survival strategy for a tree that can no longer maintain a complete functional shell of sapwood and bark.

Dysfunction induced by injury

A completely intact tree has a covering of bark over its entire woody cylinder and a covering of epidermis or other protective layers over its non-woody extremities. In practice, virtually all trees suffer some degree of injury, which exposes the underlying tissue to an altered environment. In particular, exposed sapwood is often subjected to desiccation and a consequent increase in gas exchange (Boddy and Rayner 1983). In many cases, there is also a direct severance of conductive pathways. These changes lead to a loss of physiological function in the affected tissues, often culminating in the death of tissue within discrete anatomical compartments (Shigo and Marx 1977). In old trees, such changes are of course accompanied by processes of aging which may lead to dysfunction in their own right. (The term 'veteran tree' is sometimes used to describe a tree of any age that has survived the vicissitudes of life, irrespective of whether it is ancient or has merely undergone much injury or stress.)

In extreme cases, trees can become entirely dysfunctional as a result of severe injury and thus die. This is particularly likely to happen in the case of ancient trees which, have a very narrow and attenuated layer of functional xylem and phloem, overlying a large mass of older dysfunctional wood. It is even more likely to happen if the tree species is one that lacks a durable heartwood, since rapid fungal colonisation of the exposed dysfunctional core can often spread to the overlying sapwood. This will be considered below in relation to the colonisation strategies of different fungi.

Even if the entire crown of a tree is removed, this does not immediately cause the death of tree, but it does destroy all conductive function within the entire cross-sectional area of wood in the stem. Also the removal of foliage deprives the tree of its photosynthetic capacity, so that there is a severe drain on carbohydrate reserves and a consequent impairment of active processes in the formation of defensive barriers (Shigo and Marx 1977). Also, there is much observational evidence that sapwood tends to become dysfunctional if becomes isolated from the continuous network of living cytoplasm (the symplast) which normally exists throughout the root and shoot systems.

As mentioned above, a tree with large, exposed areas of dysfunctional tissue can survive, provided that its main stem retains functional strips of wood and bark. Such strips represent living channels between the foliage and the tips of the roots and they appear to be of key importance in the survival of ancient trees (Lonsdale 1996). Such trees may need to be managed so as lighten a load of heavy branches that would otherwise fail and cause the break-up these trees. In doing such work, it is recognised that living connections should be protected, which can be achieved by retaining some of the branches. Some past attempts to manage neglected ancient trees in Britain led to excessive wounding and hence to the severance of all the living channels and in many cases death of the trees concerned.

The risk of ancient trees dying after major branch breakage or severance appears to be increased by drought stress, leading to severe moisture loss from the exposed wood. Direct heating of the stem, and perhaps also of the ground surface in the rooting zone, due to the removal of shade appears to have a similar effect (E. Green, personal communication). On the other hand, excessive retention of shade can inhibit the development of healthy new shoots. The extent to which shading needs to be reduced or retained depends partly on the tree species concerned; i.e. whether it is shade-tolerant. The local climate, the time of year and the soil conditions are important factors in this respect.

If a tree loses most of its crown, its continued survival depends very largely on its ability to form new branches and foliage. It has been observed in Britain that many of the trees that have lived long enough to be considered ancient have, as individuals, a strong tendency to produce epicormic shoots, especially in the case of *Quercus robur* and *Q. petraea* (Fig, 3). If a branch breaks or is removed, such shoots can rapidly develop into new branches, thus maintaining physiological function within their associated parts of the main stem. It has also been observed that individual trees of a given species differ in their ability to produce new shoots from dormant buds (Read *et al*. 1996; Read 2000). Branches that have grown slowly have more nodes per metre and hence more dormant buds. Another observation is that adventitious buds in some species (e.g. *Fraxinus excelsior*) form more readily along the torn margins of a branch break-out injury than in the vicinity of a saw cut.

When new branches grow following injury, they can continue to survive and thus to contribute to the vitality of the tree only if they become independent of the existing tissues before these undergo inevitable dieback and microbial attack. Once the new aerial growth is producing enough photosynthetic material to support both root regeneration and the production of new wood in the main stem of the pollard, the survival of the 'new tree' is usually assured. In some cases, trees have survived long enough to produce new growth, but this has subsequently died back (Fig 4), perhaps because it was not linked via channels of new tissue to the root system. Such dieback may be associated with fungal colonisation, as discussed below. In such cases, the entire tree can die very quickly. Sometimes, however, further shoot formation may begin lower down and thus closer to surviving roots.

Although a pollarded tree can be killed by total re-cutting of the crown, there are some species, such as *Salix* spp., *Tilia* spp. and *Taxus baccata* that often produce new shoots readily after such treatment. There are others that can also respond well, but that are more likely to survive if at least one or two branches are retained; these include *Ilex aquifolium*, *Carpinus betulus* and *Fraxinus excelsior*. Some species of oak, including *Q. robur* and *Q. petraea*, often respond well even if most of the upper foliage-bearing branches are removed.

Dysfunction in the central part of the root system

Decay initiated below ground appears to be a common feature of all ancient trees, whether or not they also have decay developing extensively from above-ground wounds. The apparent seat of decay below-ground is often the region immediately under the main stem, where there were once roots that formed early in the life of the tree. It is not entirely clear at which stage such roots typically become dysfunctional, but the presence of decay in the stem base is often not externally apparent until the tree is in the post-mature phase of its life. Such decay can occur in younger trees, sometimes when there is a history of root injury or disturbance. Well known examples of fungi that colonise the central rooting zone of trees include the basidiomycetes *Armillaria* spp., *Ganoderma* spp, *Meripilus giganteus*, *Phaeolus schweinitzii*, *Sparassis crispa* and the ascomycete *Ustulina deusta* (Lonsdale 1999; Schwarze *et al*. 2000a). Extensive decay can also be caused by *Inonotus dryadeus* and *Grifola frondosa* , both of which are particularly common on *Quercus* spp., but these fungi often appear to leave enough of the lateral roots intact to ensure good stability.

The significance of sapwood and of old central wood in the survival of ancient trees

The high moisture content of functional sapwood usually provides insufficient gas exchange for significant decay to occur. This is a form of passive defence against most decay fungi (Boddy and Rayner, 1983). Even if dysfunction develops in sapwood due to injury or disease, the dysfunctional zone may remain very localised within pre-existing anatomical boundaries, such as vessel endings, or the interfaces between annual increments. The anatomy of the wood is, therefore, an additional passive defence (Shigo and Marx 1977).

It is possible for a dysfunctional zone to become larger, due to further drying of the wood, but this is often prevented by an active response of the sapwood, which helps to seal off the damaged tissue. In this response, the cell lumina and inter-cellular spaces become impregnated with substances which are produced by the parenchyma cells. These impregnating materials may include gums, resins and suberin, as well as phenolic compounds which inhibit fungal growth. Also, as pointed out by Shigo and Marx (*loc. cit*.), the new annual increments which are laid down after the exposure of the sapwood are especially well protected against the spread of dysfunction and decay.

The ability of sapwood to respond actively to injury and fungal invasion declines with age because the parenchyma cells have a limited life. In some tree species, such as beech (*Fagus sylvatica*), the process of cell death occurs gradually over several decades so that the wood becomes less able to respond to fungal invasion if it happens to be exposed by a wound. The same is true of certain other species, such as *Aesculus hippocastanum* and *Fraxinus excelsior*, in which the heartwood is distinct from sapwood but lacks the active defence mechanisms of sapwood. In yet other species, such as *Quercus robur* and *Q. petraea*, however, the xylem parenchyma is programmed to die after a number of years, so that the sapwood is converted into a distinct heartwood which contains substances that protect it against microbial colonisation and which represents a form of passive defence.

Tree species in which the central core of dysfunctional wood is readily colonised by decay fungi tend to live less long than species with a durable heartwood. This difference in average lifespan is probably due in part to the tendency for extensive decay to lead to major mechanical failure, which leads to massive exposure of wood to the atmosphere, an accelerated rate of fungal development and in many cases death of the tree soon afterwards. Such a sequence of events is well recognised in species such as *F. sylvatica*. If, however, the central wood is a relatively durable heartwood (as in the case of *Q. robur*, for example), fungal decay is often so slow that major weakening and catastrophic mechanical failure do not occur until a very late stage, perhaps after several centuries have passed. In many such cases failure never occurs, because it becomes less likely as the small-scale failure of individual branches leads to a reduction in the size of the crown. Also, the radial growth of the tree may to some extent keep pace with the development of the decay.

The role of different fungi in the death or survival of ancient trees

Species of decay fungi differ considerably in their ability to colonise and to degrade the wood of trees (Rayner and Boddy 1988; Schwarze *et al*. 2000a). These differences relate to their tolerance to or preference for particular conditions. These conditions include moisture content, gas exchange rate, nitrogen content, and various defensive substances including some that form physical barriers and others that are fungitoxic or fungistatic (Pearce, 1996). The ability of a particular fungus to cope with a particular set of conditions determines its ability to colonise functional sapwood, or dysfunctional wood which may be of high or durability.

Sapwood pathogens tend to have a rapid *invasion strategy*, by which they can colonise sapwood rapidly and extensively, but without causing decay until the wood later dries out partially. At this early stage, they exploit easily assimilated food sources, such as sugars, while colonising the tissues so rapidly that there is not enough time for the active defences of the tree to halt their attack. At least some of these fungi also suppress the active defences of the tree by secreting toxins which damage or kill the xylem parenchyma cells.

Such fungi are often known as fresh wound parasites or wound rot fungi, as they are specialised invaders of living sapwood and are usually not adapted to colonise old wounds.

The most aggressive fresh wound parasites, such as *Chondrostereum purpureum,* are not usually associated much with ancient trees, but there are other fungi such as *Stereum* species and *Bjerkandera adusta*, which can colonise sapwood rapidly when it has been rendered partially dysfunctional by wounding or disease (Lonsdale and Wainhouse 1987), especially under desiccating conditions. The dead specimen of *Carpinus betulus* in Fig. 4 was colonised and probably killed by *B. adusta*. Another fungus that can colonise trees desiccated by sunscorch or fire damage is *Schizophyllum commune* (Butin 1995).

Another strategy by which some decay fungi colonise sapwood is by spreading out from a column of colonisation well established within the central dysfunctional wood of the tree. Such fungi are probably more likely to limit the longevity of trees than those that remain confined to the dysfunctional core. For example, Schwarze and Ferner (2003) have shown that species of *Ganoderma* differ in their ability to colonise sapwood. They found that *G. adspersum* was able to penetrate the defensive barrier separating functional from dysfunctional wood. On the other hand, *G. applanatum* did not have this ability, but had a greater potential to degrade the wood.

Within durable heartwood, only fungi with tolerance to the relatively adverse conditions, in particular a high concentration of anti-microbial substances, can cause extensive decay. Such fungi, such as the brown rotter *Laetiporus sulphureus*, tend to develop slowly, so that ancient trees can often co-exist with them for many decades or even centuries. In this context, one of the most benign decay fungi is probably *Fistulina hepatica*, which degrades the tannins in heartwood for a long period before starting to degrade the cell walls (Schwarze *et al*. 2000b).

Another important colonisation strategy by certain decay involves a latent or endophytic establishment phase, in which no overt change occurs within the wood (Lonsdale, 1983, 1997). These fungi commonly occur throughout most of the sapwood of a wide range of broadleaved tree species. In some cases, a genetically uniform fungal individual is present within a strip of wood that can be several metres long (Boddy and Rayner 1981). Usually, these fungi enter into an active decay or pathogenic phase only if the host tissues are damaged or altered in some way, especially by desiccation. In ancient trees, fungi such as *Vuilleminia comedens* and *Peniophora quercina* (Boddy & Rayner, 1991; 1984) frequently develop in individual branches that have declined in vitality They can play a part in 'natural pruning' (Butin and Kowalski 1983), sometimes to the benefit of the tree if its crown would otherwise remain too large to withstand strong winds. Some of these fungi, however, such as *Eutypa spinosa* (Hendry 1993; Hendry et al. 1998), seem able to kill trees that have been stressed. The type of wood degradation caused by a particular fungal species is another factor in the ability of ancient trees to survive, as some kinds of decay are more likely than others to weaken the wood (Schwarze *et al*. 1997). The main distinction is between brittle decay and non-brittle decay, but there are many types of decay with intermediate mechanical properties. Brown rot fungi, such as *Laetiporus sulphureus*, produce a brittle decay because they degrade the rope like cellulose component of the wood, leaving the cement like lignin almost intact. In contrast, fungi that cause a selective white rot degrade the lignin preferentially, so that the wood retains some of its tensile strength, but loses its stiffness. In some extreme cases, species of *Ganoderma* leave so much of the cellulose unaltered that the wood can be bent like a rope, without breaking.

A relatively brittle decay can be produced by other kinds of white rot (simultaneous white rot), in which the cellulose and lignin are degraded at about the same rate. The decay produced by *Fomes fomentarius* is of this type. Eventually, either a selective or a simultaneous white rot sometimes progresses to the complete destruction of the wood, so that a cavity is formed. A relatively brittle kind of decay can also result from a form of rot in which the fungal hyphae tunnel within the cell walls, degrading the cellulose microfibrils as in a soft rot. This mode of degradation, known mainly in timber, is now known to be induced by a wide range of tree decay fungi, such as *Inonotus hispidus*, (Schwarze *et al*. 1995), a species commonly found in old specimens of *Fraxinus excelsior,* which also cause white rots, and in a few cases brown rots (Schwarze *et al*. 2000a).

Alteration of the tree's growing conditions due to its continued growth

The idea that trees alter their own growing conditions as they grow larger is perhaps based more on observation and on theoretical assumptions, rather than on rigorous data. As far as soil moisture and aeration are concerned, one observation is that signs of anaerobic conditions, shown by the presence of a bluish colouration, are sometimes found in the soil underneath the central zones of the rootplates of uprooted trees. Such colouration underneath rootplates can be expected to occur in waterlogged or compacted soils, but it is sometimes found in light, open-textured soils. It seems possible that, through respiration of roots themselves, or of organisms colonising them, oxygen can become locally depleted. Whether this is a factor in the eventual death of roots directly beneath the stem of a large tree is uncertain. As mentioned above, this pattern of death appears to be important in the development of below-ground decay in ancient trees.

Mineral nutrients such as potassium are clearly sequestrated within the wood of a large tree, but it is not clear whether this process commonly results in a deficiency for the tree itself. The decay process releases nutrients and is therefore likely to be of nutritional benefit to the tree. In many cases, a hollow tree develops adventitious roots within its own cavity, so that it can directly re-absorb nutrients that were previously locked up within its dysfunctional core.

Conclusions

The aging of trees is often compared to that of humans and other animals, and there are indeed some analogies that can be recognised. However, there are fundamental differences due to the manner in which trees can continue to grow and to the microbial exploitation of their accumulated dead tissue.

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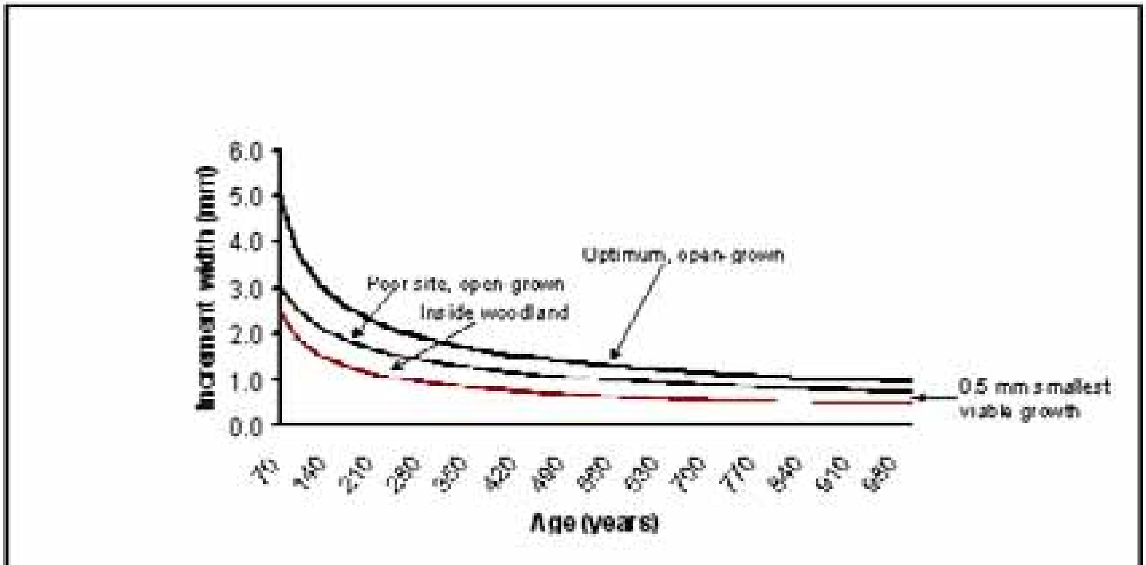

Quercus robur: increment width up to 1000 years, based on White's (1998) model of uniform annual incremental area

Fig. 1

Fig. 2 Veteran *Castanea sativa* with one strip of functional stem tissue

Fig. 3 Ancient *Quercus robur with abundant epicormic growth*

Fig. 4 Ancient pollard of *Carpinus betulus* with dieback of new twigs that formed after severe cutting

NEW ENTOMOLOGICAL ASPECTS AND STRATEGIES OF LOW ENVIRONMENTAL IMPACT

A. Alma

Di.Va.P.R.A. – Entomologia e Zoologia applicate all'Ambiente "Carlo Vidano", Università degli Studi di Torino - Grugliasco (TO), Italy

Broadleaf and coniferous trees are often attacked by different pests, that cause direct and indirect damage and, in the most serious cases, may compromise irreversibly the plant's functionality. The most common and dangerous infestations are due to leaf-eating moths, beetles and wasps, to wood-eating moths and beetles, and to plant-sucking bugs.

Indigenous species

Among the plenty dangerous indigenous species, one can remember the processionary moths *Thaumetopoea processionea* (L.) and *Traumatocampa pityocampa* (Denis & Schiffermüller) and the bark beetles, in particular *Scolytus multistriatus* (Marsham).

***Thaumetopoea processionea* and *Traumatocampa pityocampa*.** They have very hairy larvae, characterized above all by the presence of a lot of stinging hairs. These hairs, very thin and small, detach easily from the body of the larvae and spread on the plants and in the surrounding area. Such hairs may cause skin irritations and serious damage to vertebrates, including man; especially when they affect the eyes or the respiratory mucose.

The larvae, normally hide inside silk nests. As they are gregarious, when they get out of their shelters in search of food or of a place where to pupate, they move in long rows. For this peculiar behaviour they are called with the common name of "processionary moths".

Th. processionea lives on different species of deciduous oaks. It overwinters as eggs laid in groups of 200-300 elements, protected by abdominal hairs on the bark of trunks and branches. The gregarious and nocturnal larvae attack at first the younger leaves and on the higher part of the canopy, then they feed on the lower part. At the beginning of July the larvae reach maturity and spin a silk cocoon mixed with hairs and pupate inside the nest or at the base of the infested plants. The adults emerge in August and after some days copulate and lay the overwintering eggs.

T. pityocampa commonly known as the pine processionary moth attacks different species of the genera *Pinus* and *Cedrus*. The infested pines are more or less defoliated according to the density of nests and are proner to the attacks of xilophagous insects. This moth accomplishes one generation a year. The adults are on the wing in July; the female lays the eggs around a couple of needles so to form a sleeve completely covered by abdominal scales. The larvae hatch at mid August and begin to feed on the needles near the egg cluster; then they erode the needles at the end of the branches after having covered them with silk threads. At the beginning of autumn they build a compact nest suitable to contain the overwintering larvae inside. In the following spring, as soon as they reach maturity, the larvae move in a procession to the ground, where they reach a sunny and dry site and bury themselves and then spin a cocoon in which they remain in diapause and afterwards they complete their metamorphosis. When the environmental conditions are not favourable the diapause lasts until the summer after.

The two defoliating moths must be controlled in the larval stage. The interventions are necessary above all in sites visited by people, so to prevent the considerable trouble caused by the larval stinging hairs. As an alternative to the use of synthetic insecticides, one may employ commercial formulations based on *Bacillus thuringiensis* Berliner variety *kurstaki*. This product is particularly efficacious against young larvae (1st and 2nd instars). In the case of initial infestations and whenever the size of the trees enables it, one can carry out a manual collection of the nests by cutting the branches bearing them. Against *T. pityocampa*, the control is compulsory (DM 17-04-1998) if the presence of this insect menaces seriously the production or the survival of the trees or represents a risk for human and animal health.

***Scolytus multistriatus*.** This bark beetle is common and present in all Italy. It has settled and spread in all North America. It lives almost exclusively on elms and is the most important spreader of the fungus *Ophiostoma ulmi* (Schwarz) Nannfeld the agent of the disease called Dutch elm disease. The spores of the fungus are transported by the adults inside the feeding galleries dug at the base of gems and twigs of healthy elm trees. *S. multistriatus* overwinters in the larval stage inside galleries dug in branches and trunk. In spring the newly emerged adults dig feeding galleries and then the females lay the eggs in galleries dug in the bark. The larvae dig individual galleries until they reach the bark and the sapwood. At the end of summer the new adults are on the wing and give birth to a second generation.

Presently there is no perspective to refrain the infestations of this insect and of the disease caused by the fungus; until now no resistant strains of elms have appeared. The only kind of control is prevention, trying to keep the plants in optimal vegetative conditions, effecting, if necessary and possible, also recovery irrigations during the hottest period of summer. Moreover, it is useful to avoid increasing the bark beetle's populations by felling and destroying the suffering and infested trees. The synthetic aggregating pheromone is more useful for phenologic surveys than for efficient adult mass capture strategies.

New entomological problems

Besides the number of problems caused by the activity of the different local pests, with a higher frequency, almost daily, new entomological emergencies have to be faced, due to the incidental introduction of exotic species and in some cases to the sudden and unexpected aggressivity of species that were before indifferent and poorly known. Of the different species reported by several authors, here I consider those that cause the most relevant problems or that are held as potentially dangerous and therefore need the establishment of adequate defense strategies for the safeguard of the infested plants (tab. 1).

Table 1. List of the species causing new entomological problems in Italy.

Species	Host plant
RHYNCHOTA	
Tingidae	
Corythucha ciliata Say	*Platanus* spp.
Corythucha arcuata (Say)	*Quercus* spp.
Aphididae	
Illinoia liriodendri (Monell)	*Liriodendron tulipifera*
LEPIDOPTERA	
Gracillariidae	
Cameraria ohridella Deschka & Dimic	*Aesculus hippocastanum*
Arctiidae	
Hyphantria cunea (Drury)	Polyphagous on broadleaf trees
COLEOPTERA	
Cerambycidae	
Anoplophora malasiaca Thomson	Polyphagous on broadleaf trees
HYMENOPTERA	
Cynipidae	
Dryocosmus kuriphilus Yatsumatsu	*Castanea* spp.

***Corythucha ciliata*.** This Northamerican bug has become the most common insect of plane trees. It was found for the first time in Italy and spread to different countries of south Europe, France and Spain; central Europe, Switzerland, Germany, and Austria; east Europe, Hungary, Rumania, Czech Republic, Slovakia, and Bulgary. The adults that overwintered beneath the bark of the trunk migrate in spring to the foliage and feed on young apical leaves. Young and adults live on the lower leaf page and feed sucking the cytoplasmic contents of the palisade and spongy layer cells. Along the year from two to three generations are completed; at the beginning of autumn the adults move to the trunks for overwintering. In summer the leaves appear completely depigmented and assume a yellowish colour. Much more serious than the aesthetic effect is the physiological damage that is caused to the plant; such problems affect the general vegetative state of the plant and in the most serious cases may reduce the wood growth.

The defense from *C. ciliata* is very difficult. In spite of a great number of local predators that adapted themselves to the exotic species, their action proved to be insufficient in refraining efficiently the infestations. On big trees a control of the pest by chemical treatments is badly effectable, keeping in consideration the volume of the canopy. Good results may be obtained by trunk injections (endotherapic method) of formulations registered for this use.

***Corythucha arcuata*.** This new species of the genus *Corythucha* was recorded for the first time in Europe in 2000 during entomological samplings in a park in the outskirts of Milan. *C. arcuata* is widespread in Northamerica and in particular in southeast Canada. In its area of origin, this insect lives mostly on different species of the genus *Quercus* and on *Castanea americana*; occasionally it was found also on apple and maple. In Italy it was observed especially on *Q. robur* and less on *Q. pubescens* and *Q. petrea.* This insect overwinters in the adult stage and in spring, towards the middle of the month of May, the females lay eggs between the secondary veins of the leaves. The first adults appear towards the middle of June; in one year *C. arcuata* accomplishes three generations. The trophic activity of young and adults provokes the appearance of obvious depigmented areas on the leaves; in the case of strong infestations there is an early leaf fall at end summer.

In USA, in particular on strongly infested ornamental oaks, chemical treatments were carried out, above all to control the first generation of this pest. It is therefore possible to infer that *C. arcuata*, as it already happened for the congeneric *C. ciliata*, monophagous on plane, could rapidly spread and cause even strong infestations on oaks, not only in woods, but also in reforestations and in urban green.

Illinoia liriodendri. This aphid, recorded until now in Northamerica and Japan, was found for the first time in Europe in parks of north Italy on plants of *Liriodendron tulipifera*. This species colonized exclusively *L. tulipifera*; the infested plants are easily identifiable by the shiny leaves covered with abundant honeydew produced by the aphid. The infestation begins with the colonization of the lower leaf page, but soon, as the colony grows, also the upper page is used. The introduction into Europe of this new Nearctic aphid will cause remarkable problems for the use of *L. tulipifera*, until now widely employed in the realization of parks, gardens, and avenues, since it was without pests. In fact, the abundant honeydew produced by the aphid dirties the underlying surfaces and makes them unenjoyable by the public. The strongly infested plants go through a partial leaf fall.

A biological control could be effected by local natural enemies that gradually adapt themselves to the new aphid, thus creating a new biocoenotic complex.

Cameraria ohridella. This moth was described for the first time in 1986 in the Republic of Macedonia; in Italy it was recorded in 1992. This leaf miner spread with a surprising speed and with so high population densities as to cause early leaf fall already at end July on *Aesculus hippocastanum* trees. The white flowered horse chestnut proved to be more susceptible to the infestations of this pest. *C. ohridella* overwinters in the pupal stage inside the fallen leaves. In spring the females lay isolated eggs on the upper leaf page. The larva digs a mine in which it pupates at maturity. This moth carries out four generations in one year; the first damage to the plants can be observed with considerable populations in correspondence with the development of the second generation. Besides the summer leaf fall, in case of heavy infestations there can be a reshooting and reblooming in late summer.

The technique of collecting and eliminating the fallen leaves that host the overwintering chrysalids in the mines, even if it represents a control measure by reducing the initial population in spring of the new year, does not refrain this leaf miner in a sufficient way. The same applies for the action of local parasitoids that, though they show a satisfying capacity of adaptation, as well as it happened in other countries affected by this phytopathological problem, at present they do not appear able to control efficiently this pest.

Currently, chemical defense with the use of registered phytosanitary products is the only means available to try to control *C. ohridella* infestations. Foliar treatments have remarkable execution difficulties, as the trees are of great size and often placed in towns. Therefore, in order to avoid consequent sanitary problems connected with the dispersal of pesticides in the environment, the attention was drawn on endotherapy. Endotherapic treatments can be applied by means of natural absorption or with pressure. The regular translocation of the insecticide, necessary to assure the efficacy of the treatment, is conditioned by abiotic factors (temperature, RH) and above all by the sanitary state of the treated plant.

Hyphantria cunea. This moth of Northamerican origin was found in Italy in 1980. It is polyphagous, living on broadleaf trees, preferring mulberry, maple and walnut. The larvae feed on leaves that are enveloped in a silk canvas and eroded at first on the lower page, then they are entirely skeletonized. Normally there are two generations a year, in years or areas with a milder autumn, there can be the beginning of a third generation. Overwintering is in the pupal stage, sheltered in cracks of the trunk and of main branches. When the moth appears with heavy infestations the plants are completely covered with silk and defoliated.

In the zones that have been recently colonized, the control of infestations can be made eliminating the first infestations, as much as possible, by cutting and destroying the branches attacked by the larvae. Localized insecticide interventions or treatments on the whole canopy must be carried out on the young larvae, employing preferably formulates based on *B. thuringiensis* variety *kurstaki.*

Anoplophora malasiaca. This cerambycid of Oriental origin, spread in Japan, Korea, and Taiwan, was reported for the first time in Europe in 2001 from plant material imported into north Italy. It is xylophagous and polyphagous and feeds on 50 species of broadleaf trees. In the area of origin its biological cycle lasts one or two years, according to when the eggs are laid. The adults emerge in June; females feed on young leaves and twigs. Eggs are laid singly under the bark at the base of the trunk. The larvae dig galleries and feed on phloem and xylem tissues, weakening the plant and leading it to death. Among the many plants attacked by this cerambycid in Italy, there are: *Acer saccharinum, Aesculus hyppocastanum, Carpinus betulus, Fagus sylvatica, Platanus acerifolia* and *Quercus robur.*

Very probably, this new pest, favoured also by its high polyphagy, will represent a new problem for broadleaf tree management. In the attempt to control *A. malasiaca* biologically, research has begun to identify parasitoids and predators of this oriental cerambycid.

***Dryocosmus kuriphilus*.** It is a gall wasp of Chinese origin living on *Castanea* spp., introduced into Japan in 1941, into South Korea in 1961, and into USA in 1974; it was recorded in Italy in 2002. This species carries out one generation a year, at the beginning of summer the females lay the eggs inside the gems. First instar larvae overwinter without showing any obvious alterations on the gems. At vegetative recovery, galls grow at the expense of the shoots and compromise the plant's development with a consequent decrease of fructification and vigour, in the case of repeated attacks the plant may die. This gall wasp spreads by means of the trade of infested shoots or scions and the flight of females.

Pruning and destroying infested shoots may slow down the diffusion of this pest. Keeping in mind the inefficacy of insecticide treatments, in Japan this wasp was controlled biologically by introducing its specific parasitoid *Torymus sinensis* Kamijo from China. Considering the good results obtained in Japan in 2003, at less than one year from the first record of the exotic pest, a biologic control plan has been set up for the introduction of *T. sinensis* in Italy. From parasitized *D. kuriphilus* galls coming from Japan a first nucleus of parasitoids was reared in the laboratory in Italy. In the current year, after further studies on the parasitoid's population, the opportunity to spread *T. sinensis* in the field will be evaluated. The expected results are a slow establishment of the parasitoid followed by a rapid decline of the gall wasp populations until the reaching of a biological balance, as it happened in Japan during a period of about five years.

As it can be seen, the new entomological emergences, almost always due to exotic insects introduced incidentally, have been growing constantly and worryingly in the last years. The continuous alarm points out on the one hand the difficulties encountered by the institutions in charge of carrying out a punctual and serious check of the biological material imported and on the other hand obliges the researchers to find out endlessly control strategies able to refrain efficiently the new pests without causing repercussions on local biocoenoses and on the environment as a whole. Therefore, whenever possible, it is convenient to employ selective synthetic insecticides, natural insecticides, entomopathogenic microrganisms, and biologic control projects by introducing exotic natural enemies, coming from the same places considered originary of the pest to be controlled, so to reach, usually in a medium or long term, a lasting containment of the pest.

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CAN VETERAN TREES BE STIMULATED BY MYCORRHIZAL FUNGI?

S. Egli

Swiss Federal Institute for Forest, Snow and Landscape Research WSL, CH-8903 Birmensdorf, Switzerland

1. Introduction

What are mycorrhizal fungi and mycorrhizas

The roots of almost all vascular plant species are known to form mutualistic symbioses with a certain group of fungi, so called mycorrhizal fungi. The colonized roots are termed mycorrhizas ("fungus roots", from the Greek: *mykes* = mushroom or fungus and *rhiza* = root). Mycorrhizal fungi - members of the Basidiomycetes, Ascomycetes and Zygomycetes - play a crucial role in plant health by enhancing nutrient acquisition, drought tolerance and pathogen resistance of their hosts (Smith & Read, 1997). In return, the autotrophic plant hosts provide their heterotrophic fungal partners with photosynthetically derived carbon compounds (sugars). Based on morphology and the fungal and plant species involved, several different mycorrhizal types are recognised. The most important are:

Vesicular-arbuscular mycorrhizas (VAM) are found on the vast majority of wild and crop plants, and most tropical tree species. They are associations where Zygomycete fungi in the Glomales produce arbuscules, hyphae and vesicles within root cells. Spores are formed in soil or roots. These associations are defined by the presence of arbuscules. VAM fungi are generalists, i.e. they can associate with thousands of different host plant species. About 150 VAM forming species are known worldwide.

Ectomycorrhizas (EM) are characteristic of most forest tree species in the temperate and boreal regions of the world - for example pines, spruces, firs, oaks, birches in the Northern Hemisphere and eucalypts in Australia. However, some trees (e.g. willows) can have both ectomycorrhizas and vesicular-arbuscular mycorrhizas. Ectomycorrhizas are associations where Basidiomycetes and other fungi colonise short roots and form short swollen lateral roots covered by a mantle of hyphae. These roots have Hartig net hyphae around the cells in the epidermis or cortex.

EM fungi are predominantly host specific, i.e. they form associations with certain tree species or a restricted number of them. About 5'000 EM forming species have been described to date. *Orchid mycorrhizas* consist of coils of hyphae within roots or stems of plants in the family Orchidaceae. *Ericoid mycorrhizas* have hyphal coils in outer cells of the narrow "hair roots" of plants in the plant order Ericales

Why mycorrhizal fungi are important

Mycorrhizal fungi increase plant nutrient supply by extending the volume of soil accessible to plants and by acquiring nutrient forms that would not normally be available to plants. Root colonisation by mycorrhizal fungi can provide protection from parasitic fungi and nematodes.

Carbon transfer through EM fungus mycelia connecting different plant species has been measured. Networks of hyphae supported by dominant trees may help seedlings become established or contribute to the growth of shaded understorey plants.

Hyphae of VAM fungi are thought to contribute to soil structure by mechanical aggregation of soil particles.

Epigeous and hypogeous sporocarps of EM fungi are important food sources for forest inhabiting animals and some of them are economically important as human food resources.

How to detect mycorrhizal fungi in the soil

Most of the EM fungi produce conspicuous fruitbodies: forest mushrooms such as boletes, amanitas, chanterelles or subterranean truffles. The presence of fruitbodies is evidence for the presence of mycorrhizal mycelium in the soil. However, if there are no fruitbodies apparent, it does not mean that there are no mycorrhizal fungi present in the soil, since EM fungi do not form fruitbodies on a regular basis.

The detection of VAM fungi in the soil by the naked eye is entirely impossible, since they do not form visible fruitbodies, but only microscopic spores.

Nowadays there are new, highly sophisticated methods of detecting and identifying mycelium of VAM and EM fungi in the soil using molecular tools, such as the T-RFLP method or the DGGE (sequencing of cloned PCR-products). The progress in methodology in this field is very fast-paced. A much easier way is to look at plant roots. If there are mycorrhizal fungi in the soil, they colonise plant roots and form mycorrhizas; this is imperative, for they would not be able to survive without doing so. Mycorrhizas can be investigated morphologically and anatomically (morphotyping) or by molecular identification of the fungus by comparing genetic fingerprints of unknown mycorrhizas with a reference data base.

2. Artificial mycorrhizal inoculation

The need of tree species for mycorrhizal associations was discovered when attempts to establish plantations of exotic pines failed until the essential mycorrhizal fungi were introduced (Marx, 1980). Since the seventies attempts have been made to artificially colonise seedlings in the nursery with mycelia of EM fungi. The aim was to improve early growth of forest plantations. So-called "controlled inoculation" was regarded as an energy-saving and environment-friendly alternative to chemical fertilizers and pesticides. Today the production of ecto- and endomycorrhizal inoculants is at a commercial level and a wide variety of products is available.

Techniques of artificial inoculation

There are three main methods of application of mycorrhizal inoculum with regard to the age of the tree to be inoculated:
- seedling inoculation in the nursery
- inoculation of trees at time of transplanting
- inoculation of mature trees at the site

Inoculant types vary from simple forms (e.g. inoculation with forest soil) to highly sophisticated aseptically produced inocula based on pure cultures or spores, incorporated into carriers and supplemented with growth stimulating additives, such as hydrogels, natural humates, yucca plant extracts, seaweed extracts, kelp, humus, vitamins, amino acids, or other beneficial soil microorganisms like *Trichoderma* species or rhizosphere bacteria.

EM inoculum can be applied as spores or mycelium grown in pure culture. Mycelium inoculum usually causes faster infection but is more sensitive to desiccation and other environmental factors. VAM fungi can be applied only as spores or as infected roots, because they cannot be grown in pure culture on nutrient media. The fungi are multiplied by infecting roots of an intermediate host through the use of spores.

Table 1: types of inoculum products and application ranges (s = seedling inoculation; t = inoculation at time of transplanting; o = inoculation of mature trees)

inoculum type	fungi	Application range			Advantages	Disadvantages
		s	t	o		
soil, soil mixtures	EM VAM	x	x		balanced population of microsymbionts, low-priced	may contain infective pathogens. Sourcing and transport problems.
infected roots	(EM)VAM	x	x		balanced population of microsymbionts	sourcing problems.
spores, sporocarps	EM	x	x		defined species	sourcing problems, limited spectrum of species
pellets, granules	VAM EM	x	x		easy to apply, facility for incorporating growth stimulators	storage problems, expensive
root dips	EM		x		easy to apply	expensive
injectible solubles	EM VAM			x	easy to apply	expensive

Can the success of an artificial inoculation be guaranteed?

Artificial mycorrhizal inoculation may be successful only when the following conditions are fulfilled:
1. There is no natural or appropriate inoculum in the soil or the inoculum level is low
2. The species present are less efficient at aiding the plant host than those being introduced
3. The host tree produces enough carbohydrates to keep the symbiotic fungi alive

As a result of the fact that almost all vascular plants live in symbiosis with mycorrhizal fungi, these fungi are widely distributed all over the regions of the world covered by vegetation. There are some special situations where the natural mycorrhizal populations can be perturbed or insufficient: on sterile soils, e.g. mine spoils, artificial substrates, or on degraded soils, e.g. in urban environments

The success of artificial mycorrhizal inoculation can never be guaranteed for two main reasons:

1. the competition between the introduced and the soilborne fungi. Most soils already contain a complement of mycorrhizal fungi that can out-compete the newly introduced species.
2. the soil conditions may not be adequate for the growth of mycorrhizal fungi.

Costs

According to the dosage instructions of the producers the application costs of commercial inoculum range from Euro 0.5 to Euro 10 per thousand seedlings (nursery application) and between Euro 0.25 and Euro 0.70 per tree at time of transplanting. For soil restoration the costs range from Euro 0.1/m^2 (surface application) up to Euro 60/m^3 (full soil inoculation). Inoculation of mature trees by injection of liquid inoculum into the soil may cost even more, depending on the dimension of the tree and its root system.

Selection of fungi for artificial inoculation: economics versus ecology

The first and most important selection criteria is the behaviour of the symbiont in pure culture and the possibilities of producing inoculum in abundant quantities.

For EM inoculum the choice is very restricted because only a limited number of species are cultivatable, e.g. *Laccaria, Hebeloma, Paxillus*. The large and widespread families of *Cortinarius* or *Lactarius* are very difficult to take into culture even though they are known as "late-stage" species, i.e. they preferentally colonise mature trees. Seedling inoculation requires early-stage fungi, such as *Hebeloma*, *Laccaria* and *Paxillus*, whereas mature trees should be inoculated with late-stage fungi, such as *Boletus* or *Cortinarius* species.

Another major criteria for selecting fungal symbionts to be utilized for inoculation of mature trees is their root-colonizing ability and competitiveness against wild symbionts already present in the soil. Artificial ectomycorrhizal inoculation *Pisolithus tinctorius* spores have been the main component of commercial EM inoculum since the beginning. Fruitbodies of *Pisolithus tinctorius* fungus produce high quantities of spores, but it can be questioned whether this fungus is a good choice from an ecological point of view. It is known from various studies that this species gives good results on mine spoils, but there is no evidence that this fungus is competitive enough on other soil types.

The most important problem is that soil conditions in the landscape may be too variable to be able to make generalizations about the usefulness of artificial inoculation with the few selected species available commercially. Mycorrhizal fungi are - as vascular plants - site and host specific. And above all they are not identical in their effect to the host plant. Some species may have a positive effect, a neutral effect or under certain circumstances even a detrimental effect on the host plant (Klironomos, 2003).

Inoculation of mature trees in urban environments

Urban soils are very different to forest soils since they are influenced by human activities and therefore the soil's natural characteristics that benefit trees are often degraded. They rarely have an organic layer and they may have disrupted soil profiles as the result of organic top layers having been removed or turned into mineral subsoil horizons by construction activities. Often these soils are compacted, have an altered drainage and an elevated pH. Additionally, they are submitted to stresses such as de-icing salt in winter and air pollution from exhaust fumes. All these factors may harm root growth and health of the trees growing on these soils and they also disturb the mycorrhizal flora. Since urban trees have the same biological needs as forest trees, the idea of improving the soil by artificial inoculation with mycorrhizal fungi was born.

An important point which makes the inoculation of mature trees problematic compared to seedling inoculation in the nursery, is that the roots of mature trees are normally already colonised by mycorrhizal fungi. In theory, the introduction of an alien fungus into an environment that already is fully occupied by indigenous fungi is less likely to be successful than its use in a situation devoid of such fungi.

The inoculation method for mature trees is limited to the injection technique using liquid inoculum, or eventually the application of solid inoculum combined with a mulching procedure. On the other hand seedlings are much easier to inoculate compared to mature trees: the inoculum can be allocated directly to the root system in the nursery by mixing the inoculum into the planting substrate of the seedbed or into the planting pot. The inoculum gets in direct contact with the fine roots and root colonisation can happen easily. The soil can be sterilized before inoculation to eliminate competing resident symbionts or pathogenic microorganisms. Such a treatment can not be performed on mature trees.

3. Experiences to date with artificial mycorrhizal inoculation

Inoculation of seedlings in the nursery

In nursery inoculation there is a large body of experience and hundreds of studies which show the positive effect of artificial inoculation with mycorrhizal fungi on seedlings: they grow faster with less fertilisers. But the key question is what happens with these fungi after outplanting? The existing literature indicates that fungal associations often change when the plants are transplanted into the field.

Inoculation of trees at time of transplanting

At present there is very limited unbiased scientific evidence that artificial mycorrhizal inoculation of trees at time of transplanting makes plant establishment more successful or that the inoculated plants grow better over time.

Garbaye & Churin (1996) inoculated 8-year-old silver limes (*Tilia tomentosa*) with three ectomycorhizal fungi. In spite of irregular colonization of the roots by the introduced symbionts, tree growth was significantly stimulated in the three fungal treatments and yellowing of leaves in autumn was delayed. Negative results are reported from Alvarez & Trappe (1983): dusting roots with *Pisolithus tinctorius* spores even reduced seedling survival in some cases. Pilz and Znerold (1986) inoculated Douglas firs with a slurry of *Pisolithus tinctorius* spores and concluded that "the application of P.t. spores to a seedling's roots immediately preceeding outplanting appears to be ineffective" South and Skinner (1998) reported on a study where no benefit was obtained by injecting freeze-dried *Rhizopogon* spores into the soil after transplanting. Other negative results are published by Martin & Stutz (1994) and Gilman (2001): Inoculation of Argentine mesquite (*Prosopis alba*) with the VAM fungus *Glomus intraradices* and of Live oak (*Quercus virginiana*) with a commercial inoculum, respectively, showed no effect on growth or survival. In contrast, nursery production methods and irrigation had a large and significant impact on water stress, tree death and growth after transplanting. However, adding soil to the planting hole at time of transplanting seems to be more promising. Two studies report positive results in survival and growth of Douglas fir seedlings (Amaranthus & Perry, 1989; Colinas et al., 1994) after adding forest soil to the planting hole.

Inoculation of mature trees at the site

There have only been two studies up to now which present results of inoculation of mature trees (Marx et al., 1997; Smiley et al., 1997). Both studies show positive effects of inoculation and/or fertilisation on fine root biomass and mycorrhizal colonisation of up to 250-year-old live oaks (*Quercus virginiana*). As inoculant a spore suspension of *Pisolithus tinctorius* was injected into the root system to a depth of 20 cm.

No other publications presenting results of inoculation of mature trees exist. This could either be due to a lack of studies or a tendency of reviewers to reject papers that show no significant positive treatment effect.

5. Conclusions

The inoculation of mature trees with mycorrhizal fungi is technically possible but the decision of whether an application is advisable or not needs careful analysis of the circumstances. This is not because an inoculation could be injurious to the tree but because the effort and the expenses could be economised if the prospects of success are analysed from a realistic and objective perspective.

First of all we have to look at possible reasons for a tree's loss of vitality, keeping in mind the statement of Buschena (2000): "Remember that interactions between mycorrhizal fungi and other components of the landscape ecosystem are very complex. The problems with your trees may not be related to the lack of mycorrhizal fungi. They quite often may be related to the presence of some other organism or condition that is harmful to the trees."

If the tree is simply too old, inoculation will not make it younger. In addition, if the living conditions of a tree are bad due to unfavourable soil conditions or environmental impacts, inoculation only makes sense if the mycorrhizal flora is suffering from these conditions. We have to consider that the two partners of a mycorrhizal symbiosis are living together in a mutualistic relationship. It is not a one-way-profit system from the fungus to the tree. If the tree is no longer able to sufficiently assimilate carbohydrates, the mycorrhizal fungus will be suffering itself and will no longer be able to fully fulfill its beneficial functions for the tree. Furthermore, if the chemical or physical soil properties are completely unfavourable for the existence of mycorrhizal fungi, it would not make sense to artificially introduce them.

Consequently, a reasonable approach of ameliorating growth conditions of trees in urban landscape, or of veteran trees, is to improve the basic conditions for tree growth. Current research suggests that organic soil amendment, particularly the addition of composted mulches, greatly enhances the mycorrhizal status of landscape trees. Another possibility is to protect the trees against unfavourable influences (e.g. de-icing salt), or to select tree species which are more resistant against such factors.

If artificial mycorrhizal inoculation is to be evaluated at all, the following points should be considered:

- Use only correctly labeled inoculum that clearly states the fungal species and number of propagules.
- The inoculum should contain propagules that are alive and effective and that correspond in number to the claims on the label.
- Inoculum and inoculation procedures should be lower in cost than possible alternatives (fertilization, pest control, site/soil amelioration).

In assessing the prospects of success of artificial inoculation we have to be conscious of the fact that about 99% of positive effects of mycorrhizal fungi on their host plant demonstrated in literature are based on experimental designs under more or less controlled conditions. Observations of the reactions of plants to an inoculation after outplanting to the landscape are very rare. The lack of knowledge in this field is underlined by the existence of only these two previously mentioned publications about artificial inoculation of mature trees under field conditions. One of the authors involved in these two papers refers to this problem in one of his earlier papers (Marx, 1980): "The ultimate proof of the value of inoculation of bare-root or container grown nursery seedlings with specific fungi is their performance under diverse field conditions. Meaningful conclusions can only be obtained from properly designed, installed, and maintained field experiments which include periodic tree measurements and mycorrhizal assessments conducted over several years. Only limited field data of this type is available in the literature." In regards to mycorrhizal inoculation at outplanting or inoculation of mature trees, this statement is as true today as it was in 1980.

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HOW TO PROMOTE AND ENHANCE THE ROOT VITALITY ON VETERAN TREES: RESPONSES TO NATURAL AND CHEMICAL PRODUCTS

G. Watson
The Morton Arboretum, Lisle, IL - USA

The Key to Longevity

Veteran trees have been defined as "Trees of interest biologically, aesthetically or culturally because of their age, trees in the ancient state of their life, and trees that are old relative to others of the same species" (Helen Read, Veteran Trees – a guide to good management. English Nature 2000). In order to care for these trees properly, and insure their survival for many more years, it is important to try to understand why these trees have been able to live so long already.

One of the largest Kauri trees in the forests of Northern New Zealand

It has been estimated that Britain may be home to around 80% of Europe's ancient trees (The Ancient Tree Forum). It doesn't take the deductive reasoning powers of Sherlock Holmes to realize that the nearly ideal, moist, cool summer/moderate winter climate imposes minimal stress on trees in Britain. The veteran trees seen in photographs are always in open spaces with minimal restrictions above and below ground. The situation is similar in the Pacific coast where most of the very large old trees in the US can be found, and for the giant Kauri trees of New Zealand. Under these conditions, demands on the root system are moderate, and episodes of stress are infrequent and not severe. In contrast, trees planted in the center of American cities in small root spaces, where stress is both frequent and severe, have been estimated to have an average life span of only seven years. The environment must play a major role in longevity.

Bristlecone pine over 4,000 years old

There are other situations where trees can live a very long time. On dry windswept mountaintops of the Great Basin in the western United States grow earth's oldest living inhabitants, the bristlecone pines *(Pinus longaeva, Pinus aristata)*. Many of the trees living today were seedlings when the pyramids were being constructed over 4,000 years ago, and mature in the time of Christ. In this environment, the roots must find moisture between the rocks, crowns are small, and the trees never get more than 8.3m tall, and usually much less. These are very specific adaptations to survive in this harsh environment.Though not normally classified as veteran trees, Bonsai trees do fit the definition. These tiny trees can easily live in pots for hundreds of years. What do all these old trees have in common? They have a good balance between the crown and root development. The branches and roots of bonsai trees are pruned regularly to keep them healthy, but small. Traditional pollarding used for centuries on trees of Europe has the same effect of keeping the crown small and rejuvenated, extending the life of the tree almost indefinitely. Once pollarding is discontinued, it is only a matter of time until the tree dies of old age. The crowns of the Bristlecone pine trees usually have much evidence of dieback, and are often very small with only a small strip of live cambium supporting this partial crown. Even in the nearly ideal climates of Britain and the US Pacific Northwest, many of these very old trees show a

A bonsai tree over 400 years old

The largest giant sequoia tree in California. Note dieback in the crown

history of dieback to rebalance the crown with the root system. In all of these examples, the crown is manipulated by nature or by man to reach a balance with the root system. Promoting good root health is also important in helping veteran trees to reach that optimum above- and below-ground balance.

Soils and Root Growth

Healthy soil is required for healthy, vigorous root growth. Roots will naturally develop to the full extent that is possible in the existing environment – poor soils are associated with poor root development. Root growth is influenced by numerous factors supplied by the soil. Most of the fine absorbing roots will usually be found in the upper soil layers regardless of tree size, because conditions for root growth are most often optimum there.

Even during periods of drought, the natural forest soil environment can remain moist. This points out the need for maintaining even soil moisture in the root zone. Root growth stops in most species when soil moisture is reduced to -500 mbar soil moisture tension. Accelerated root suberization (the deposition of a waterproof layer in the walls of cells near the root surface) restricts absorption and is accelerated in dry soil. Roots do not regain their full capacity for water uptake until new root tips can be produced. When plants are watered immediately after cessation of root elongation, roots may not resume elongation for at least one week. Resumption of root growth takes up to five weeks if water is withheld longer. If the soil becomes too dry, some of the smaller roots may die.

Veteran trees must be well adapted to the site where they have been growing for centuries, but subtle changes imposed in recent decades, within the tree's root zone or surrounding areas, can impact the soil environment immediately surrounding the trees and lead to problems. Soil wetness and related drainage conditions are controlled by a number of factors including: 1) precipitation, 2) soil texture and structure, 3) permeability, 4) infiltration characteristics, and 5) landscape position. Soils are poorly drained if water accumulates on the ground surface, or in the subsoil, for several days or weeks during wet periods. This is especially prevalent in topographically low or flat sites that receive runoff from surrounding areas, even if the slopes are very gradual. Seasonal wetness causes decline in plants not adapted to wet conditions.

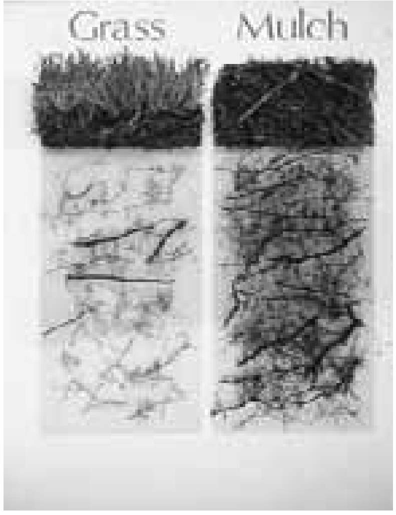
The importance of soil aeration cannot be overemphasized. Plant roots require oxygen. Roots are generally not sensitive to soil saturation itself, but excessive soil moisture reduces soil aeration because the water replaces the air normally held in the pores of the soil. Compaction reduces air space and compounds the problem. In most soils, 8 to 10 percent oxygen in the soil atmosphere is considered the minimum for good root growth. Below this level, growth is inhibited. With the exclusion of air, roots are killed and cannot take up moisture causing desiccation of foliage. As a result, drowning plants often exhibit the same leaf symptoms as those suffering from drought. Lack of adequate gas exchange in waterlogged soils can also lead to an increase in carbon dioxide, which is toxic to roots in higher than normal concentrations.

Several types of air injection equipment have been developed to reduce soil compaction and increase aeration. The effectiveness of these is questionable. They may be most effective in light soils where they are needed the least. There have been no confirmed reports of successfully improving root development as a result of their use.

Even when soil conditions are excellent, root systems are normally quite shallow and spread far beyond the branch tips, regardless of tree size and age. Root penetration into deeper soils is limited by most soils. Subsoils often have little pore space and the pore space that is available may be filled with water at certain times during the year. With little oxygen available, roots cannot survive there. At the time of the year when these subsoils begin to dry out, aeration is improved. As soils dry, they often shrink and cracks form up to several meters deep. The cracks help to improve aeration, allowing roots to penetrate deeply to access deep soil moisture when surface moisture may be scarce. Though the amount of root biomass in deep soils is quite small, these roots can be very important for tree survival during drought. These roots will likely die back toward the surface during the next wet season. Though it has not been studied directly, one of the keys to veteran tree survival may be that they are growing in soils that allow unusually deep root penetration that helps them to get through extreme weather periods without stress.

Optimizing Root Growth

Mulching – The critical aspects of the forest soil environment in which the roots of most tree species evolved must be maintained for good root health. The natural litter and humus covered environment of the forest floor provides an even temperature and supply of moisture, oxygen and nutrients to roots near the surface. Mulching has the same effect. A sustained mulch layer can reduce soil compaction, increase soil organic matter, water holding capacity, and biological activity. The result can be a dramatic increase in the development of fine absorbing roots. Compared to bare soil, or competition with lawn grasses, mulch can easily double the fine root density in the soil beneath, and increase it by as much as 15-fold in some circumstances. Roots also grow in the mulch itself, increasing the total surface of the root system even further.



Mulching can increase root development substantially

Roots of trees normally grow in a symbiotic association with certain soil fungi to form mycorrhizae (means 'fungus root'). These fungi have evolved along with the trees and are favored by the same conditions that promote root growth. Mulching has been shown to increase development of both fine roots and mycorrhizae, which in turn increases a tree's ability to absorb available water and nutrients from the soil.

Surface mulching is easy and effective in improving soil conditions beneath it over time, but in some situations there has been a desire to actually replace the soil. Development of air and water excavation methods and tools has made it possible to remove soil with minimal damage to even the smallest roots. An early study of partial soil replacement in the root zone of mature trees did show that root development can be improved and twig growth increased. The replaced soil may also favorably affect the soil beneath it, just as mulch does, but it has no effect laterally if a pattern of deep narrow holes is used. Wide shallow areas would be better.

Fertilization – Phosphorous has long been thought to promote root growth. There is no strong evidence to support this contention. Studies have shown that there is no increase in root growth associated with phosphorous or potassium fertilization where levels were already adequate. In nutrient-rich zones of the soil, the growth of the main root is reduced while branching of lateral roots is increased resulting in greater fine root development. Similarly, localized applications of nitrogen fertilizer can increase root density in the immediate area. Though the addition of nitrogen fertilizer increases root density near the point of application, this may not represent an increase in the total root mass. Root development in other parts of the root system may be reduced. Excess nitrogen fertilization may reduce overall fine root formation.

Fertilization could force the crown to grow excessively, enlarging the crown without enlarging the root system. Increased shoot growth of radiata pine (*Pinus radiata*) and red maple (*Acer ruburm*) due to high soil fertility resulted in a lower root:shoot ratio.

It is sometimes contended that fertilization will lead to greener, larger leaves and increased carbohydrate projection, which would then provide increased carbohydrate supply to the roots and increase root growth. This reasoning assumes that carbohydrates are in short supply in trees that are growing slowly or showing signs of decline. Large declining white oaks (*Quercus alba*) with poor root development were shown to have very high levels of stored carbohydrates. However, trees that had been in similar condition at one time, but then subjected to an aggressive fertilization program to bring back the green color and increase shoot growth, had no increased root development and had very low carbohydrate reserves. Fertilization increased the imbalance between the crown and root system. In this case, fertilization of veteran trees should be limited to correcting demonstrated nutrient deficiencies.

Tree Growth Regulators – The growth regulator paclobutrazol (PBZ), a gibberellin biosynthesis inhibitor, has been shown to reduce the shoot growth of many species. In some situations, PBZ is also known to increase certain aspects of root growth. As a result of reduced shoot growth and/or root growth stimulation, the effect of PBZ can be to increase root/shoot ratio. Photosynthesis is not reduced by PBZ treatments and increases in root growth may be due partially to increased carbohydrate supply to roots. Higher levels of ABA often associated with PBZ treatment have been shown to maintain growth of roots under drought stress. An increase in fine root development implies a more favorable root/crown balance and less stress in treated trees. Reduced water use and improved water status has been reported after treatment with PBZ. Apparent improvements in vigor, color and drought resistance may be related to a greater capacity of the root system to absorb moisture and mineral nutrients from the soil.

White oak at time of paclobutrazol treatment (left) and 10 years later

Mature, declining white oaks (*Quercus alba*) were treated with PBZ. Root density nearly doubled in 3 years. Signs of crown improvement began to show (slightly greener color) the second year after treatment and continued for over a decade. New growth was deep green and vigorous and the leaves were not noticeably smaller. The leaves were much less scorched by mid-summer compared to leaves of an untreated tree nearby. This technique is new and untested on large trees that are centuries old, but it may someday prove to be a useful tool for caring for veteran trees.

Any tree that can maintain an even physiological balance between the demands of the crown for water and nutrients, and the ability of the root system to supply them, can thrive indefinitely. Veteran trees have been able to do this, or they would not have survived. This same approach can be used to improve health and lengthen the life span of any tree, even those growing on very difficult urban sites.

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ASSESSING ENVIRONMENTAL FUNCTIONS AND VALUES OF VETERAN TREES

D.J. Nowak

USDA Forest Service, Northeastern Research Station 5 Moon Library, SUNY-ESF Syracuse, NY 13210

Introduction

Urban trees can provide many benefits to society. These benefits include improvements in air and water quality, building energy conservation, cooler air temperatures, reductions in ultraviolet (UV) radiation, enhanced property values, and many other environmental and social benefits (Nowak and Dwyer, 2000). These multiple benefits combine to improve urban environmental conditions and associated human health and well-being.

However, not all trees are equal in the benefits that they provide for society. Selection of proper species and locations can enhance desired benefits. Another important factor is tree size. Veteran trees – trees that have lived a long time and are significant elements of the landscape – often contribute substantially more benefits to society relative to other (smaller) trees in the landscape.

Not only do veteran trees contribute the most cumulative benefits due to their relatively long life span, but if healthy, these trees will also typically contribute the greatest annual benefits per tree. The purpose of this paper is to illustrate, based on field data and modeling from various cities, how the environmental benefits and values of veteran trees differ from smaller, more typical urban trees. The benefits discussed in this paper are:

- Air temperature cooling and UV radiation reduction
- Building energy conservation
- Carbon storage and sequestration
- Air pollution removal

Though the focus of this paper will be on the environmental benefits of veteran trees, it must be recognized that these trees also often have significant social benefits relative to smaller trees (Dwyer et al., 1991; Barro et al., 1997; Nowak and Dwyer, 2000).

Urban Forests

Urban forests include the assemblage of all trees and other vegetation within an urban area. To understand the structure and functions of these forests, data were collected on trees throughout all land uses in selected cities. In the late 1990's, approximately 200 randomly located 0.04 hectare field plots were measured in Atlanta, GA; Baltimore, MD; Boston, MA; Jersey City, NJ; New York, NY; Philadelphia, PA; Syracuse, NY; and Toronto, Ontario. These field data were combined with local hourly meteorological and pollution concentration data within the Urban Forest Effects (UFORE) model (Nowak and Crane, 2000) to quantify urban tree structure, functions, and values in each city. Results from these analyses were summarized by diameter class to illustrate the difference in benefits by tree size. Detailed methods and field sampling techniques can be found in Nowak et al. (1998, 2000, 2002), Nowak and Crane (2002) and www.fs.fed.us/ne/syracuse. For this paper, veteran trees are defined as trees greater than 76.2 cm in diameter at breast height (1.37 m) (dbh).

Results from the cities reveal that typically the majority of trees are less than 15.2 cm in dbh, and less than 3% of the population is veteran trees greater than 76.2 cm in dbh (Table 1). Even though there are relative few veteran trees, these trees averaged between 35 to 65 times more leaf surface area than small trees less than 7.6 cm in dbh in the cities analyzed.

Table 1. Percent of total tree population in selected dbh ranges

City	% less than 15.2 cm dbh	% greater than 76.2 cm dbh
Atlanta, GA	68.5	1.0
Baltimore, MD	62.8	2.3
Boston, MA	47.2	1.8
Jersey City, NY	67.9	0.8
New York, NY	42.8	1.4
Philadelphia, PA	57.4	2.6
Syracuse, NY	58.4	2.1
Toronto, ON	57.8	0.9

Temperature and UV Effects

Leaf area is a critical factor in determining many environmental benefits of trees. Typically the more healthy functional leaf surface area on a tree, the greater the environmental benefits. Assuming a tree has ample soil moisture and all other factors are equal, trees with a greater leaf surface area will typically transpire more water, thereby leading to greater evaporative cooling (e.g., University of California Cooperative Extension, 2000). Increased canopy cover can help reduce air temperatures, with reported reductions of maximum mid-day air temperatures ranging from 0.04ºC to 0.2ºC per percent increase in canopy cover (Simpson, 1998).

In 1995, a heat wave in Chicago caused 514 heat-related deaths, and a heat wave in London caused a 15% increase in all-cause mortality. Excess mortality during heat waves is greatest with the elderly and people with preexisting illness. Much of this excess mortality from heat waves is related to cardiovascular, cerebrovascular, and respiratory disease (IPCC, 2001). Increased urban canopy cover and leaf area, and its consequent reduction in urban area temperature can have a significant human health impact.

Increased leaf area and canopy size will also typically lead to greater shading effects, which consequently can affect the amount of ultraviolet radiation (UV) received by humans. Rates of skin cancer have increased greatly in recent years, and increased ultraviolet B radiation caused by reductions in stratospheric ozone may be responsible for this increase. Epidemiological considerations suggest that routine exposure to UV in urban areas can produce adverse health effects (Heisler and Grant, 2000). As tree leaves typically absorb greater than 90% of ultraviolet radiation reaching its surface, larger tree canopies can lead to greater reductions in UV rays reaching urban inhabitants.

Building Energy Conservation

Trees affect local building heating and cooling energy needs by shading buildings and reducing air temperatures in the summer, and by blocking winds in winter. However, trees that shade buildings in winter also can increase heating needs. Energy conservation from trees varies by regional climate, the size and amount of tree foliage, and the location of trees around buildings. Tree arrangements that save energy provide shade primarily on east and west walls and roofs, and wind protection from the direction of prevailing winter winds. Energy use in a house with trees can be 20 to 25% lower per year than that for the same house in an open area (Heisler, 1986).

Based on results of energy simulations for 11 different climate zones in the United States (McPherson and Simpson, 1999), large (> 15 m tall) deciduous trees adjacent to buildings have an average effect on building energy use 4 to 27 greater than small deciduous trees (6-10 m tall) in the same position (median value = 9 fold difference between large and small trees). This range is based on the average difference between large and small trees, with one tree at each of the 8 cardinal directions around a post-1980 vintage building. Model results of these trees revealed energy reductions in the cooling season and increased energy use in the heating season in all climate zones analyzed.

Carbon Storage and Sequestration

Increasing levels of atmospheric carbon dioxide (CO_2) and other "greenhouse" gases (e.g., methane, chlorofluorocarbons, nitrous oxide) are thought by many to be contributing to an increase in atmospheric temperatures by trapping cer-tain wavelengths of heat in the atmosphere. Globally averaged air temperature at the Earth's surface has increased between 0.3 and 0.6ºC since the late 1800's. A current estimate of the expected rise in average surface air temperature globally is between 1 to 3.5ºC by the year 2100 (Hamburg et al., 1997). Global warming is implicated in the recent discovery that floating ice over the Arctic Ocean has thinned from an average thickness of 10 feet in 1950 to less than 6 feet in the late 1990's, and a large expanse of ice-free water that has opened up at the North Pole in 2000 (Appenzeller, 2000; BBC News, 2000).

By storing carbon through their growth process, trees act as a sink for atmospheric CO_2, a dominant greenhouse gas. Larger trees, due to their increased size, will store larger amounts of carbon in their tissue as approximately half of the dry-weight of a tree is carbon. In addition, large healthy trees will typically be able to sequester more carbon annually than trees with smaller diameters. To estimate monetary value associated with urban tree carbon storage and sequestration, carbon values were multiplied by $20.3/tC based on the estimated marginal social costs of carbon dioxide emissions (Fankhauser, 1994).Based on data from various cities, veteran trees store between 600 to 1,000 times more carbon within their biomass than trees less than 7.6 cm dbh (Table 2). In addition, veteran trees continue to store additional carbon and annually sequester between 30 to 80 times more carbon than small trees less than 7.6 cm dbh (Table 3).

Table 2. Differences in estimated carbon storage and value between small (< 7.6 cm dbh) and veteran (> 76.2 cm dbh) trees in various cities.

	≤ 7.6 cm dbh		≥ 76.2 cm dbh	
City	**Storage (kgC)**	**Value (USD)**	**Storage (kgC)**	**Value (USD)**
Atlanta, GA	4.2	$0.09	2,834	$57.54
Baltimore, MD	3.4	$0.07	3,210	$65.16
Boston, MA	5.7	$0.12	3,446	$69.96
Jersey City, NY	2.3	$0.05	2,342	$47.54
New York, NY	4.8	$0.10	2,965	$60.19
Philadelphia, PA	3.8	$0.08	2,791	$56.65
Syracuse, NY	3.2	$0.06	2,665	$54.10
Toronto, ON	3.8	$0.08	2,487	$50.48

Table 3. Differences in estimated annual carbon sequestration and value between small (< 7.6 cm dbh) and veteran (> 76.2 cm dbh) trees in various cities.

	≤ 7.6 cm dbh		≥ 76.2 cm dbh	
City	**Sequest. (kgC/yr)**	**Value (USD/yr)**	**Sequest. (kgC/yr)**	**Value (USD/yr)**
Atlanta, GA	0.7	$0.01	58	$1.18
Baltimore, MD	0.6	$0.01	42	$0.84
Boston, MA	1.3	$0.03	43	$0.86
Jersey City, NY	0.7	$0.01	52	$1.06
New York, NY	1.0	$0.02	44	$0.89
Philadelphia, PA	0.9	$0.02	42	$0.85
Syracuse, NY	0.7	$0.01	43	$0.87
Toronto, ON	0.9	$0.02	53	$1.08

Air Pollution Removal

Air pollution is a multibillion dollar problem that affects many major cities worldwide. Air pollution is a significant human health concern as it can cause coughing, headaches, lung, throat, and eye irritation, respiratory and heart disease, and cancer. It is estimated that about 60,000 people die annually in the United States from the effects of particulate pollution (Franchine 1991). In addition, air pollution damages vegetation and various anthropogenic materials.

Major air pollutants in urban areas are carbon monoxide (CO), predominantly from automobiles; nitrogen oxides (NO_x), mainly from automobiles and stationary combustion sources; ozone (O_3), formed through chemical reactions involving the principal precursors of NO_x and volatile organic compounds; sulfur dioxide (SO_2), emissions mostly from stationary combustion sources and smelting of ores; and particulate matter. Small particulate matter results from local soils, industrial processes, combustion products, and chemical reactions involving gaseous pollutants.

Gaseous pollution removal by trees occurs predominantly through the leaf stomata, though some deposition occurs on the plant surface (e.g., Smith 1990; Fowler 1985; Murphy and Sigmon 1990). During daylight hours when plant leaves are transpiring water and taking up CO_2, other gases including pollutants are taken up into the leaf. Once inside the leaf, these gases diffuse into intercellular spaces and can be absorbed by water films on inner-leaf surfaces. Pollutant uptake by plants is highly variable as it is regulated by numerous plant, pollutant, and environmental forces (e.g., plant water deficit, light intensity, windspeed, gas solubility in water, leaf size and geometry, etc.) (Smith 1990).

Particles can be dry deposited on plant surfaces through sedimentation under the influence of gravity or through impaction resulting from wind. Particles hitting the tree may be retained on the surface, rebound off it, or be retained temporarily and subsequently removed (resuspended into air or transported to soil or other surface) (Smith 1990). Thus, vegetation generally is only a temporary retention site for atmospheric particles as particles can be resuspended to the atmosphere, be washed off by rain, or drop to the ground through leaf and twig fall.

Trees can also emit volatile organic compounds such as isoprene and monoterpenes into the atmosphere. These compounds are natural chemicals that make up essential oils, resins, and other plant products, and may be useful in attracting pollinators or repelling predators (Kramer and Kozlowski 1979). These compounds can also contribute to ozone formation (Brasseur and Chatfield, 1991). Even though trees may emit VOCs, other attributes of trees (air temperature reduction, pollution removal) can lead to reductions in ozone. Comprehensive ozone studies are revealing that increased urban tree canopy cover leads to reduced ozone concentrations (Cardelino and Chameides, 1990; Taha, 1996; Nowak et al., 2000; Luley and Bond, 2002).

A significant factor affecting the influence of trees on air pollution is the amount of functional leaf surface area. Veteran trees remove 30 to 65 times more air pollution annually than small trees less than 7.6 cm in diameter in selected cities (Table 4).

Table 4. Differences in estimated annual average air pollution removal and value between small (< 7.6 cm dbh) and veteran (> 76.2 cm dbh) trees in selected cities. Pollution removal is the total for carbon monoxide, nitrogen dioxide, ozone, particulate matter less than 10 microns, and sulfur dioxide. Values are based on median U.S. externality values for each pollutant (Murray, 1994)

	< 7.6 cm dbh		> 76.2 cm dbh	
City	Removal (kg/yr)	Value (USD/yr)	Removal (kg/yr)	Value (USD/yr)
Atlanta, GA	0.04	$0.19	1.6	$8.90
Baltimore, MD	0.03	$0.18	1.4	$7.66
Boston, MA	0.03	$0.14	1.1	$6.05
Jersey City, NY	0.04	$0.21	2.6	$13.81
New York, NY	0.05	$0.24	1.3	$6.94
Philadelphia, PA	0.04	$0.19	1.4	$7.36
Syracuse, NY	0.01	$0.08	0.6	$3.64
Toronto, ON	0.03	$0.16	1.0	$5.46

Conclusion

On a per tree basis, veteran trees typically contribute significantly more environmental benefits and value to society than smaller trees. These beneficial functions provided by veteran trees require that these trees be healthy, functioning elements in the urban landscape. By being healthy, veteran trees offer significantly more leaf surface area to interact with the surrounding environment. The gas exchange exhibited by large, functioning veteran trees can provide significant environmental benefits such as air pollution removal, carbon sequestration, and air temperature reduction. In addition, the relative large leaf surface area of veteran trees often provides more shade than smaller trees, leading to increased potential benefits from reduced building energy use (if trees are located in the proper position around buildings) and reduced exposure to ultraviolet radiation. As veteran trees produce some of the greatest environmental values, these trees can offer the greatest single tree effects to improve human health and well-being in urban areas.

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RESTORATION AND MANAGEMENT OF HISTORICAL PARKS

G. Bovo, G.M. Cirulli
Municipality of Turin – Green Management Section

General

What does monumental tree mean? If we try to give a spontaneous and immediate definition, we think of an important tree, a tree of remarkable age and size, worth of particular care. If we want to give this mayby somewhat simplistic definition a more authoritative and exhaustive outline, we find a number of prescriptive references which widen the concept and meaning of monumental tree:

- ***Law 1089/39***, absorbed into unified code 490/99, gives the definition of a cultural asset and states that objects being of a historical and artistic interest (and therefore trees too) must be at least 50 years old, states the principle of a public enjoyment of cultural assets, stipulates about authorisations in the case of an intervention of any nature on the cultural asset, imposes the principle of conservation also to private possessors of objects being of a cultural interest, states sanctions in the case of a breach of said principles;
- ***Law 1497/39, "Protection of the beauties of nature",*** also includes villas and parks not protected by particular rules but distinguishing for their unusual beauty, provides for the compilation of lists on provincial basis by a dedicated panel;
- ***Unified Code no. 490/99*** that collected all environmental laws and rules into a sole law instrument;
- ***Regional Law no. 50 of April 3rd, 1995,*** to protect and improve Piedmont monumental trees having a high naturalistic and historical value. It is a specific law aimed at identifying the monumental trees and rows, being of an interest from the landscape point of view, that are present on the region and at promoting their protection and improvement. It defines, as monumental trees and rows, being of an interest from the point view of history and culture, as well as environment and landscape:

¨ trees either isolated or belonging to natural or artificial wood formation *which can be considered as rare examples of imposing and long-lived trees for their age or size*;
¨ trees having a precise *reference to events or memories rilevant from a historical or cultural point of view;*
¨ tree rows of *particular value from the landscape point of view, as monumental trees, and from a historical or cultural point of view*, including rows inserted into urban centres.

The law is also aimed at producing a census the list of which is published on Piedmont Region Official Bulletin (B.U.R.) and sets up a Technical Committee for the protection and improvement of monumental trees and rows. It is a definitely important measure, specifically focused on monumental trees subject. Besides involving particular regulations, monumental trees have features, quite different from ordinary trees, requiring specific actions and interventions:

- they are to a greater extent subjected to meteorological and climatic events (the action of wind, changes in humidity, sudden changes in temperature, excessive solar radiations,….), therefore resulting that it is important to regularly monitor their conditions, mainly after particularly severe events;
- they are characterised in the so called *"terminal growth"*, i.e. crown developed mainly on their terminal portion and very heavy branches accumulating strains and breakage risks, which can be pruned for lightening by cutting out their dry parts, also with the purpose of making light access easier and photosynthesising superface larger;
- felling neighbouring trees results in loosing the "*wood*" effect and making sudden crashes more likely; this is an event which occurred in plenty of instances, both in private homes and public green areas, sometimes with unpleasant consequences;
- frequent are problems at root level, which result in a lower growth, thinned out leaves, chlorotic colour;
- cavities are more likely to be found where it is possible to intervene both by reducing the crown and restoring its balance and by using dynamic tie rods. The latter is a technical contrivance which is still unfrequently used but could where matched to a sound pruning remarkably contribute to improve the safety coefficient of trees having problems related to performance and steadiness.

It results from these short considerations that monumental trees may have health problems, that they may be somehow delicate subjects and that also for these reasons, besides their importance, a historic park and its trees must be considered a heritage to be protected and at the same time shared and kept alive.

Cavour park at Santena

Benso of Cavour park lies at Santena settlement, a village close to Turin, and, although developing over an area having a rather small size (about 16 hectares), it represents a very interesting example of a historical Park with a public management and use owing to history and tree heritage contaied (several specimens result to have been registered already in 1762). It started as a a private residence and, after a turbulent and articulate history rich in ups and downs, it finally become a public park with characteristics that are atypical with respect to ordinary standards.

Benso Family was rooted on Santena region and their presence in this small village is proved by documents already since XII century: it results from this fact that the history and events of the park and and buildings that are present there were closely connected to the chequered fortune of the family. In the second half of XVIII century, a park could be already identified, having a geometric design, made up of four *parterres*, a vineyard bounded by borders and a stream (*Old Santena*) crossing the area splitting it into two portions and flowing into *Banna torrent*; there were also regular curve tree lines bounding garden central visual space. The *parterres* were then converted into a sole large regular meadow maybe fit out for agricultural purposes.

Banna torrent control works go back to the period between XVIII and XIX century. This torrent often overflew into Santena property and settlement. Back to this period goes a project to modify the garden. This project can be attributed to *architect Lorenzo Lombardi*, who had already devised 1797 Turin Napoleonic Land Use Plan. This was the first complete project of the park, named *"Plan Geometrique des Jardines de Santena"* [Geometric Plan of the Gardens of Santena], where the main role was assigned to the arrangement of vegetation by using shrubs, hedges, borders. As a matter of fact, no reliable testimonies of this project live on. Therefore, it was either left uncompleted or distroyed by one of Banna torrent floods. Park present shape and size were reached in early XIX century thanks to the arrangement of *Abbot of Arvillars*, commissioned by Benso Family. As a matter of fact, no evidences proved by documents and reliable confirmations of his contribution exist about this step too. Anyhow, the park results to have had at a *"romantic"* feature that time, with vegetation elements arranged in groups and groves and winding paths, all this providing an informal atmosphere.

Based on the example of main European courts, in Piedmont too the art of building gardens became popular and *Xavier Kurten*, one of the best known landscapists of the time, was in 1820 appointed Director of the gardens of the House of Savoy and of the park of the residence of Racconigi. The influence of this great landscapist, thanks to his being backed at Savoy court, spread out not only into royal residences but also into numerous residences of nobles. The known landscapist was commissioned to intervene on the park of Santena, also considering that the role of Benso Family wthin Royal Family had now become relevant and that the residence needed to be transformed from an agricultural firm into a country palace.

Kurten operated a number of botanical choices on a general plant which was already defined at that time (*1830*). His botanical choices represent the park artitecture itself. From the avenues, he chose the most significant and representative tree specimens, which were kept isolated or clustered. Evident is the use of compositive categories that are typical of this designer, such as the isolated tree, aligned tree, group and grove, although adapted to park small size. Park area hydrogeological characteristics are one peculiar elements. Already in XVIII century, there was a marshy area because of both neighbouring Banna torrent and Old Santena torrent flowing splitting the property into two portions. Banna torrent control by building a two-metre bank and burying Old Santena torrent allowed to recover the area, even though the nature of the soil did not cange, so that Kurten decided to keep existing ponds providing an aesthetic feature.

The so sketched park can be led back to three prevailing elements concerning the landscape that are related to to the project:
- a circular path characterised by imposing present trees;
- a path, maybe prior to Kurten's intervention, connecting the Villa to the pond;
- a third path, connecting the two, with a more evident panoramic feature.

From the intervention by Kurten in the first half of XIX century to nowadays, the park was not subjected to big modifications but for some planting on the celebration of the centenary of the Unification of Italy (in the '60s) and for some maintenance interventions needed after Banna torrente floods; the most significant floods occurred in 1901 and 1951.

In 1958, the City of Turin operated a number of interventions through Gardens and Trees Lines Service in order to make the park more accessible to the public and, on this occasion, a hundredth of veteran trees, which were considered to be unstable and dangerous, were felled. A successive opening of the park to the public, joined to a defective conservation management of the tree heritage, forced massive phytosanitary interventions in late '80s, with felling of seriously impaired specimens.

In this period, there are both a complete inventory of the tree heritage by filing the specimens from a phytopathological point of view integrating visual checks with instrumental analises using a Pressler's sampling borer (V.T.A. was not yet mentioned) and collaboration with the University of Turin aimed at gaining scientific information and data useful for improving park management. In early '90s, in the Park, there were made the first stability investigations with V.T.A. (Visual Tree Assessment) method. This technique was at that time innovative. It was used at a national level for the first time. In 1996, Park monitoring was completed with V.T.A. This method has since then been a consolidated practice contributing to define trees health state on a yearly basis. Trees health state is a data that is fundamental in setting maintenance interventions.

Between 1994 and 1997, the City of Turin commisioned the University to make a study aimed at trying to investigate on the crash of monumental specimens appearing to be healthy but in retrospect showing limited root development. The study results did not include particularly serious pathological situations and the study identified following contributory factors among possible causes:

- abundant water present in surface profiles with resulting root aparatus in surface horizons;
- consequent development unbalanced between hypogeous and epigeous portions;
- numerous trees slanted as first bed out in clusters, then led into rows;
- soil chemical and physical characteristics not contributing to cohesivenss between soil and root.

Just to give an idea about figures and connected maintenance needs (in economic terms, without being limited by them), consider that the Park at present includes about 800 tree specimens (580 of them are taller than 10 metres) often having an extraordinary size in crown both height and diameter, the species most abundantly present being the plane (going back to XVIII century for numerous specimens, which are taller than 30 metres), oak (common oak and durmast), hornbeam, cypress.

Benso of Cavour park is a particular instance also from property point of view. After chequered fortunes and numerous conveyances of propriety, in 1947, Marquis Visconti Venosta donated the Palace and the buildings of Cavour Museum and Archive to the City of Turin.

Since 1988, a covenant, now expiring, has been in force governing the relations among the City of Turin, the City of Santena and the Camillo Cavour Foundation (set up in 1955) and has established the technical and legal terms that are relating to the managemt of assets. The Foundation is managing the buildings (the Palace, Cavour Museum and Archive) and a park portion relevant to them, while park remaining portion is up to Santena Municipality, the two being superseded by the City of Turin to which the management of all area tree property is up in consideration of the specificity of specimens present.

Such an articulate and artificial splitting of competence and duties into three bodies is not responsive to functionality criterions and further generates plenty of logistics and management troubles; most of all, considering that two of these bodies (the Foundation and Santena Municipality) are rather unwilling to schedule funds for managing the asset, also because of their actual difficulty in finding dedicated resources, an area overall situation results not being adequate to the importance and history of the park itself. In last months, the paperwork to roll over the already expired covenant has been in progress. The priciple the paperwork is based on is a revival of this historical residence on the whole (Palace, Library and Park) and its innovative element is the identification of a body which will be entrusted with the management of the whole asset and obviously will have to meet regulation constraints and jontly agree upon and operate with both proprietor (the City of Turin) and Public Green in all management choices and actions.

The drafting of a park avorall restoration program has been recently (1994) commissioned to achitects skilled in historical residences and gardens. The estate use and management program guide lines have also been identified and defined in this drafting.

The project provides to maintain and recover the arrangement, proposed by Kurten, through the analysis of architectural, botanic, landscape and phytosanitary components. It highlights as a negative element the splitting of management competence into more bodies and reckons that the implementation of the restoration program is closely depending on a more functional and organic arrangement, with a lightening of use load through the realisation of a riverine park in the portion now subjected to agricultural use and with an improvement of the distincion among areas uses.

About arboreal part, the project provides to: maintain the most abundantly present and most representative species (plates, oaks, limes and hornbeams) as single, twinned or clustered trees; reintroduce clustered minute texture species, and only use coniferous trees for extending sight (thanks to dark leaves) and creating groves within a limited space and time. It proposes to reintroduce either native species or species that became acclimatised thanks to leaf chromatic alterations (copper beech, white popler, catalpa), to be used at points of particular interest.

It is desirable that the future manager of the area applies the line guides that have been identified in this restoration program in preparing a new covenant, with the purpose to give back the park and residence the status and role deserved by them.

Monumental trees management and the instance of Santena

The subject of managing "aged" tree specimens is quite involving and there are often clashing postions. Recently, in some contexts, it seems that a critical line is prevailing with respect to management choices, which are aimed at keeping alive not perfect specimens, because of economic costs considered unsustainable, perhaps thinking to apply firm and industrial principles where all is depending on economic rules.

Urban tree lines and also trees in historical gardens and parks often are not in optimal healthy conditions indeed; in some cases, they are affected by age and hard life together with man, the city and connected needs, with a management which did not prove to be adequate at a both technical and cultural level. Replacing partially impaired specimens by new specimens can make some sense in determined circumstances, but it is not a care for all problems. Monumental trees are to be considered as an integral part of cultural heritage and, therefore, must be treated from the point of view of conservative management, avoiding to compare historical green to conventional urban green, working on terms of maintenance, conservation and restoration. A frequent question made by people or by ourselves is *"till when have I to keep (alive) trees?"*

A reply could be: till they are sure, and longer, if I can. Arboricolture technologies and know-how make it possible to best manage aged tree lines preserving the specimen considered to be valuable and undertaking to reintroduce new ones in valid stational conditions rather than just to step into a breach and show that "something is being made", either using specimens and trying to keep the original design or through a smooth replacement or an integral reconstruction of arboreal. population

Ordinary and extraordinary maintenance interventions in a histotical context must be an integral part of a management plan resulting from the analysis of original project, vegetation component, landscape and architecture knowledhe/significance, aspectations, **user safety**, and its interactions.

Tree management must be based on criterions, that are objective, and not only linked to technical know-how, as well as on the identification of intervention priority levels. This is also to avoid that, within a context characterised in a constant lack of funds, choices are forcedly conditioned by a subjective (or, more correctly, emotional) component.

In the City of Turin, there has for some 10 years been developing a cultural transformation process in tree management with the aim of introducing a model which, starting from (technical and territory) knowledge and based on objective criterions, is aimed at optimising the choices and substantially includes three main stepss:

- knowledge
- planning
- action

One of main points in this new management model is introducing a planning tool to identify intervention priorities named *"Arrangement Plan" (P.d.A.)*.

It is a tool based on the identification of technical and scientific parametars making a snapshot of analysed object (the tree line, in this case), where each pareameter is given a fixed, not weighed out weight (score); the addition of the various scores defines the tree line potential risk level. Used parameters include dimensional, physiological data, linked to trees health state and context where trees are located. By adding the data relating to maintenance history, the urgency level is obtaiend, so a grid is generated, which simply and objectively defines, for each tree line or homogeneous unit, both a score that is linked to the potential risk level and an intervention urgency level index.

This tool is used to manage pruning and stability checks and is provided with verification and self-checking mechanisms allowing for analysing and possibly justfying in retrospect the choices that were made. This is a fundamental value, in a sector where management results in responsibilities at civil and penal level. It is a tool which, coupled to the knowledge of the region and the experience of cultivation/tree technique, also enables to plan and schedule the interventions. Turin experience showed that, while maintaing the first position to the role of the technician, with his/her know-how and experience, it is useful to use management systems which somehow aseptically and objectively identify risks and priorities. In a linear and somehow homogeneous context, such as the one of a tree line, it is simpler to adopt this management guide line, also because the health state of trees, the presence of anthropic activities force somehow the need of regularly intervening with more or less regular shifts (provided that economic availability allows it).

In a reality characterised in differing features, such as the one of a historical park with monumental trees, the point of view is changed, because the identification of a risk index not necessarily must correspond to a concrete action, which could irreversibly damage the specimen, although, on the other hand, a normal event like a dry branch fall can produce serious consequences on oversized trees. Having to manage plenty of historical parks used by the public, it can be useful to transfer this objective and functional management model fitting it to the peculiarity of the arboreal populations of these sites, with the aim of creating a data frame allowing to somehow standardise the approach, being aware that there are faced specimens that are in some way sole specimen, where the priority is to know, not to plan. Tecnichal and operational choices such as stability check, the application of more or less regular pruning shifts on monumental trees can become meaningless and be insufficient to assure asset good management and even obtaining a priority index could be unsuitable to the context. Using "urban tree lines" pda, modifications were made and parameters were introduced being more suitable to the reality of the historical park which were grouped into homogeneous sub-groups, obtaining a set of categories taking into account:

- stability analysis with relating risk class;
- potential risk from the tree objactively occurring, for its position (target of and exposition to wind), this being an element which can be managed but not modified;
- potential risk linked to tree size (hight, diameter, crown) and faults present (rot, stringy branches, slanted trunk, etc..), this being a data which acan be modified and managed with cultivation operations;
- morphological and geological peculiarities linked to context, in the case of Santena the presence of the surfice layer which conditions root apparatus growth and tree stability.

In this way, there are not obtained any overall final scores, which wuold have been rather useless, but a set of distinct values, which define aframe repreenting the peculiarities of monumental trees in a historical park and identifies "risk areas", attention thresholds where interventions are to be focused to a greater extent.

The different data can be used either disaggregated or together in order to decide maintenance interventions also considering the point where trees are located and personalising choices depending on cases; as an example, on trees with stability problems having a high target, crown reduction operations shall be performed, while isolated trees can just be kept under observation limiting interventions to dry portions removal and periodic stability verification. This data can be trasferred to plans in order to map risk areas and obtain a region deep knowledge visual frame. So a transition is made from the management of a typical urban environment, where, owing to large figures and management needs, the judgement about the tree unit is uniformed and where we are somehow forced to manage trees in the logic of "compulsory" rated interventions, to a management which, although adopting an objective methodology, takes into account both context and particolarities odf specimen which are sole specimens. It is an operation requiring a remarkable expenditure of energy in the preliminary step, but the result achieved is a an easy-to-use tool which does not pervert the technical role and is anyhow the evidence of adequate involvment and care, as well as a summary of what is provided by arboricolture techique and technology as applied to an atypical context.

In a reality of this kind taken in account can also be management improvement choices such as elevation check, root inspections, which, in urban contexts, can involve huge difficulties in application and a risk of creating a precedent.

Considerations

Tree management probably needs a cold blood or perhaps sound madness, as well as a serenity in facing living being which, by dying, may unfortunately create even serous problems to users and environment.Looking at past texts, you find out that wood rot was considered in XVIII and XIX centuries by our collegues as a natural event, a sign of the age, especially for very old trees, while serenely accepting the cours of nature and time. Perhaps such serenity came from missing legal implications on users' safety, but also from a more aware relationship between man and nature, where the decay and death of a tree were correctly considered as all natural events.

In tree management in last decades a transition occurred from choices borrowed from other fields (namely agriculture), to panic linked to bad events, running after a remedy to dispose of / release from problems, responsibilities, risks. As soon as a serious event occurs linked to the fall of a tree, there is a temptation to react trying to remove the problem, maybe even before understanding what happened and why, without caring about whether making like this it is nullified a heritage of knowledge, experience and results buit up over years. If the point is removing any responsibility, there is a sole reply: not being involved in managing trees or convincing the one who holds the reins that in front of any doubt the problem must be suppressed at the root (fitting, isn't it?….).

In my opinion, it can now be tried to approach again to a serene but aware management concerning the treatment of monumental trees marked by time and man. Research, technique and technology, and current practice have extended the range of choices and management capabilities, while keeping steady the strong points, which are the respect of the dignity of the tree and what is represented by it whlile guaranteeing users' safety.

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MANAGEMENT OF MONUMENTAL TREES: REVIEW ON THE EFFECTS ON PHYSIOLOGICAL BALANCE AND ON TREE BIOMECHANICS

F. Ferrini
Dipartimento di Produzione Vegetale - Università di Milano

Introduction

It is known that as a tree ages its growth markedly changes and that several physiological changes are associated with plant aging. Unfortunately, while aging of cells and organs (i.e. leaves) has been deeply studied, only limited information can be found on woody plants considered as a whole. As a matter of fact, though woody plants show significant and predictable patterns of changes in morphology and physiology as they age, the study of the possible mechanisms controlling these changes is quite difficult because of the large biomass interested and the complexity of the processes involved which have also arisen some controversies among the different authors.

Understanding the growth and the physiological behavior of old trees is important both for ecological studies of natural stands (Ishii et al., 2000) and, as in our case, to know what are the effects on tree physiology and on tree biomechanics of some technical practices which are commonly applied in mature to veteran tree management.

Aspect of aging

It is quite difficult to situate exactly the beginning of the aging (senile period) in woody plants, because the processes that regulate aging are not fully understood in these kind of plants like they are in animals and annual plants, which aging and senescence are genetically regulated (Bond, 2000). We may consider that it happens at the moment when both vegetative growth and differentiation phenomena reach their maximum expression. Senility then can be defined as the phase of life that begins when the individual is at the last stage of adultness and it is characterized by erosive processes which conduct toward death. Similarly to what happen in the change from juvenile to mature phase (Greenwood, 1995), there are probably a number of "switches", either in series or parallel, both endogenous and exogenous that must be activated for the senescence phase to occur.

It is evident that at least in some woody plants the absolute quantity of organic matter does not increase during the senile period; on the contrary it diminishes. The changes that take place during this period are mostly endogenous and of physiological and biochemical nature, circumstances that make the bibliographical search not easy. In addition ontogenetic aging (maturation) in trees has received less attention compared to other research topics because, as already stated, the study of woody plants becomes more difficult with aging and tree size.

In spite of some studies published on this subject, it is not easy to distinguish between the effect of age, size or environmental changes connected to aging, much less the interactions among these factors. However, new techniques (i.e. analysis of stable isotopes, improved approaches for measuring sap flow) and better field equipment are helping to make studies of tree aging more feasible, though we are far from a comprehensive understanding (Bond, 2000). Furthermore there is no full agreements about what the word "aging" really means, because terms related to plants can have a similar or different meaning (Fontanier and Jonkers, 1976; Nooden and Leopold, 1988). As underlined by Trippi (1963) many authors refers to "aging" when they talk about the transition from juvenile phase to adult or senile phase; also when they talk of vegetative and reproductive state (in this case the term "maturation" seems to be more appropriate). Others state that the senescent phase begins when the trees start to deteriorate as a results of damage or disease (Del Tredici, 2000). Paraphrases such as "decreasing vitality" and other definitions have been used for it (Bernatsky, 1978).

According to other authors we can describe three different types of aging in plants (Fontanier and Jonkers, 1976; Clark, 1983; Del Tredici, 2000; Fay, 2002).

- chronological aging, which is the time that has elapsed in the course of the lifespan of the entire plant or some part of it.
- Ontogenetical aging, related to the process of a plant passing through different phases of development (i.e from seedling to senescent phase). The ontogenetical aging process, called maturation or phase change by some authors (Ritchie and Keeley, 1994), is controlled by the meristematic tissues of the tree and it's not uncommon for different parts of the tree to be in different growth phases at any point in time, as when juvenile suckers originate from

fully mature trunk tissues. According to Fontanier and Jonkers (1976), ontogenetical aging is genetically programmed, localized in the meristems, not related to exhaustion, and cannot easily be reversed.

- Physiological aging (senescence), referring to the general condition of the whole plant, describes the development as well as the deterioration of the life-support systems of the tree. It represents the negative aspects of aging such as loss of growth vigor, the increased susceptibility to adverse conditions (stresses), etc. These negative aspects gave origin to a new branch of science called phytogerontology which, however, hasn't developed like others. Del Tredici (2000) states that physiological aging specifically covers the loss of vigor in the root or shoot system that results from environmental stresses or from the damage caused by wind, fire, ice and snow. In general, the physiological aging process is controlled by the differentiated tissues of the tree. Physiological aging is correlatively influenced and caused by an increase disorganization and exhaustion, and it is not localized in the meristems. When not advanced, a reversal is possible (Fontaniers and Jonkers, 1976).

This paper will be mainly focused on reviewing the present knowledge with regard to the changes that happen during physiological aging.

The major symptoms of this phenomenon are a decrease of the metabolism, decrease in both photosynthesis and respiration, changes in enzymes activity, reduced growth of vegetative and reproductive tissues, different hydraulic and mechanical properties of woody tissue, increase in dead branches, heartwood formation. Slow wound healing, and changes in resistance to invasion by certain insects and pathogens are other typical features of woody plant senility (Kozlowski, 1971; Fontanier and Jonkers, 1976).

Some of the mentioned aspects are the object of other presentation in this Congress so I will focus, according to the title, on the physiological aspects of woody plant aging and on the effect of some management techniques on tree physiology and biomechanics.

Physiological and anatomical changes

The phase of aging is characterized by a slowing down of metabolism activity. Some studies have shown that while leaf area of aging trees remains practically constant, its total photosynthetic output slightly declines while respiratory consumption of food increases (due to the increased amount of non-photosynthetic tissue increase), so that the leaves are not able to provide adequate photosynthates for the requirements of the old tree (Kozlowski, 1971; Day et al., 2001). The results obtained from research carried out on conifer trees have shown an age-related trends in both morphology and physiology, an increased competition for nutrients between the various parts of the plant (Moorby and Wareing, 1963) a decrease in photosynthetic rates contributing to declining productivity in old trees (Bond, 2000; Day et al., 2001). Several studies attribute this lower photosynthetic rates in older trees to a reduction in stomatal (or crown) conductance with increasing tree age which, in turn, is caused by a lower hydraulic conductivity in their longer or more complex hydraulic pathways. Based on this some authors have proposed the "hydraulic limitation hypothesis" (Ryan and Yoder, 1997), which states that with increasing tree height growth and productivity decline because of stomatal limitation induced by greater tortuosity (i.e. branch juncture), increased hydraulic pathway length resistance and gravity and reduced allocation to roots (Ryan and Yoder, 1997; Bond, 2000; Phillips et al., 2002). Increases in hydraulic resistance could reduce the supply of water for transportation, which in turn could limit stomatal conductance and photosynthesis (Bond, 2000; Coder, 2002). This hypothesis is supported by recent data obtained on *Quercus robur* mature trees (Rust and Roloff, 2002). In addition to the lower conductivity of xylem in old trees, structural changes in shoot and crown architecture need to be considered when analyzing water relations and photosynthesis in mature and declining trees (Rust and Roloff, 2002). However, some contrasting results do exist and it seems that hydraulic limitation, though may be a significant factor determining growth reduction (Battaglia, 2001), does not act on photosynthesis in a simple mechanistic way or that other factors play a key role in age-related decline in some species (Day et al., 2001). Actually, as shown by West et al. (1999) conducting tubes must taper and, consequently, the resistance to fluid flow per tube are independent of the total path length and plant size. Becker et al. (2000) state that leaf area:sapwood area ratio rather than path length, may dominate in determining whole plant conductance. These authors also state that the structure of the xylem cells might change as tree grow older to make the wood less resistant to water flow. As a consequence the sapwood area per unit area might increase and the sapwood of large trees might store large amounts of water, thus "buffering" the effect of hydraulic resistance (Bond, 2000; McDowell et al., 2002).

According to Coder (2002), several physiological causes are involved in tree aging responses. He reports that 25% of these responses are due to photosynthesis reduction, 10% to sapwood respiration, 20% to soil resource availability, 39% to transport path length and complexity, 5% to detrimental mutations in genetic materials and 1% to reduced defense ability. Grulke et al. (2001) also found a different allocation, with young plants having the highest allocation in roots and foliage and older plant in woody tissues, though their work was limited to mature and not senescence trees.

Among the other physiological factors it is known that hormones play a dynamic causal role in endogenous regulation and control of plant senescence (Noodén and Leopold, 1988). While this concept is generally accepted, much is yet to be learnt about their effect on mature tree physiology. Actually, even if research on the classical plant hormones continues to uncover fascinating interactions among these crucial regulatory compounds and how these interactions can affect signal transduction or hormone biosynthesis (Fontanier and Jonkers, 1976; Ross and O'Neill, 2001), the results are mainly related to herbaceous plants and, as such, not always can be directly applied to explain some physiological traits of woody plants.

Vegetative growth

Even perfectly healthy and undamaged trees slow down in growth as they reach an advanced age. This lack of vigor may also cause an increase in susceptibility to insect pests and to pathogens. With aging shoots become shorter and weaker, the amount of food absorbed being insufficient to support the whole crown, and as time goes on they gradually die downwards towards the trunk. Clark (1983), referring to other authors' works, states that as the tree grows larger, the ability to respond to environmental stimuli or timing of that response increases. This can explain why older trees in landscape situations are much more sensitive to site disturbances. Kozlowski (Kozlowski, 1971) affirms that loss of apical dominance usually accompanies reduction of shoot growth in aging trees. The same author, referring to a previous research on conifers, states that as the branches became older, they changed their growth angle to a more horizontal, so that the structure of the crown can be strongly modified. This has to be taken into account when managing monumental trees.

Changes in wood characteristics

In the old trees the wood is not uniform throughout the trunk: there is a definite pattern in its development which reflects the changing activities of the vascular cambium and changes in cellular differentiation at different periods in the life of a tree (Jane, 1970).

In fact, several important anatomical changes occur during the aging of trees which influence wood quality. Kozlowski (1971), reviewing other Author's papers, states that with increasing age the percentage of latewood (wood formed later in the season) increases for a number of years and this change is accompanied by increase in specific gravity and strength. In over-mature trees, however, the specific gravity of wood often declines and little or no latewood is produced. Also the over-mature wood can have a higher lignin and lower α-cellulose content than wood formed when the tree is younger.

Another change of paramount importance regarding wood anatomical and mechanical characteristics is the heartwood formation. As known the wood of young trees is entirely made of sapwood which is physiologically active (it contains from 5 up to 40% of living cells) because it serves as an avenue for translocation of water and minerals (Kozlowski, 1971). The changes in wood associated with aging are a result of a genetically controlled process (Shigo, 1984) and are primarily functional, for, after a time, the parenchyma in any zone of wood in a tree loose their its living protoplasts and the vessels and tracheids cease their conductive function (Jane, 1970). It is generally believed that after these changes have taken place, the only functions of the wood are those of support and as a repository for waste materials and is considered physiologically inactive, although it has been suggested that the wood may still serve as water reservoir.

As sapwood passes into heartwood, some changes in physiology and anatomy happen. These include altered metabolic rates, changes in enzymatic activity (i.e. increased peroxidase activity), starch and food reserves depletion, darkening of xylem associated with deposition of extractives, gums, resinous and phenolic components, tannins, coloring matters, changes in wood density, anatomical changes such as increase pit aspiration in gymnosperms and formation of tyloses in angiosperms, and changes (decrease) in moisture content (Jane, 1970; Kozlowski, 1971; Gjerdrum, 2003). These changes can have a direct influence on wood disease resistance, because heartwood is less prone to be attacked by fungi and insect due to its higher content in preservatives substances, though this statement has been disputed by old and recent studies because there is a sufficient air in the heartwood for fungal growth, while the wetter sapwood does not contain enough air to make it suitable substrate for wood-rotting fungi (Jane, 1970; Read, 2000). Decay of the inner wood can be actually positive because the hollowing are part of a nutrient recycling process and as stated by some authors (Read, 2000), tree can make use of the products of wood decay inside the trunk by producing aerial roots form its above ground parts, which grow into the rotting stem.

Management techniques of veteran trees

The problem which quite frequently arises is whether it is worth spending money on very old trees in order to lengthen their existence, or whether they should be left alone and a young tree planted somewhere in the vicinity. No one would spend money in a obvious wreck, but any tree worth keeping is worth some sort of attention. It needs very little, as a rule to keep a tree wind- and water tight (Le Seur, 1934).

According to Read (2000) the first thing to be considered is to distinguish two types of veteran trees: those that have been actively managed in the past and those which are not, though in practice, the techniques may not be so diverse. In addition we should bear in mind the location of the tree. Veteran trees located in the urban environment are subjected, compared to those located in the open country, to several stresses which can strongly affect their health and shorten their lifespan; this must be considered when managing these trees. There are numerous management techniques that must reflect the changing and the function and that must consider the long-term consequences of environmental changes (Clark and Matheny, 1991). Some of them (tree securing, use of biostimulants, growth retardants and mycorrhizal fungi) have been extensively reviewed by other speakers in this Congress; therefore they will not be considered in this paper that will try to provide an outline of the literature pertaining to the effects of pruning and, in general, of some cultural techniques on tree function and structure. However, according to Clark and Matheny (1991) we can state that "the maintenance of a balance between growth and the environment is a basic requirement for continue development and longevity….Arborists must strive to maintain stable growing condition through long-term programs of care and facilitate the restoration of balance within a tree whose environment has been disturbed". The same authors arise a practical question that is: "what management techniques can be applied to a tree to avert or postpone the development of the mortality spiral?"[1].

Pruning

The first answer to the question is to help the plant to develop a stable structure. Crown structure has a fundamental importance for tree physiological behaviour determining substantially the spatial distribution of the photosynthetic surface, the water loss (evaporation and transpiration) and, as a consequence, directly influencing the mechanisms of water and nutrient uptake and transport. Crown structure also affects the mechanical resistance of the tree though a notable variability exists in the geometric structure due to a great phenotypic plasticity, that makes the schematizations difficult but, on the other hand, allows great manipulation possibility of tree form.

In this scenario we can easily guess how pruning techniques can affect tree physiology and have strong effects on tree health. Actually, pruning determines a different partitioning of the total dry weight, with a greater production of new shoots and a smaller development of the structure (branches, trunk and roots). However the growth of such new shoots is proportional to pruning intensity only to a certain extent, over which it decreases.

Fontanier and Jonkers (1976) state that a severe pruning of the branches or stems is effective in delaying the time of aging. It shortens the internal transport system and improves the supply of the periphery with water and nutrients. This can be regarded as a physiological rejuvenation. Pruning also induces younger buds or tissue to form normal or adventitious shoots, those being more juvenile than those removed. This can be seen as a kind of semi-ontogenetical rejuvenation. Though severe pruning and crown restructure can be required for safety reason, such a rejuvenation cannot be continued indefinitely, because each pruning activates the present meristems, involved the commitment of significant resources; the typical response to this kind of pruning is profuse sprouting that can result in energy depletion, dieback, increased susceptibility to secondary pests or decline, thus inflict an additional stress to old (or declining trees), and stimulating their ontogenetical aging (Clark and Matheny, 1991). Furthermore the elevated production of new vegetation strongly reduces nutrients reserves, in particular of carbohydrates, stored in the unpruned part of the tree. In fact plants subjected to pruning show alterations in carbohydrates metabolism in comparison with the unpruned plants, in particular at the beginning of the vegetative season, when, in the shoots in active growth, a presence of an elevated level of soluble carbohydrates, above all with regard to the contained in starch, can be detected, while the reserve accumulation phase begins more lately. According to Evans (2004) this kind of pruning has deleterious repercussions on the relative allocations and prioritisation of a tree's carbohydrates budget.

A review on this subject was made by Clair-Maczulajtys et al. (1999). Based on the assumption that reserves are not homogeneously distributed in the tree, but are stored in special areas or "compartments", in relation to the species, stage of development, environmental conditions, and cultural techniques like pruning, they showed how tree pruning (especially when heavy pruning is applied) can induce a decrease in the quantity of reserves (crown volume reduction, foliage removal, new sinks) and determine important changes in their partitioning. They underlined how abrupt changes in tree care, can have deleterious effects on tree health, causing a general decrease of reserves and, as a consequence, reduce the resistance to pathogens and predators and to the environmental factors. Thus, to avoid radical pruning effects on tree structural stability and on pest problems, pollarding can be considered as a real alternative (Coder, 1996). A tree responds to pollarding by building a dense mass of woody fibres around the cutting points. This bulky mass resists decay and effectively divides the vigorous juvenile growth from the aging stem (Harris et al., 1999). Hence, the defensive and structural integrity of the tree is maximized using this pruning system, because pruning cuts are made when biological reactivity of the trees is quite high and living cells quickly react to wounds and environmental changes and can develop a strong defensive reaction (Coder, 1996). Also pollarded trees develop a constantly rejuvenated, energy-creating young canopy, on top of an increasingly ancient trunk. This slows the tree's normal aging processes. However, while some species can positively react to pollarding (*Quercus*, *Platanus*, *Tilia*), some others (*Fagus* and *Acer* species) do not always tolerate pruning (Mattheck and Bethge, 1998). According to Raimbault (1995) we can state that pollarded trees anticipate the natural, uninfluenced behaviour of at least some species.

Even the hormonal frame of pruned plants can be deeply altered because of the removal and activation of numerous meristems that are, at the same time, hormone producers and users. In particular an increase in the activity of cytochinins, auxins and gibberellins has been found, with some fluctuations according to the phenological phase of the plant. Cytochinins content and activity is very high in the growing shoots of pruned plants, while gibberellins content is relatively low in the bud break phase to significantly increase only later in the season, showing substantial differences among pruned and unpruned plants. The auxins seem to increase above all in the branches following the stimulus induced by cytochinins, even if a strong activity of synthesis of the root system, due to the altered crown/root ratio cannot be excluded. The increase in the auxins and gibberellins synthesis promotes the development of the vascular system and activates nutrient transport, thus intensifying the growth of the new vegetation.

Bearing in mind this knowledge about how pruning can influence the physiological balance of a tree it is easy to guess how difficult is to manage veteran trees in order to improve their stability without negatively affecting their physiological balance which, in the long term, can push them ahead into a mortality spiral (Clark and Matheny, 1991).

Older trees, due to their health and stage of life, require more attention before pruning. They cannot withstand pruning as easily as younger, vigorously growing trees, because they have limited energy reserves to fight invading diseases and insects, especially at the pruning wounds (NAA, 2004), and when they have been subjected for years to irregular pruning which creates zones impoverished in carbohydrates (Clair-Maczulajtys et al.,1999). As a consequence old trees should be pruned only as needed. Pruning should be limited to remove dead, suppressed, structurally weak, diseased and insect damaged branches or to lighten heavy horizontal branches. In general, it is better to remove less than 25% (other authors recommend less than 10%) of the total tree leaf area (or branches) per year (Gilman, 1997; Elmendorf, 1998), or even better, limit the cuts to crown cleaning without removing living tissue ("do as little as possible in the way of cutting", Read, 2000).

It is fundamental to keep in mind that the destabilisation of thinning operations increases exponentially with increasing tree age and height. Niklas (2002) underlined that "when stems are exposed by the removal of neighbouring portion of a tree, parts that were sheltered and strong might deform or break even under normal wind conditions". Pruning also shifts the self-loading conditions of branches or roots. This can have negative effect on tree biomechanics by decreasing the safety factor (the quotient of the load capability and the actual load of a structure or the ratio of the breaking stress of a structure to the estimated maximum stress in ordinary use)(Niklas, 1999; 2002). Further, when trees are topped, overpruned, or stressed, they produce epicormic shoots which are weakly attached and prone to mechanical failure (Hayes, 2002). The modelisation of tree mechanical characteristics has been subjected to some critics by some researchers who state that also morphological, histological, and physiological aspects must be considered (Fournier-Djimbi and Chanson, 1999). Recently a new failure criterion for non decayed wood has been proposed by Mattheck et al. (2002) based on the Height/Diameter (H/D) ratio that relates a higher mechanical safety and a better biological supply with water and assimilates to tree with a lower H/D ratio. Management techniques (first of all planting not too dense) should be aimed to decrease or maintain a lower H/D ratio.

In conclusion, according to Davis (2002) we can state that there is no hard-and-fast rule as to how much an individual tree's growth can be cut back. Different species can differently react to heavy pruning and disagreement in the literature is not surprising given that different species where studied, and that in many cases the environmental conditions and the historical background differed. Also, as previously stated the negative effects of improper pruning should be taken into greater consideration when dealing with veteran tree in the urban environment and different management techniques might be needed.

Root Pruning

Trees in the urban environment are often subjected to heavy root loss due to soil excavation near trunks. This is not obviously a management technique and its long-term effect on tree health and structural stability is really negative (Harris et al., 1999). As a matter of fact, there is a direct relationship between root loss and growth reduction which triggers a negative-feedback loop, alters the root-shoot ratio, stimulate decay and internal defects, and pushes a tree in the mortality spiral. In fact, beside nutritional interactions, there is also evidence that hormones play a role in mediating root-shoot interactions. Auxins produced by the leaves flow downward to the roots and stimulate new root formation and cytochinins, probably the major antisenescence hormone (Noodén and Leopold, 1988), produced by the roots go upward to the leaves, stimulating shoot growth. Altering this balance can have a direct on plant health.

As a consequence, we have to be very careful when cutting roots, because, besides increasing uprooting potential (short-term effect), due to the fact that root not adequately anchor the tree against wind and weight, we deeply alter the physiology of the tree (long-term effect). Heavy crown pruning in this case, it is probably not the best way to restore the balance between the root system and the canopy, but we have to consider to stabilize the tree or to reduce the force of the wind against the tree by crown thinning, which, however should not be considered a long-term solution to root loss and deformities (Gilman, 1997; Elmendorf, 1998).

Other cultural techniques

As described, pruning is by far the technique that most affects tree growth and physiology, but there are other treatments that can be done for old trees. All the techniques should be aimed to reduce the stresses of various type both intrinsic to the site (soil physical and chemical characteristics) and extrinsic (severe chilling, heat, drought, diseases), that are able to induce or accelerate many changes related to plant senescence. Some of them are directly applied to the plants, some others are aimed to the improvement of soil fertility and to prevent conditions which are known to be the trigger for any kind of disease. However, as stated by Clark and Matheny (1991), each of the treatments may have good and bad consequences on tree health because they can both positively and negatively interact with the development of a stable environment.

Coder (2002) indicates several treatments that can be applied to old trees that can be summarized in keeping the tree healthy by establishing good and stable soil and environment conditions. Among them improving soil fertility seems to have a certain effect, although controversy exists about the effect of fertilization on veteran tree physiological health and on the interaction between fertilization and other management technique like pruning.

When fertilizing it should be underlined that N efficient uptake occurs during period of active growth and depends on active photosynthesis. If we reduce the photosynthetic area, we can negatively affect N uptake. Also high N applications reduce the concentration of defensive compounds increasing the tree's susceptibility to certain pests (Struve, 2002).

Fertilizers should be applied lightly for mature and old trees in late summer or early fall to promote nutrient storage. Mulching can reduce environmental stresses by providing trees with a stable root environment that is cooler and contains more moisture than the surrounding soil. Mulch can also prevent mechanical damage by keeping machines such as lawnmowers and weedwhips away from the tree's base. Further, mulch reduce competition from surrounding weeds and turf (ISA, 2004).

Conclusion

In spite of the progresses made in the different topics related to plant physiology our present knowledge about the process of aging is not fully adequate to enable us to fully explain it. Understanding aging process is important for setting up management techniques to operate on mature or veteran trees. Such information would be also useful in determining how biotic and abiotic stresses contribute to the loss of vigor and eventually lead to mortality in old trees and how these individuals will respond to the different treatments.

We believe that it is necessary to point out the need for special studies, in order to elucidate the real ontogenetical significance from the morphological and physiological changes associated with the different phases of life juvenile, adult and senile.

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(Footnotes)

[1] A mortality spiral describes the sequenze of the events as a tree
's condition changes from healthy to stresses to declining to death (Harris et al., 1999)

SURVEY METHODS & DEVELOPMENT OF INNOVATIVE ARBORICULTURAL TECHNIQUES IN KEY UK VETERAN TREE SITES

N. Fay

Arboricultural Consultant: Treework Environmental Practice, Chairman of the Ancient Tree Forum

Summary

The quality and condition of Britain's old tree heritage is reflected in the great number of ancient tree sites found in the British Isles, reputed to be among the finest in Northern Europe. Environmental arboriculture and veteran tree conservation methods have been influenced by a multidisciplinary approach that considers the tree in co-evolutionary terms, inherently linked to its ecological context. This approach considers the importance of the ageing process and the use of terminology relating to the developmental stages a tree passes through. The interactions between trees, fungi and other dependent organisms are considered, particularly in the light of the need for arboriculture to take account of how tree management can work to maintain or re-establish conditions suitable for a functioning tree-ecosystem. Understanding the rates of decline in old tree populations has been improved considerably in the UK since the development and use of the Specialist Survey Method. Studies of important veteran tree sites indicate that the rate of tree loss may be unsustainable. This in turn threatens the continuity of dependent saproxylic communities. Innovation in arboricultural management techniques has been influenced by observations of natural processes. The recent emergence of environmental arboriculture provides a framework for considering such issues and for developing appropriate practices to manage trees to enhance longevity and biodiversity. Principal among these is the development of Individual Tree Management Plans for veteran trees, which set planned treatments programmes for 30 to 100 years. Environmental arboriculture, while responding to all current conventional arboricultural considerations and practices (including tree hazard management and amenity tree care), offers scope for an interdisciplinary synthesis of perspectives between all those involved in the appreciation of veteran and ancient trees.

Terminology: Veteran & Ancient

In the UK the term 'veteran' is used to describe both the age and condition of a tree. A 'veteran tree' has the anthropomorphic, cultural connotations of a battle-scarred survivor: a valued, old comrade that has been through the tribulations of life. 'Veteran' has come to describe the quality of dead wood habitat in trees. The term is widely used, being both accessible to the specialist and to the public imagination. In recent years an increasing appreciation that decay in trees is important for wildlife. As a result, arboricultural techniques have evolved that inflict deliberate damage or wounding on trees to induce conditions suitable for the progression of rot or other niche habitats. This has caused the need to invent and convey unusual concepts, such as 'to veteranise' and 'veteranisation'. These express effects or actions (deliberate or inadvertent) that impact upon trees, causing the development of dead wood habitat features.

The terms 'veteran', 'old' and 'ancient' are all used to describe trees that are 'of interest, biologically, aesthetically or culturally' (Sissitka 1996) as a product of 'age or condition' (Read 2000). Moreover, 'veteran' is used to describe an 'old' and valued specimen, which may have survived beyond the typical age range for the species' (Lonsdale 1999). These terms are often used interchangeably. This paper will explore the conceptual difference between the factors of age and condition and why it is important to clarify these concepts for the purposes of developing appropriate criteria for recording the biodiversity value of such trees and for the formulation of appropriate methods for their conservation. In broad terms, 'old' and 'ancient' refer to age class, while 'veteran' refers to habitat condition (Fay 2002).

The term 'ancient tree' may be understood as an age classification to describe the stage when, after the loss of apical dominance a tree passes beyond full maturity and the crown begins to shed redundant parts and accumulate dead wood. The crown begins to reduce in size (crown retrenchment) and the annual increment (CAI) eventually reduces, compared to earlier developmental stages in the trees growth (White 1998). This is the final stage in the life of the tree (Read 2000) and, where conditions are favourable, can be the longest.

While all ancient trees will have habitat features sufficient to qualify them as 'veteran trees', all veteran trees will not necessarily have entered into the 'ancient' age-class. Mature trees that show a moderate to high level of veteran features are now termed 'early veterans'. Until recently, the terms veteran and ancient had been used interchangeably, however it is useful to clarify this distinction. For survey purposes, when required to quantify veteran trees to assess the quality of tree habitat, all ancient and early veteran trees will typically be included. When surveying to evaluate the age structure of the tree population, the inventory of the ancient age class will include only those trees past full maturity. Therefore, as there is scope for misinterpretation, it is important that, when using the terms 'ancient' and 'veteran', the above contextual distinctions are understood and explicit.

As the ageing process progresses, dead and dysfunctional woody tissue is colonised by fungi, which change the nature and condition of wood material. Natural damage and shedding of tree parts can lead to trunk hollowing, branch cavities, live stubs, shattered branch ends, loose bark, sap runs and a range of rot types. The organs of the saproxylic fungi (fruiting body, mycelia etc) may in turn be colonised, for example, by specialised invertebrates. This complex saproxylic substrate, held within a living sapwood envelope of the tree, provides specialised niches for different organisms with diverse 'life-styles'. A recognised exemplary system, developed in the UK, provides an index of conservation value for woody habitats. This is known as the Saproxylic Quality Index, which compares the site-specific species richness of saproxylic Coleoptera (dead wood beetles) against a standard list, for which rarity scores have been assigned (Fowles, Alexander & Key 1999). Colonising saproxylic invertebrates may have very limited powers of dispersal and certain species may only colonise rot sites once circumstances are favourable. The greater the length of time a group of trees exists on a site, the greater the possibility for particular specialised and rare species to colonise dead wood habitat. Alexander notes that six percent of British invertebrate fauna depend on other species that, in turn, depend upon decaying wood. He estimates that as many as 1,700 invertebrate species are dependent on ancient trees (Butler, Alexander & Green 2002). Continuity is therefore a major factor in biodiversity associated with old trees (Alexander 1996 & 1999).

UK Context

History of Tree Cover: wood-pasture and parkland

In the UK, wood-pastures are the natural inheritance of medieval hunting forests, historic parks and wooded commons. Records indicate that there has been continuous grazing in wooded landscapes throughout lowland Britain, dating from the Norman Conquest. These show that large areas of wood-pasture existed both in private ownership and on common land in the eleventh century (Rackham 1993). Recently, the significance of grazing animals in the development of wooded landscapes has been examined with the conclusion that grazers are effectively a natural agent of landscape management. Taking the oak as a focus of study, Vera examines the natural processes involved in wood-pasture mosaic habitats, and concludes that the relationship between herbivores and trees is co-evolutionary (Vera 2000).

Grazing history has been a major factor in the formation of the British landscape. Britain has a history of emparkment dating from medieval times. Our ancestors used wooden staves, hedging and walling to enclose deer, and the relics of these boundary features can still be found in many parks. After the Norman Conquest, fallow deer (*Dama dama*) were introduced and the practice of establishing new parks spread. By the fourteenth century, it is claimed that 3,200 parks were recorded in England, estimated to cover 2% of the country (Rackham 1980).

While many original parklands still exist, the Romantic Movement that flourished in the seventeenth and eighteenth century inspired the construction of naturalistic, designed landscapes with formal gardens and features. These parks were associated with the conscious planting of trees of great character, often intended to provide pleasure gardens and framed views. Tree plantings were often superimposed on an existing matrix of old trees (Fay 2001). Parklands today typically contain examples of tree populations dating from the earliest period of recorded emparkment to modern times, including a great number of pollard trees, cut to prevent deer from browsing regrowth.

Pollards were cut and managed as 'working trees' (Green 1996) for a wide range of produce. The size and frequency of cutting depended on local and regional economic requirements (Read 2000). Principal traditional pollard species include oak (*Quercus robur* and *Q. petraea*), hornbeam (*Carpinus betulus*), beech (*Fagus sylvaticus*), common lime (*Tilia cordata*), willow (*Salix fragilis* et al), ash (*Fraxinus excelsior,* holly (*Ilex aquifolium*) and sweet chestnut (*Castanea sativa*).

In the UK, old trees are abundantly found in old growth woods, parklands and wood-pastures, and to a lesser extent in hedgerows, river and boundary banks, commons and churchyards, (Read 2000). In woodlands, their long-term presence is often the result of coppice history, where it was periodically necessary to manage and restrict grazing animals to prevent browsing of new growth.

The cultural tradition of pollarding exists throughout the European wooded landscape. Old pollards may be seen from the wooded meadows and pastures of Sweden and Finland (Hæggström 1998; Ranius 2000; Slotte 2000) to the silvopastoral 'La Dehesa' systems of southern Spain (Montero, San Miguel & Canellas, 1998). They are found in wood-pastures in upland Scotland (Quelch 2000) and in the grazed olive groves of Crete (Rackham & Moody 1996). Their continued presence today owes much to methods of husbandry. The practice of cutting tree crowns above grazing level for produce, while varied by region, culture and species, has ensured the endurance of pollards in the landscape as open grown trees (Green 1996).

Pollard wood-use included fodder, firewood and charcoal, fencing, furniture, tannin, wicker-work, and house and boat building, and it is interesting that a very large population of old pollards still exists within a twenty-mile radius of the London conurbation. An example is Epping Forest, with an estimated population of 50,000 veteran trees over 400 years in age, the majority of which are pollards. This forest, like many wood-pasture sites, is characterised by areas of open space, roads, housing and extensive areas of pollards set in grassland and shrub. It historically formed part of the medieval Royal Forest of Waltham, subject to Forest law according to which commoners enjoyed rights of pasture and woodcutting. Many wood-pasture sites passed through different ownerships while retaining their open wooded character, despite periodic attempts to enclose portions and suppress commoners' rights of use. Since the late eighteenth century, throughout most of Britain, pollard management practices have progressively fallen into disuse. At Royal hunting forests such as Epping Forest, dwindling deer populations coincided with declining Crown interest, illicit enclosure and urban exploitation.

Wood-pasture systems are richly present in the UK and widely distributed. Many contain a significant population of pollard trees with a mosaic of habitats, showing continuity and structure remaining unchanged for many centuries. Hatfield Forest is one such example that has been extensively documented. Recorded originally in the Doomsday Book in 1086, it has remained virtually unaltered for over one thousand years, still containing 'all the elements of a medieval forest' (Rackham 1998). The ancient trees at this site have been surveyed and monitored, the results of which have been used to inform management prescriptions for environmental arboriculture restoration treatment (Fay & Fay 2000), as will be discussed later in this paper.

Initiatives to Record & Conserve Veteran Trees: Habitat Action Plans

The UK Biodiversity Group (1998) refers to lowland wood-pastures and parkland as 'the product of historic land management systems and represent a vegetation structure rather than being a particular plant community. Typically, this structure consists of large open-grown or high forest trees (often pollards) at various densities, in a matrix of grazed grassland, heathland and/or woodland floras'. Much of the nature conservation effort in Britain is currently directed through Habitat Action Plans (HAPs). One of these is the Lowland Parkland and Wood-Pasture HAP. It recognises that various factors are necessary for the biodiversity of old tree habitat, and in particular, that the high levels of light and warmth afforded by open-grown trees favour special colonising communities.

The loss of old trees is identified as a major cause of the decline and poor condition of dead wood habitat and dependent communities. The Common Agricultural Policy (CAP) has caused considerable harm to veteran trees in arable and pasture land. Deep ploughing, the use of herbicides, inorganic fertilisers, wormicides and other veterinary pharmaceutical products, have damaged soil structure, mycorrhizae and other parts of the root ecosystems. In the UK veteran tree populations have suffered from the effects of poor tree and land management. Isolation and fragmentation of wood-pasture habitats are a threat to dependant communities. Where there are large populations of veteran trees with officially recognised nature conservation value, such sites usually have a survey history. However, survey methods are typically inconsistent with respect to veteran tree data collection. While the value of many UK veteran tree sites is acknowledged, the habitat quality and tree condition is poorly documented and understood. This situation is slowly changing. One of the factors influencing the momentum for improvement has been the involvement of arboriculturists with conservationists.

During the early 1990s, there was a growing interest in the necessity to compare information gathered about veteran trees. Until that time, no standardised system had been developed. English Nature (UK government agency for implementing nature conservation policy) identified a broad strategy for improving survey data quality and methodology. The

Ancient Tree Forum (ATF) is the lead UK NGO for the conservation of ancient trees and their habitat. It is a collaborative group of conservation professionals, specialists and managers. The ATF identified the need for a standardised recording system to collect tree habitat information. This was considered essential to the understanding of the national status of veteran trees through recording and monitoring key factors influencing population dynamics. (Fay & de Berker 2003).

A multidisciplinary approach, led by arboriculturists, resulted in the publication of the Specialist Survey Method (SSM). This is the current national standard for veteran tree surveying. It operates on three levels. *Level 1* is the introductory standard for non-specialists; *Level 2* is the first level technical standard (typically for arborists, foresters, etc.); *Level 3* is used by conservation specialists. The SSM records basic tree data (position, species, form, dimensions), dead wood habitat (tears, scars, stubs, hollowing, rot, dead wood), tree associates (flora and fauna) and growing context (damage, shade, management) (Fay & de Berker 1997).

Conservation experts claim that Britain contains the greatest number and the best concentrations of old trees in Europe (Alexander, Green & Key 1996). This claim has both raised awareness and stimulated study in attempts to quantify the population. Recent research has shown that surveys using the SSM have recorded over 45,000 veteran trees at key UK sites (Fay & de Berker 2003). Assuming that 1 in 200 trees have been recorded, as a conservative estimate, this would indicate that there are more than 9 million veteran trees in the UK. To date, the traceable investment in nature conservation surveying of old tree habitat using the SSM is an estimated £291,000.

While veteran trees may be present in great numbers in the UK, there are disturbing trends. Studies show that many veteran trees are under threat and there is evidence that the future of veteran trees at these UK sites is not promising. Data collected from a number of populations indicates that, even at protected sites, and those that are considered to be in the best condition (Cox & Sanderson 2001), populations are susceptible to unsustainable rates of tree loss, posing a direct threat to the dead wood (saproxylic) communities.

Fig 1:The Bowthorpe wood-pasture oak: Britain's largest *Quercus robur*, (Girth at 1.5m height is 12.79m) Shed a major part of pollard crown in 2003.This tree is said to be over 1000years old

Fig 2: Ancient tree wood-pasture at Brockworth, Gloucestershire. The fate of many veteran trees in the UK. Lapsed pollards with crown limbs prone to mechanical failure. Often crown limb loss threatens the viability of the entire tree

Population Dynamics

One of the major ancient tree sites in the UK is Burnham Beeches, occupying 220 hectares of wooded common. In the seventeenth century, there were 3,000 pollard trees. By 1957, this number was reduced to approximately 1,300. In 1990, when survey methods became more detailed, the population numbered 555. By the year 2000, the total had fallen to 463. The rate of population decline in recent decades is typical for many ancient tree sites. At Burnham Beeches, the rate of loss represents 16.6%, which is an average of 1.6 trees per annum (Read 2000). Attrition rates of between 0.9% and 1.8% are common. The main cause is loss from collapse from mechanical failure (as a result of the cessation of pollard practice) (see Fig 1) and rapid decline from environmental impacts (Fay & Rose 2003).

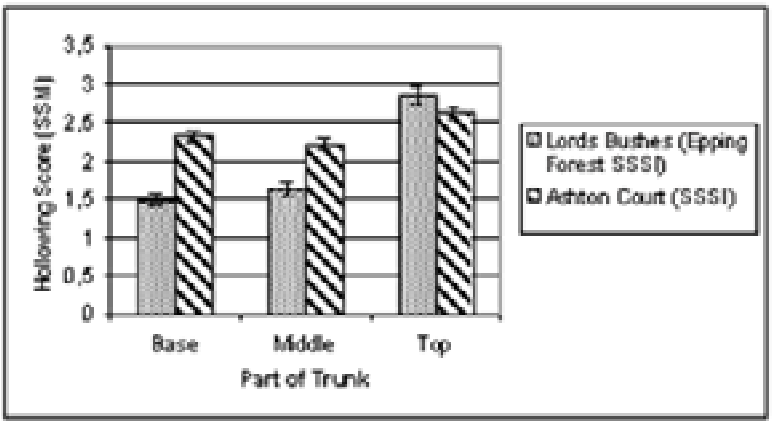

Fig 3: Survey of ancient pollards at Ashton Court, Bristol and Lords Bushes, Epping Forest. Data derived from surveys at two key sites of 444 trees and 155 trees respectively, with neglected, lapsed pollards, shows trunk hollowing to be significantly higher at the top of the bole, whereas hollowing is common at the base of maiden veteran trees. Failure trends are the result of heavy pollard branches breaking at mechanically weakened pollard points or tipping the entire tree due to excessive end loading (error bars ± one standard error). (Fay & Rose 2003)

Recognition of current rates of loss in old tree populations has resulted arboricultural intervention to mitigate the risks posed to trees.

Modelling a Sustainable Population

The key to a sustainable population capable of supporting a functioning ecosystem requires that first an existing ancient tree population is consolidated. Secondly sufficient numbers of trees must remain in the vicinity of the current population to be capable of becoming veteran and then reaching the ancient stage. This may require the recruitment of non-veteran mature trees and veteranising these (to 'prematurely' create bridge saproxylic habitats). This treatment involves implementing techniques that mimic natural damage.

Tree population dynamics have conventionally been used to model populations based on utility. In this context, full maturity is regarded to be the optimum target age class. Utility considerations of trees places value on the sound wood condition of the main trunk prior to the development of decay. Techniques of tree population management have yet to be developed that favour post-mature age classes. Such an approach requires the assessment of numbers and mortality rates in each age class. It is then necessary to ascertain whether sufficient numbers are present to ensure successors for older age classes to produce a sustainable population structure. Typically this involves considering arboricultural intervention to reduce mortality rates in the older pre-ancient generations. Site management techniques also need to be targeted to enhance tree longevity for all age classes.

Management for a sustainable tree population, targeted to maintaining functioning tree ecosystems, must be based on knowledge of tree mortality. This needs to take account of loss in each age class within the overall population. By responding to these factors, the required rate of recruitment into the veteran population can be estimated. This form of modelling can identify expected change in the veteran population over time and is vital to understanding the actual vulnerability of the ecosystem at a particular locality. This method has been applied to a number of sites to identify the safeguard-requirement of younger age-class trees. The need for tree planting is widely recognised. However, the reasons for conserving mature and fully-mature age classes are now better understood.

Tree life expectancy in the UK may be progressively being eroded due to human influences on the environment. If the future ancient tree populations are insufficient in size or integrity, local populations of dependant species may collapse. If this takes place then current investment in the conservation of wood-decay ecosystems will fail. It is therefore a priority that resources are targeted to evaluating ancient tree populations, requirements for succession and sustainable management.

Management: concepts of environmental arboricultural

Compared with the animal kingdom, ageing in trees is not necessarily unidirectional. Trees and fungi may both be described as indeterminate systems (Rayner 1993), equipped with the ability to alter developmental patterns in response to environmental stimuli. The meristematic (embryonic) system provides the tree with the potential for rejuvenation so that at any stage different parts of the tree may be in a different growth phases. Del Tredici refers to the various rejuvenation processes that occur in trees (ontogenetic, natural and physiological) reflecting the way the "ageing clock" is influenced by genetic or environmental factors (del Tredici 2000). Protracted serial rejuvenation in some species of tree is so effective that there is a tendency to near immortality (*Pinus longaeva*, *Tillia cordata*, *Taxus baccata*).

Fig 4: Phoenix *Crataegus monogyna* at Hatfield Forest, Essex

Natural vegetative regeneration in old trees may be considered as a survival strategy. When this occurrence is successful, the re-generated tree is termed a 'phoenix tree' (Fay & de Berker 1997). A number of phoenix strategies have been noted in UK fieldwork. Examples include cases where following tree collapse, the specimen layers, establishes roots and second-order laterals become first-order trunks of a successive generation. Similarly, when the adventitious roots become established within a hollow trunk, the roots may eventually change their mode and develop structural functions (and become independent). Hollow ancient trunks have been observed to rot ands break up to form two or more columns, each becoming independent and capable of breaking free from the original system. These processes are significant in the context of continuity of habitat, when considering that the woody substrate of the tree acts as a 'Noah's ark' for the dependent colonising fauna and flora. These observations are significant, as they have influenced arboricultural management practices intended to support strategies for tree longevity.

The convergence between arboriculture and other disciplines, particularly with ecology has led to a transformation in the understanding and appreciation of ancient trees, especially when considering the tree as a co-evolutionary partner that has developed in association with colonising species. Significantly, there has been a reconsideration of the interactions between fungi and tree. Much of the arboricultural terminology typically used to describe the presence of fungi in trees, presumes or implies a pathogenic relationship. Ingress is a basic presumption and the presence of fungi in or on trees is generally described in terms of 'invasion', with modes of 'attack' and degrees of 'aggression'; implying that the tree has evolved a primarily and comprehensively defensive relationship with respect to fungi.

During the 1990s, new insights were gained from investigations into the range of colonising strategies of different fungal species. Mycological research began to surface in the field of arboriculture, introducing notions of complexity not previously recognised. This described the presence of endophytic (dormant or latent) fungi that operate territorially and become visible after bark wounding and dysfunction have occurred. This complexity is evident where natural processes may be observed in sites such as old growth forests and low-intervention wood pasture. Arrays of different fungal modes operate including wood decomposition, recycling, nutrient foraging and pathogenic processes, all potentially organised through mycelial interconnection (Rayner 1993). The perception of the tree-fungi-system as complex, multifunctional and interactive is a vital concept in environmental arboriculture. It is fundamental to comprehending the co-evolution process as a factor of tree longevity and to informing tree health and pathology diagnosis.

New Arboricultural Techniques for Veteran Tree Management

In the eyes of environmental arborists, chainsaw cuts result in an unnatural flat plane-surface (i.e. such surfaces are literally not found in nature) and apart from the concern to replicate 'naturalness of form', there are further ecological considerations that have promoted work to develop natural fracture pruning methods. Branch breakage (from mechanical weakness and storm damage to trunk and limbs) results in a variety of effects on wood tissue at the point of breakage, leading to fibre separation (along the grain) and splintering in various planes (linear, radial and circumferential). This occurrence creates microhabitats that are colonised by microorganisms and succession species.

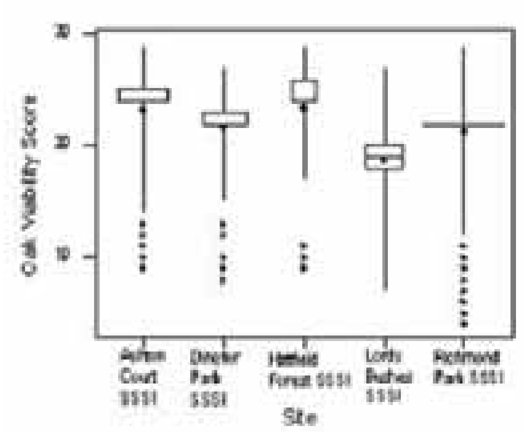

Fig 5: Viability assessments of veteran oak populations at four key UK ancient tree sites. The Specialist Survey Method has been further developed to enable an arboricultural assessment of tree stability and vitality to be carried out. This is used to inform an assessment of tree viability to allow comparisons between sites and inform30-year individual tree management plans

Interactions between trees and the species that live on them may have developed over exceptionally long periods of time, and as some trees may be several thousand years old, speculation therefore may extend to the relationships between tree longevity and the continuity of the organisms living on and inside the tree, and those living underground that are associated with the rhyzosphere. Over recent decades there has been a prejudice against dead wood in arboriculture, forestry and agriculture. This is now being redressed. There is an emerging trend to value biodiversity and to promote arboricultural practices for the benefit of wildlife, leading to the development of techniques designed to retain (and even create dead wood habitat) in crown management.

Fig 6: Natural and artificial breakage in an oak tree:
both show high levels of growth response at Melbury Park, Dorset

Natural Fracture: Techniques that Mimic Natural Processes

Coronet cuts - Dead wood management

Natural fracture techniques involve pruning methods that are used to mimic the way that tears and fractured ends naturally occur on trunks and branches. A coronet cut is a type of natural fracture technique that is particularly intended to mimic jagged edges characteristically seen on broken branches following storm damage or static limb failure. It is carried out as a pruning treatment to a stub or reduced limb to mimic natural breakage. The form of the coronet cut is designed to shape the branch or trunk end-surface to resemble the fracture that might be imagined following a storm, (such as Beaufort storm force 9/10) and is cut to resemble a broken or shattered appearance. Early experimental work exploring methods of cutting dead branches to mimic natural breakage was carried out at Ashtead Common National Nature Reserve, Surrey. This led to further developments and the current use of coronet cuts in both living and dead limbs. It was first trialed following a catastrophic fire, which seriously scorched, damaged or killed several hundred veteran trees on the Ashtead Common, affecting a significant proportion (10%) of the population of over 2000 veteran oaks at that site (Adam Curtis, James Green and Bob Warnock. 2000). The presence of so many dead trees in an area frequented by the public initially prompted a requirement to remove the trees for public safety. After consideration of the conservation values of the dead wood habitat, it was decided to retain as many standing dead trees as possible, while carrying out varying degrees of reduction to reduce risk of crown or trunk breakage to an acceptable level. Dead wood (over 150mm) was deemed potentially suitable for carrying out this exploratory coronet-cutting work.

Earlier attempts at replicating what was observed in nature had varying results. Trials at Stowe Park, Buckinghamshire, were carried out in the early nineties using explosives on dead trees to see what type of fragmented ends would result (Finch 1996). The use of explosives is *not* now advocated in the UK for both the obvious reason of safety and that outcomes are uncontrollable. The author witnessed similar attempts during a visit to Sweden in 1992, where the Swedish army had been recruited at a nature reserve to use explosives on live trees attempting to recreate habitat-types suitable for rare invertebrates.

Other experiments carried out at Windsor Great Park, involved winching off partially cut branches to produce rip or tear-cuts on dead trees. This was in some measure successful, but it proved impossible to predict the appropriate winch-tension necessary to effect breakage. Many trees failed at their roots before the attached branch broke off. As a result such practice has for the most part been stopped as it is deemed to be harmful to the root system.

Where trees are scheduled for felling coronet cutting is typically carried out as an alternative in order that a part of the trunk may be safely retained, in reduced-scale as dead wood habitat, following the removal of the scaffold branches. It is also carried out following branch reduction – (usually of second or third-order limbs).

Trials took place between 1997 and 1999 to retain as much of dead oak as standing hulks with a reduced branch framework. Many of the truncated trees were experimented upon to promote a natural breakage effect through skilful chainsaw use. This resulted in the first studied attempts at coronet cutting (The practice was so called because of the crown-like appearance of the branch ends). It is noteworthy that this was well received by the public.

Retained standing trunks have been termed 'Monoliths' (Alexander, Green & Key 1993) and are defined as those trees where tree removal would normally be required but are retained as standing trunks in reduced and stabilised form (usually at some 4m to 6m height) as dead wood habitat. It is necessary to re-inspect monoliths to assess and address tree stability and the risks posed, as with any standing tree.

As aerial deadwood is valuable habitat, its removal is only specified where its presence about the tree is considered a threat to tree stability or public safety. In such cases, the removal of dead wood should apply only to the material that is considered unstable and prone to failure. Where dead wood removal is proposed it should be restricted to those aspects of the crown where dead wood failure may cause damage or harm. Elsewhere, dead wood may be retained and reduced in extent to stable proportions (Davis, Fay & Mynors 2000).

It is noted that with oak, hardened dead aerial branches can often be retained without undue risk, however where risks may be present from dead wood breakage, it is essential that this is assessed and managed as with any part of the tree. As a result of these developments in environmental arboriculture, current guidelines for risk management of aerial dead wood now frequently stipulates that aerial dead wood can be preserved, subject to an assessment of its condition so that it may be retained in stable form (with reduced lever arm and end-loading).

Coronet cuts-Live wood management

Currently the techniques involved in dead wood management are now also considered in the pruning of live amenity trees. Since the work at Ashtead, some pioneering work has been carried out by arboricultural practices in the UK. Treework Environmental Practice and others involved in environmental arboriculture have extended this form of dead wood management to the management of living trees to promote dead wood habitat (Fay 2002). This practice is termed 'veteranisation' (Cowan 2003).

Fig 7: Coronet cut on live *Quercus robur* stub at Richmond Park, Surrey

The general guideline for this technique requires the selection of potentially suitable stubs for retention. These are cut at a minimum distance that is approximately five times the diameter of the branch when measured at the point of attachment to the stem or higher order branch. Suitable branches will have a diameter greater than 150mm in diameter. The stub length is estimated from the point of attachment with the parent higher order member. Stubs are cut into a coronet appearance through skilful chainsaw use. Live branches may be selected for this treatment where crown reduction (see retrenchment pruning) is being carried out. A proportion of suitable live limbs (up to 15%) are typically selected for coronet cutting. This type of natural fracture pruning is applied to non-crucial structural members only. Cutting is carried out to give the appearance of deep uneven, shattered ends; optimally with an acute angle. Where occasional major stems require heavy reduction truncation, the final cuts are varied to promote a jagged finish.

Retrenchment pruning

Retrenchment pruning is a term coined by Paul Muir of Treework Environmental Practice to describe the technique. It is a refinement of the concept of restoration pruning referred to in the European Treeworker Handbook (EAC 2000) and has been developed to imitate the natural process of crown ageing, often referred to as the stage beyond full maturity when the tree 'grows downwards' (Green 1996). The term 'crown retrenchment' is used to describe the way in which peripheral dieback occurs as the tree redirects energy and growth to the formation of a consolidated lower region of the crown. Crown retrenchment pruning is used to extend tree viability, (both in relation to vitality and stability), whilst retaining habitat features associated with ageing.

Retrenchment pruning is a technique that can be used to reduce the potential for a fully mature, late-mature or ancient tree to collapse or disintegrate under its own weight, as a result of excessive end-loading associated with long or weakly attached limbs. It is carried out according to a long term programme - typically termed 'Individual Tree Management Plan' (the ITMP). The ITMP may typically extend up to thirty years.

The technique is also used in trees where incipient decline appears to result from excessive transportation distances from the root system to the crown periphery. While this technique may have a general value, it is especially useful for managing lapsed old pollards and mature maiden trees that show signs of dieback, physiological stress or a tendency to long-term limb breakage (i.e., not where there is an urgent need to reduce crown limbs to avoid breakage).

The practice of retrenchment pruning follows a detailed inspection, which assesses the viability of the tree in terms of current vitality, the probability of tree loss as a result of expected decline in vitality or from structural collapse. This assessment informs decisions as to whether retrenchment pruning is appropriate. If the tree is an important specimen prone to imminent mechanical failure, threatening its viability, then gradual retrenchment treatment would not be appropriate. In such cases an alternative method is suggested involving significant reduction to selected failure-prone limbs (see Read 2000, pp 42-43).

If the tree shows a moderate level of vitality and mechanical stability appears vulnerable in the long term, while being sufficient to support a moderately reduced crown structure in the short term, then retrenchment pruning may be carried out to restructure the framework.

The Individual Tree Management Plan will follow from the assessment of tree viability, and will specify the first stage of treatment (possibly involving as little as 10% or less than a metre reduction). The Plan sets an ultimate height above the bolling or from ground level (Target Height) to which the crown will eventually be reduced at the time of Plan completion. In addition this will specify the return period (Retrenchment Cycle) for future retrenchment pruning visits, typically 3 to 5 years. Lastly the Plan Duration is set. This is overall duration for the programme of treatments up to completion (usually between 12 to 30 years, but sometimes up to 100 years).

Retrenchment pruning is carried out in stages and involves the reduction of the tree height and the extent of crown growth over a protracted period of time. It is carried out to 4th or 5th order branching, often within the constraints of using a turbo saw and secateurs, and usually involves at least three return treatments involving periodic monitoring and allowing re-growth to occur in the interim.

The process is intended to promote early crown stabilisation and reduce the risk of traumatic structural failure by reducing the lever arm, while at the same time increasing light penetration to inner aspects of the scaffold limbs. Epicormic growth arising from these lower and internal crown areas have the potential of becoming the scaffold limbs of a future reduced crown framework. The method is intended to stimulate internal and lower crown growth (rejuvenation) through reducing apical dominance to redirect hormonal growth regulation capable of re-iterative stimulation. Eventually retrenchment pruning will create a reduced crown framework over the Plan Duration.

For trees with moderate to high vitality, the first stage of retrenchment pruning should avoid overall reduction by more than 20%. For trees with low vitality the first stage of retrenchment pruning is typically less than 10%. Where tree stability is already heavily compromised reduction levels should be sufficient to reduce the lever arm to an acceptable level.

Conclusion

In the UK, governmental and non-governmental conservation agencies have recognised the value of old trees for wildlife. Through the work of a number of pioneering conservationists, drawn mainly from the ranks of the Ancient Tree Forum and the Woodland Trust (lead voluntary agencies with interest in old tree conservation), understanding of the biological and cultural values has been improved. A wide consultation between owners, managers, conservationists and professionals, involved in the study and care of old trees, has led to a number of publications to guide survey methodology and management. The publication of the Specialist Survey Method as the UK national standard for surveying veteran trees has provided the framework for consistent recording and data collection. While the British Isles is recognised to contain a very high proportion of Northern Europe's ancient trees, population studies at key UK wood-pasture sites have shown that there is an unacceptable rate of tree failure. This recognition and the convergence between arboriculture and ecology has resulted in an improved understanding of the ageing process in trees. Fungi are now understood to have a principally benign interactive relationship in the tree-fungi-system, creating conditions for colonisation by dependent species, many of which have poor powers of dispersal. The UK arboricultural profession is beginning to recognise that it is necessary to develop appropriate tree management techniques to foster optimum conditions suitable for the continuity and diversity of saproxylic species-rich communities. As the ancient tree is the 'ark' that carries these species through time, it is necessary that the features of value to dependent organisms are a focus for management practice. This approach has led to arboricultural innovations, such as the development of natural fracture techniques, coronet cutting and retrenchment pruning, and particularly the need to manage old trees in terms of appropriate space and time. When determining work programmes for old trees, management processes need to consider the whole environment of the tree's root-space and soil ecosystem. The conceptual framework for management prescriptions should consider the 'tree-time' (not human economic-time) necessary to implement a long-term Individual Tree Management Plan.

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Treework Environmental Practice can be contacted on its website: www.treeworks.co.uk
The Ancient Tree Forum may be contacted on their website: www.woodland-trust.org.uk/ancient-tree-forum

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