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Pollarding and its effects on tree physiology : a look to mature and senescent tree management in Italy

Abstract

Many mature trees are radically pruned every few years just to keep them in control and out of the way. This practice of massive pruning at frequent intervals can quickly lead to tree structural and pest problems. In fact, 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. 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. 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. Pollarding was an ancient practice all over Europe and Italy it was widely used not only for aesthetic purposes but also to provide food for the animals, that could eat the fresh shoot produce by some species.

Pollarding in Italy

Pollarding has a long tradition in Italy : since the most ancient times it has allowed multiple uses of trees located on farmland or in pastures. Indeed, one of the main uses of pollarded trees was to provide grazing for domestic animals and, at the same time, pollarded stands constantly supplied stovewood for domestic consumption or wood for carving which, however, required a longer pruning cycle. For forage production, trees were cut back to allow them to produce new sprouts, which were then cut and the foliage and bark stripped by animals. The woody remains were used as firewood. The size of cuttings allowed even children with hatchets to gather wood for home fires. Woody materials were also woven into yard fences and outbuilding walls. Sometimes pollarded trees of those species that could not be used as food for livestock were used for the production of litter material. Coarse baskets and twine-making materials were also taken from the cuttings. Oak material was used to extract tannins for curing leather (Anonymous, 2006).

Therefore, a steady production of stove-wood, forage and/or litter material through pollarding was maintained at an equilibrium level that lasted for centuries.

Especially in the northern plain regions of Italy, country hedges were cultivated and utilized as source of firewood. In many cases these were formed by elms (*Ulmus campestris* L.), salix (*Salix viminalis* L.), or mulberry (*Morus alba* L.) which had originated from suckers and were thus placed closely but, often, at irregular intervals.

In addition, linear plantings which developed along channels, roads, and along the borders of the so called “capezzagne” (the rough roads at the edge of cultivated fields), formed a net of tree hedges that, together with cultivated crops, contributed to the income of the peasants and provided other important services like the consolidation of the channel banks, the formation of shelter spots for wild fauna and rendered the rural landscape more attractive and variable. After World War II, agricultural mechanization and the introduction of fossil fuels for heating, caused the gradual and, nowadays, almost complete elimination of these traditional plantings. However, at present, the restoration of these plantings to meet environmental needs is being considered and some rational models of multifunctional linear plantings are proposed (Agostinetto, 2004).

As a matter of fact, at the beginning of the 18e century the use of pollarded trees in Italy was widely used for silk production. For this purpose, mulberry *(Morus alba* L.) was used ; in commercial practice, trees were periodically (i.e. annually) pruned in order to permit harvesting at a convenient height, thereby inducing a shrubby form (Suzuki and Kohno, 1987).

In the second half of the 19e century this cultivation became so common on the flatlands and in the hills of Northern Italy that it still characterizes the agricultural landscape of some relic areas. At the same time, grapevine cultivation was mainly done using trees as a support.

The traditional viticultural system was the so called “*vite maritata”* a tradition introduced in this area by Etruscans and it was common in all the other areas where these ancient people lived. The system consisted in having the vine climbing a *live* support which usually was a hedge maple tree (*Acer campestre* L.), though sometimes also native elm (*Ulmus campestris* L.), poplar (*Populus spp*.), fraxinus (*Fraxinus ornus* L.) or mulberry (*Morus alba* L.) were used. For this reason, pollarded trees have an important part in our history and some great European landscape painters of earlier centuries clearly represented the pollarded trees of pastures, canal edges, and farmsteads. Probably the most famous painting is the “Field with Pollard Trees and Mountains” painted by Vincent Van Gogh in 1889.

Pollarding and tree physiology

The pollarding process is quite stressful for the tree, especially when they are in their mature or senescent stage. 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, while woody plants show significant and predictable patterns in morphology and physiology as they age, it is quite difficult to study of the possible mechanisms controlling these changes because of the large biomass interested and the complexity of the processes involved, facts which have brought out some controversies among various authors.

Understanding the growth and physiological behaviour 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.

Older trees, depending upon management history, may require several seasons of carefully designed directional pruning before the establishing pollarding cuts are made. Once crown geometry and mechanical loading have been developed in a tree, time is required to radically change forms. Also, in older trees, proportionally larger cuts are required, which leads to problems associated with heartwood exposure and internal boundary breaking.

Although it reduces total structural mass, pollarding reallocates mechanical loads to new locations in a tree. Bending, twist, and sway components of mechanical stress are concentrated in new locations, some of which may not be prepared for the new loading pattern. Old structural faults can be put at risk for failure as gravity and wind loading change. The three most important elements of successful renovation of older trees are :

1. carefully designed pollard head locations,
2. anticipation of sprout weight under rain, ice, and wind conditions, and
3. consideration of current structural faults that could lead to catastrophic loss (Anonymous, 2006).

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. We should be aware that as trees age and grow larger or assume particular forms, their contributions and value to the landscape notably increase. Preservation options that would not be considered as economically feasible for young trees can be justified for historic and mature specimens (Fraedrich, 1999). No one would spend money on an obvious wreck, but any tree worth keeping is worth some sort of attention. It takes very little, as a rule, to keep a tree wind- and water tight (Le Seur, 1934).

According to Read (2000) the first thing is to distinguish between two types of veteran trees : those that have been actively managed in the past (i.e. regularly pollarded trees) 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, as compared to those located in open country, to 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 character and the function of a tree and 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) should be also considered when managing old trees. However, according to Clark and Matheny (1991) it can be said that "the maintenance of a balance between growth and the environment is a basic requirement for continued development and longevity … Arborists must strive to maintain stable growing conditions through long-term programs of care and facilitate the restoration of balance within a tree whose environment has been disturbed". The same authors raise a practical question : "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 develop a stable structure. Crown structure has a fundamental importance for tree physiological behaviour, substantially determining the spatial distribution of the photosynthetic surface, water

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

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 notable variability exists in geometric structure due to a great phenotypic plasticity, making schematisations difficult but, on the other hand, allowing the possibility of great manipulation 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 restructuring can be required for safety reasons, such a rejuvenation cannot be continued indefinitely because each pruning activates the present meristems, involving the commitment of significant resources; the typical response to this kind of pruning is profuse sprouting which can result in energy depletion, dieback, increased susceptibility to secondary pests or decline, thus inflicting 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 nutrient reserves, in particular of carbohydrates, stored in the unpruned part of the tree. In fact plants subjected to pruning show alterations in carbohydrate metabolism in comparison to unpruned plants. This is true 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 content in starch, can be detected, while the reserve accumulation phase begins later. 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 written 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, predators and to 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 react positively to pollarding (i.e. *Quercus*, *Platanus*, *Tilia*, some species of *Acer*, *Alnus*, *Fraxinus*, *Liriodendron*, *Morus*, *Quercus*, *Ulmus*) some others (*Fagus* and other *Acer* species) do not always tolerate this kind of pruning (Mattheck and Bethge, 1998). According to Raimbault (1996) it can be said that pollarded trees anticipate the natural, uninfluenced behaviour of at least some species.

Even the hormonal framework of pruned plants can be deeply altered by 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. Cytochinin content and activity is very high in the growing shoots of pruned plants, while gibberellin 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. Auxins seem to increase above all in the branches following the stimulus induced by cytochinins, even if a strong activity of root system synthesis, due to the altered crown/root ratio, cannot be excluded.
The increase in auxin and gibberellin 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 it 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 depleted 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 a 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 effects 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). Furthermore, 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 criticism 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 was 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 trees with a lower H/D ratio. Management techniques (first of all planting which is not too dense) should be aimed at decreasing or maintaining a lower H/D ratio.

In conclusion, according to Davis (2002) there is no hard-and-fast rule as to how much an individual tree's growth can be cut back. Different species can react differently to heavy pruning and disagreement in the literature is not surprising given that different species have been studied, and that in many cases the environmental conditions and historical background have differed. Also, as previously stated, the negative effects of improper pruning should be taken into greater consideration when dealing with veteran trees 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, stimulates decay and internal defects, and pushes a tree into the mortality spiral.

Indeed, in addition to 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 affect 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 roots do 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, is probably not the best way to restore the balance between the root system and the canopy, but we have to consider stabilizing the tree or reducing 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 at reducing the stresses, 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 at improving soil fertility and preventing 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 and can be summarized as keeping the tree healthy by establishing good and stable soil and environment conditions.

Among these, 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 techniques like pruning.

When fertilizing, it should be underlined that N efficient uptake occurs during the 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. Furthermore, mulch reduces competition from surrounding weeds and turf (ISA, 2004).

More recently, the application of mycorrhizal fungi and of biostimulants has been proposed though the results have shown to be variable according to the species and environmental conditions (Egli, 2004; Watson, 2004)

Conclusion

Pollard trees have a great aesthetic, historical and natural interest in different parts of Europe (Rozas, 2004), but as stated above their presence is being considerably reduced, especially in the last two centuries. The study of past management practices can provide useful information for maintaining this important feature of our landscape.

According to Alex Shigo, our mentor, who recently passed away, it can be said that the all important feature of pollarding is to establish a framework in which all sprouts are cut back every year and the plant is kept healthy through an appropriate management technique.

Understanding physiological responses to pollarding and, *sensu lato*, to pruning, is also fundamental for setting up management techniques to operate on mature or veteran trees. Such information would be useful in determining how also 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.

References

Agostinetto L.(2004) *Creare impianti arborei lineari per la filiera legno-energia*. Alberi e Territorio, n° 9 p.45-49 (in Italian with English Summary)

Anonymous (2006) http://www.mntca.org/Newsletter/newsletters/pollarding.htm , retrieved, June 2006

Clair-Maczulajtys D. and Le Disquet, I. and Bory, G (1999) *Pruning trees : changes in the tree physiology and other effects on tree health*. In : Proc. Int. Symp. On Urban Tree Health. Acta Horticulturae, n°496 p.317-324

Clark J.R and N. Matheny (1991) *Management of mature trees*. Journal of Arboriculture, Vol. 17 (7) p.173-184

Coder K.D. (1996) *What was old is new again*. Arborist News, August p.53-59

Coder K.D. (2002) *How trees age : constraints of size, resource control & growth*. International Society of Arboriculture, European Chapter Conference, Oslo p.18-21 June, 2002

Davis H.F. III (2002) *Structural pruning of large shade trees*. Tree Care Industry, 9 p.8-17

Egli S. (2004) *Can veteran trees be stimulated by mychorrizal fungi* ? Proceeding of the International Congress “The trees of history”, Turin (Italy), 1-2 April 2004 p.35-39

Elmendorf B. (1998) *Pruning mature trees is best left to professional*. http://aginfo.psu.edu/News/december98/pruning.html

Evans D. (2004) *Pruning to death*. In press

Fontanier E.J. and H. Jonkers (1976) *Juvenility and maturity of plants as influenced by their ontogenetical and physiological aging*. Acta Horticulturae, 427 p.37-44
.

Fournier-Djimbi M. and B. Chansonb (1999) *Biomechanics of trees and wood for hazardous tree assessment*. Acta Horticulturae, 496 p.197-208

Fraedrich B.R. (1999) *Managing Mature trees*. Bartlett Tree Research Laboratories, Tech. Rep. 52

Gilman E. F. (1997) *An illustrated guide to pruning*. Delmar Thomson Learning Inc. 330 p.

Harris R.W., J.R. Clark., N.P. Matheny (1999) *Arboriculture*. Prentice Hall, Upper Saddle River, NJ. IV Edition

Hayes E. (2002) *Tree risk assessment & tree mechanics*. Arborist News, December p.33-38

International Society of Arboriculture (ISA) (2004) *Mature tree care* http://www.isa-uki.org/pages/Mature%20Tree%20Care.htm, retrieved February 2004

Ishii H., J.P Clement, D.C. Shaw (2000) *Branch growth and crown form in old coastal Douglas-fir*. Forest Ecology and Management, 131 p.81-91

Le Seur A.D.C. (1934) *The care and repair of ornamental trees in garden, park and street*. London Country Life Limited

Mattheck C. and K. Bethge (1998) *The mechanical survival strategy of trees*. Arboriculture Journal, Vol. 22 p.369-386

Mattheck C., K. Bethge, I. Tesari, R. Kappel (2002) *A new failure criterion for non decayed solitary trees*. Arboricultural Journal, Vol. 26 p.43-54

National Arborist Association (NAA) (2004) *Type of pruning depends on the age of tree*. www.natlarb.com retrieved February 2004

Niklas K.J. (1999) *Computing factors of safety against wind-induced tree stem damage*. Journal of Experimental Botany, Vol. 51 (345) p.797-806

Niklas K.J. (2002) *Wind, size and tree safety*. Arborist News. December p.10-13

Raimbault (1996) *La gestione dell’albero in città*. Atti del Seminario tenutosi a San Remo il 15-16 novembre 1996

Read H.J. (Editor) (2000) *Veteran trees. A guide to good management*. Veteran Trees Initiative. English Nature, Peterborough

Rozas V. (2004) *A dendro-ecological reconstruction of age structure and past management in an old-growth pollarded parkland in northern Spain*. For. Ecol. Manag., 195 p.205-219

Shigo A. L. (1991) *Modern arboriculture*. Shigo and Trees Associates, Durham, NH.

Struve D.K. (2002) *A review of shade tree nitrogen fertilization research in the United States*. Journal of Arboriculture, 28(6) p.252-263

Suzuki T. and K. Kohno (1987) *Effects of pruning on the branching habit of Morus alba L. and the abscission of the apices of the short shoots*. New Phytol., 106 p.753-758

Watson G. (2004) *How to promote and enhance the root vitality on veteran trees : responses to natural and chemical products*. Proceeding of the International Congress “The trees of history”, Turin (Italy), 1-2 April 2004 p.40-44

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