Biomechanical adaptation of the wood structure of European chestnut to growth stresses

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Background and Objective

Fig. 1: Example of ring shake in chestnut wood.

The release of stresses often is cause for cracks in wood (Kubler, 1987). The higher the stress, the likely the wood is shaken. Chestnut wood tends to develop tangential concentric splits, called ring shake (Fig. 1), while most of the other wood species form radial fractures. This defect however origin from the release of growth stresses that primarily occurs during wood manufacturing (cross cutting).

Ring shake, which is the major obstacle to the economic exploitation of chestnut wood, is assumed to be very common because of the particular weakness of its wood, that in the radial direction might be particularly weak compared to other species (Fonti *et al.*, 2002a). In fact the wood structure of chestnut is formed in such a way that makes it, compared to other wood species, specifically susceptible to tangential failure (Fig. 2). The earlywood zone, which has plenty of large vessels, represents a naturally weak zone and can consequently easily fail. Some species, as beech, cope with this weakness due to numerous and large wood rays, which through a high radial tensile strength are able to reinforce the earlywood zone (Beery *et al.*, 1983; Mattheck *et al.*, 1994; Badel and Perré, 1999; Burgert *et al.*, 1999; Burgert and Eckstein, 2001; Burgert *et al.*, 2001). But this is only partially the case for chestnut wood, which is characterized by small and thin uniseriate wood rays and thus cannot offer great resistance to failures developing in the tangential plane.

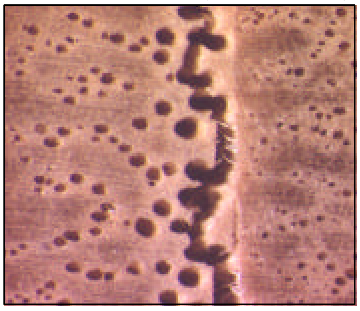

Fig. 2: Example of ring shake developing across the earlywood vessels.

Questions: Do stress-overloaded trees (i.e. ring shaken trees) adjust the wood anatomical structure in response to higher radial stresses?
Are also in chestnut tree evident indications of a mechanical self optimization against high growth stress level?

Material and Methods

The material of the study consists of wood discs sampled from the basis of shoots of three over-aged chestnut coppice plots located in the southern part of the Swiss Alps (Bedano, Gerra, Novaggio). All together 60 wood discs were sampled, 10 shake-free and 10 strong ring shaken discs from each plot.

Anatomical characteristics were surveyed using a digital image device.

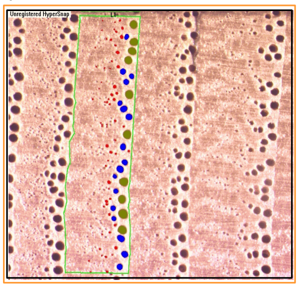

Fig. 3: Example of an analysed image. Coloured point correspond to the recognised earlywood vessels.

Earlywood vessels characteristics were measured for each annual ring along a radius through images captured directly on the cross-section of the polished discs (Fig. 3).

Measured characteristics:
number of vessels, mean and total vessels area

Radial rays characteristics were measured using a LTSEM on 6 tangential wood sections sampled regularly distributed along the same radius used for earlywood measurement (Fig. 4).

Measured characteristics:
Rays number and total rays area

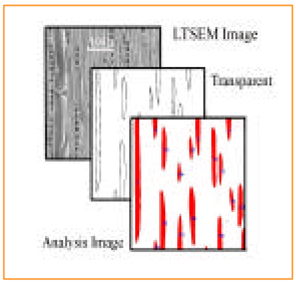

Fig. 4: Example of an analysed image. The red shapes of the foreground image represent the recognised rays.

Results

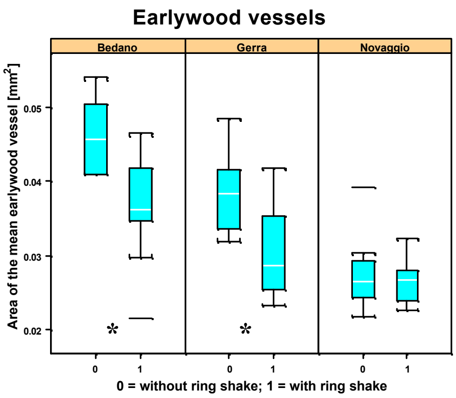

Fig. 5: Confronting analysis among vessel characteristics.

Results indicate that ring shaken wood denotes smaller earlywood vessels (Fig. 5) and a higher amount of wood rays proportion (Fig. 6) than the unshaken one. Although differences are not always statistically significant, the trend is clearly evident in each plot.

More detail about the studies on earlywood vessels and radial rays are given in Fonti *et al.* (2002b) and Fonti and Frey (2002).

* = significant differences in mean.

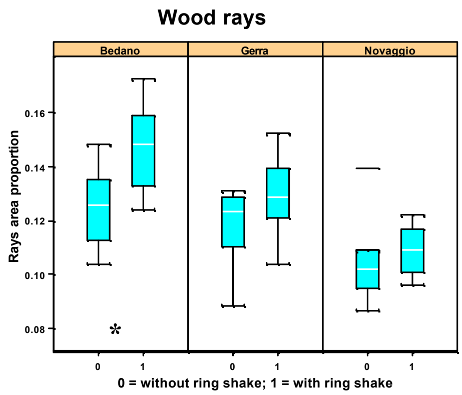

Fig. 6: Confronting analysis among rays characteristics.

Conclusion

Analysis of wood structural anatomical characteristics have shown that ring shaken wood displays a greater radial rays volume and smaller earlywood vessels lumina than the unshaken ones.

This result could be founded in tree biomechanical processes. In this case it is plausible that, in order to face the problem of ring shake, stress-overloaded trees might generally create more rays and smaller earlywood vessels lumina than the stress-poor ones. In other words, to avoid undesired fractures, the wood must be provided with bearings that compensate for these stresses through an enhanced strength.

These observations are a clear sign that also chestnut trees, during his life, can compensate for radial tensile stresses by adjusting his wood structure in order to produce a wood with high radial tensile strength.

References

- Badel, E., Perré, P. (1999). Détermination des propriétés élastiques d'éléments individuels du plan ligneux du chêne par des essais de traction sur micro-éprouvette. Ann For Sci 56: 467-478
- Bery, H., Geza, I., Mc Lain, E. (1983). Quantitative wood anatomy - relating anatomy to transverse tensile strength. Wood Fiber Sci 15: 395-407
- Burgert, I., Eckstein, D. (2001). The tensile strength of isolated wood rays of beech (*Fagus sylvatica* L.) and its significance for the biomechanics of living trees. Trees 15: 168-170
- Burgert, I. Bernasconi, A., Eckstein, D. (1999). Evidence for the strength function of rays in living trees. Holz Roh- Werkstoff 57: 397-399
- Burgert, I., Bernasconi, A., Niklas, K., Eckstein, D. (2001). The influence of rays on the transverse elastic anisotropy in green wood of deciduous trees. Holzforschung 55: 449-454
- Fonti, P., Macchioni, N., and Thibaut, B. (2002a). Ring shake in chestnut (Castanea sativa Mill.): state of the art. Ann For Sci 59: 129-140
- Fonti, P., Bräker O-U., Giudici, F. (2002b): Relationship between ring shake incidence and earlywood vessel characteristics in chestnut wood. IAWA 23: 287-298
- Fonti, P., Frey, B. (2002). Is the ray volume a possible factor influencing ring shake occurrence in chestnut wood?. Trees 16: 519-522
- Kubler, H. (1987). Growth stresses in trees and related wood properties. Forest Product Abstract 10: 61-119
- Mattheck, C., Kubler, H. (1995). Wood - The internal optimization of trees. Springer, 129p