WOOD RESEARCH
57 (3): 2012
399-408

INVESTIGATION ON THE APPEARANCE OF CRACKS IN LOGS AFTER FELLING AND BUCKING OF TREES IN A POPLAR (I-214) PLANTATION

Kiriaki Giagli, Elias Voulgaridis
Aristotle University, School of Forestry and Natural Environment, Laboratory of Forest Utilisation
Thessaloniki, Greece

(Received January 2011)

ABSTRACT

The phenomenon of crack appearance on cross sections and along the length of poplar logs (clone I-214) after felling and bucking of trunks was investigated in a plantation at the prefecture Serres, NE Greece, that is one of the most poplar wood productive regions of Greece. The appearance of such cracks is a serious defect impairing the quality of the fast growing poplar clone I-214 that may successfully substitute imports and cover wood deficits. The cracks appeared on both transversal sections of almost all experimental logs produced (95 %) and classified in three types (I, II, III) and 17 subtypes. Cracks of type I passing through the pith was the most frequently occurred (70 %) on both cross sections of logs and for all six samplings. In larger diameter, trunks and logs (d = 40–70 cm), the appearance of cracks was found to be most frequent compared to smaller diameters. Different felling time, stay of trunks for 6 months in felling site and combined circumferential cross cutting at bucking positions/ stay of merely cut trunks for six months in felling site, did not appear to have any positive effect on crack appearance by reducing the frequency of crack occurrence. The extensive crack occurrence in poplar (clone I-214) logs needs further investigation of various parameters like felling and bucking techniques, different plantation sites, presence of tension wood, and fast rate of growth, low wood density, high moisture content and size and distribution of growth stresses.

KEYWORDS: Poplar clone I-214, felling, bucking, poplar wood, cracks, NE Greece.

INTRODUCTION

During their whole growth history, trees are likely to develop growth stresses due to external or internal actions (Kübler 1987, Thibaut and Gril 2003). The tendency of a standing tree to support the total biomass weight produces support stresses, while the cell formation and development causes maturation stresses (Tribaut and Gril 2003). Due to growth stresses, tree stems improve their strength and flexibility and control their shape and orientation (Wilson and Archer 1979, Fournier et al. 1994, Thibaut et al. 2001, Almeras et al. 2002, Clair et al. 2010). Nevertheless, potential deformations appeared in standing trees are induced by growth stresses and could be correlated with the forest environmental conditions (inclination, wind, soil, sun, snow etc.) and certain morphological and anatomical abnormalities within the trees, such as reaction wood (poplar, eucalypt), etc. (Saurat and Guéneau 1976, Thibaut and Gril 2003, Ormarsson et al. 2010). Border or partly dominated trees, for example, inclined by wind or snow action, usually exhibit reaction stresses leading to a formation of reaction wood that is either compression wood in conifers or tension wood in hardwoods (Trénard and Guéneau 1975, Fournier – Djimbi et al. 1997, Yamamoto et al. 2002, Thibaut and Gril 2003).

Measurements of growth stresses can be performed on standing trees, but the most widely common technique is to observe log-end crack appearance after felling and crosscutting the trees (Thibaut and Gril 2003). Many researchers conclude that the cracking risk is much higher in hardwoods containing tension wood than in softwoods containing compression wood. It was also observed that the cracking risk tends to increase with log diameter (Jullien and Gril 2002, Thibaut and Gril 2003).

The growth stresses may be released during felling the trees and bucking the trunks, thus contributing to crack and split development on tree logs (Mattcheck and Walther 1992). The appearance of such cracks and splits on the logs impairs the quality of produced round timber in the forest (Archer 1986) and for this reason it is necessary to apply modified felling techniques (Mattcheck and Walther 1992), different harvesting periods (Tsoumis 1992) and optimum sawing patterns (Thibaut and Gril 2003). Practically, growth stress release causes lumber distortion in sawmills occurring even before any drying, and impairs timber as raw material for any further processing and utilisation of logs (Saurat and Guéneau 1976, Jullien et al. 2003, Thibaut and Gril 2003).

Various poplar clones are fast growing species and may cover partly deficits of wood of technical hardwood production or substitute tropical imported timber for plywood, solid wood and paper manufacture (Fang et al. 2008). Poplar wood production is affected by the forest station (soil quality and plantation spacing, growth conditions) and the clone type (Garyfalos and Koukos 1986, Sanz and Oliva 2000, Fang et al. 2008), while the particular structural characteristics and properties, and the appearance and intensity of defects determine the quality of wood and its utilisation (Tsoumis 1991). Longitudinal deformations caused by growth stresses in the periphery of the trunk of *Populus x euramericana* (I-214, Canada Leones, I-262, I-MC) clones were associated with the tree's inclination and the top's symmetry (Sanz and Oliva 2000). Correlations between growth stresses and structural characteristics (cell diameter, vessel and fiber proportion) as well as between growth stresses and cellulose and lignin content were observed in the clone I – 69 (*Populus deltoides* Bartr. cv. "Lux" ex I-69/55 (Fang et al. 2008). Experiments conducted on young poplar clones (*Populus deltoides* x *Populus trichocarpa* I45-51) using X-ray diffraction, have demonstrated structural changes of the microfibril orientation (Clair et al. 2010).

In a poplar plantation (clone I-214) of the prefecture Serres, which is one of the most poplar wood productive parts of Greece (Gatzogiannis 1998, Stergiopoulos 1996), it was observed that the appearance of cracks in logs after felling and bucking was very common and almost general. The aim of this paper was to investigate the creation and the appearance of cracks on cross sections of the poplar clone I-214 trees, immediately after felling and during bucking and converting them into logs.

MATERIAL AND METHODS

The investigation of crack appearance on cross sections of poplar logs (Fig. 1), took place in a plantation of prefecture Serres, according to the following dates and samplings (Tab. 1).

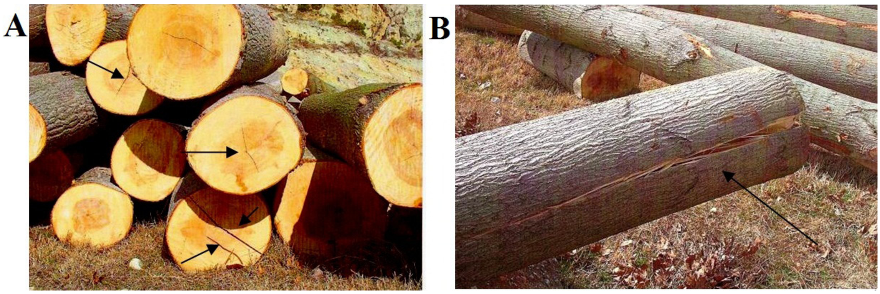


Fig. 1: Appearance of cracks on cross sections of poplar logs (see arrows) after tree felling and bucking A. In B, an intensive crack extended along the log.

Tab. 1: Dates and treatments of the 6 samplings in a poplar clone (I-214) plantation of prefecture Serres.

Sampling	**No. of trees felled**	**Date of felling**	**Date of observation - record**	**Treatment**
1st	7	12/03/2003	12/03/2003	-
2nd	10	12/03/2003	28/05/2003	6 weeks stay in the felling site
3rd	5	12/03/2003	28/05/2003	Circumferential section of cutting of logs, 5 or 10 cm in depth, by chainsaw at the positions of bucking and 6 weeks stay in the felling site
4th	10	28/05/2003	28/05/2003	-
5th	10	17/11/2003	17/11/2003	-
6th	10	17/03/2004	17/03/2004	-

In the first 3 samplings, trees were felled down on 12th March, 2003. For the first sampling, observations and measurements (type and size of crack) on crack appearance were taken immediately after bucking on both cross-sections of the logs. For the second sampling and third sampling, logs were stayed for approximately six weeks on the ground and measurements were taken on 28th May, 2003, after bucking. The trunks of the third sampling were cut by chainsaw circumferentially at the positions of bucking in a depth of 5 – 10 cm, immediately after felling, in order to investigate if this procedure releases the stresses and enhances drying of logs affecting the frequency and the intensity of cracks.

In the fourth sampling, felling, bucking and observations were done at different date (28th of May 2003) compared to first three samplings in order to investigate any effect of different felling time.

In the fifth sampling, 10 trees were felled and investigated on autumn (17th November 2003) Finally, in the sixth sampling, 10 more trees were felled and investigated in the end of winter (17th March 2004) in order to defect any seasonal effect.

Length and diameter were recorded for all experimental logs (Tab. 2).

Tab. 2: Mean length and diameter of experimental poplar logs.*

Sampling	No. of trees felled	No. of logs	Mean log length (m)	Mean log diameter (cm)
1st	7	24	2.29 (0.06)	47.44 (5.01)
2nd	10	41	2.07(0.42)	45.83 (7.08)
3rd	5	20	2.16 (0.42)	41.97 (9.32)
4th	10	48	2.25 (0.25)	45.20 (6.12)
5th	10	44	2.21 (0.44)	48.34 (9.38)
6th	10	22	2.07 (0.32)	42.00 (8.16)

*In parentheses standard deviation

Fig. 2 shows the bucking of poplar trunks into logs and the appeared cracks on both sections at each log. The cracks were distinguished into types according to their appearance, dimensions (length, width, etc.) and direction.

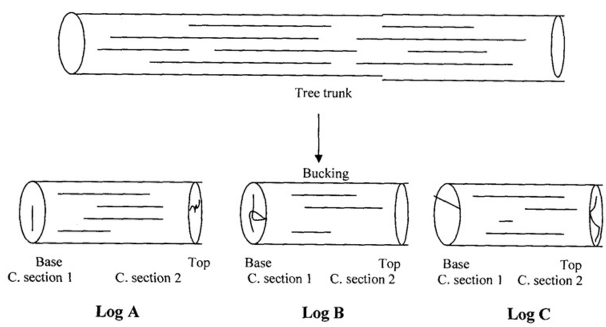


Fig. 2: Bucking of poplar tree trunk into logs and crack appearance on both transversal surfaces of each log.

Additionally, thin sampling disks, 1 cm thick, were taken from the bases of each poplar trunk, and used to determine the moisture content of wood. These disks were put in plastic bags, transferred to laboratory within a day and the moisture content was determined by using narrow radial stripes from the wood disks.

RESULTS AND DISCUSSION

The results of this paper are presented in Tabs. 3-6 and in Fig. 3.

Tab. 3: Moisture content of poplar logs for all samplings and groups tested.*

Sampling No./Group No.	Date / Days		No. of logs	Mean moisture content (%)
	Felling date – Measurement date	Days		
1	12/03/03 - 12/03/03	-	24	139.00 (20.33)
2	12/03/03 - 28/05/03	77	41	120.60 (15.36)
3	12/03/03 - 28/05/03	77	20	118.32 (8.26)
4	28/05/03 - 28/05/03	-	48	140.54 (6.41)
5	17/11/03 - 17/11/03	-	44	138.21 (12.42)
6	17/03/04 - 17/03/04	-	22	140.50 (18.87)

*In parentheses standard deviation

Moisture content of the logs

Moisture content of the experimental poplar logs (clone I-214) immediately after felling ranged between 138.2 and 140.5 % independently of cutting season (samplings 1, 4, 5 and 6, Tab. 3). Moisture content differences between the above cutting dates were very small and non-significant.

Moisture content of poplar logs for the other two samplings (2, 3) was found to be lower (118.3 – 120.6 %) but non – significant, when measured after 6 weeks stay of trunks in the felling site. In this case, it is obvious that the rate of reducing the moisture content from the logs is rather slow for the short period of 6-week time and that much longer period is required for drying the trunks sufficiently. It is worthy to mention that even in sampling 3, where a circumferential cutting at the positions of bucking was done, the reduction of moisture content was low.

Crack appearance and classification

The appearance of several various cracks observed on cross sections of poplar logs after felling and bucking of trunks as well as their dimensions (length on the cross section, width) were shown in Tabs. 3 and 4 separately, for each sampling. Tab. 4 shows in a graphic way the types of cracks as these appeared on both cross sections (base, top) of poplar logs after felling and bucking of trunks for sampling 3, the mean values of crack length (MCL) and the mean maximum crack width (MMCW) per cross section.

For this sampling, the mean crack length was ranged between 17.5 cm to 28.2 cm (bases) and from 16.4 cm to 22.7 cm (tops). While the mean maximum width varies from 1.0 mm to 1.7 mm for both, bases and tops, of poplar logs.

Tab. 5 shows the lengths and the widths (minimum and maximum values, mean values) of cracks appeared on both ends of poplar logs, after felling and bucking of trunks, for all samplings. It appears that the length values for all samplings varied between 3.0 to 47.3 cm (bases) and between 4.0 to 45.7 cm (tops), and the mean values of the samplings varied from 17.5 to 28.2 cm (base) and from 16.4 to 22.7 cm (top). For comparative purposes between the samplings the mean values of crack length are also shown in Fig. 3D.

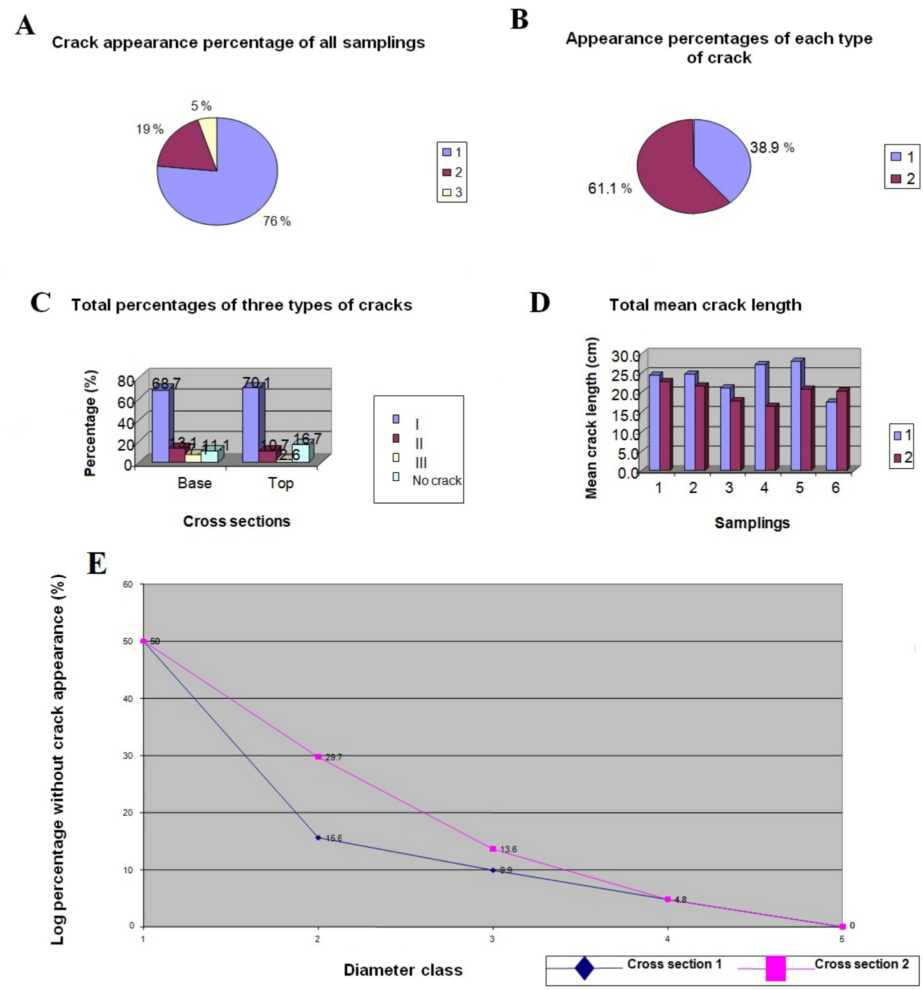
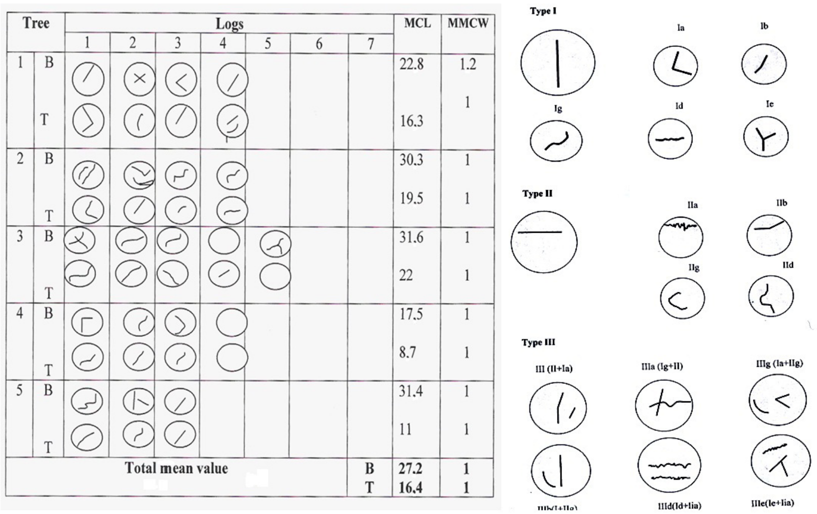


Fig. 3. A: Frequency of crack appearance (%) in all samplings (1: crack appearance on both cross sections, 2: crack appearance on one cross section, 3: no crack appearance. B. Percentages of similar (1) or different (2) type of cracks occurred in the two cross sections of poplar. C. Frequency of different crack type appearance. D. Mean crack length on both cross sections of each log (1: base, 2: top), E. Relationship of log diameter with the frequency of crack appearance on the cross sections 1 and 2 (Diameter class: 1: 21-30 cm, 2: 31-40 cm, 3: 41-50 cm, 4: 51-60 cm, 5: 61-70 cm).

*Tab. 4: An example of recording the appearance of various crack types on cross sections of poplar logs in sampling 3 and their classification to three main types and sub-types (B: Base, T: Top) *MCL: Mean crack length on cross section (cm), *MMCW: Mean Maximum crack width (mm).*



Tree		Logs 1	2	3	4	5	6	7	MCL	MMCW
1	B								22.8	1.2
	T								16.3	1
2	B								30.3	1
	T								19.5	1
3	B								31.6	1
	T								22	1
4	B								17.5	1
	T								8.7	1
5	B								31.4	1
	T								11	1
Total mean value								B	27.2	1
								T	16.4	1

*Blank cross section on the tables, implies that there was no crack appearance.

Tab. 5: Dimensions (length, width) of cracks measured in both cross sections of poplar logs.*

Sampling	Crack length: Min Max (cm)		Mean (cm)		Crack width: Min Max (mm)		Mean (mm)	
	Base	Top	Base	Top	Base	Top	Base	Top
1	15.8-36.0	8.5 –45.7	25.2 (7.0)	22.7 (9.6)	1.0 – 2.75	1.0-4.0	1.5 (0.570	1.7 (0.76)
2	8.5-40.3	8.0 –30.0	21.3 (10.1)	18.0 (8.3)	1.0-3.0	1.0-1.5	1.1 (0.36)	1.0 (0.09)
3	17.5-31.6	8.7-22.0	27.2 (4.8)	16.4 (5.4)	1.0-1.2	1.0-1.0	1.0 ±0.0	1.0 (0.0)
4	9.0-47.3	11.0-37.4	24.9 (13.4)	21.7 (8.7)	1.0-1.6	1.0-1.5	1.0 (0.14)	1.0 (0.11)
5	3.0-46.2	4.0 –29.2	28.2 (9.4)	21.0 (7.3)	1.0-2.0	1.0-2.0	1.1 (0.33)	1.1 (0.34)
6	7.5-31.3	8.0-31.5	17.5 (8.4)	20.4 (7.2)	1.0-1.0	1.0-1.0	1.0 (0.0)	1.0 (0.0)

*In parentheses standard deviation

Various types of cracks with different shape occurred on both cross sections (base, top) of poplar logs after felling and bucking of trunks. Only in some cases, there was no crack appearance. According their shape and position on the cross section, the cracks were classified into 3 basic types (I, II, and III) and sub-types (Tab. 3).

Tab. 6: Relative base and top crack length to log diameter.

Diameter class	Log diameter (cm)	Base crack length (cm)	Top crack length (cm)	Relative base crack length to log diameter (%)	Relative top crack length to log diameter (%)
I (20 - 30 cm)	29.6	18.6	13.76	31	22.9
II (31- 40 cm)	36.8	15.0	11.1	35.5	20.8
III (41 - 50 cm)	46.2	23.6	19.4	45.9	36.3
IV (51 - 60cm)	54.5	25.7	22.9	45.3	39.8
V (61 - 70 cm)	64.5	28.2	21.9	43.2	34.2

1. TYPE I. Cracks that pass through the pith including 5 sub-types.
2. TYPE II. Cracks that don't pass through the pith but they are oriented in parallel or almost in parallel to the growth rings or even they cut vertically the growth rings. This type includes 4 sub-types.
3. TYPE III. This type is a combination of the two types described above and includes 6 subtypes as shown in Tab. 3.

Further analysis of the phenomenon of crack appearance after felling and bucking poplar trunks, shows that (Fig. 3):

From the total number of 199 experimental logs, a percentage of 76 % appeared to exhibit cracks on both ends, in a percentage of 19 % cracks appeared only in one cross section, and a very low percentage of logs (5 %) did not show any sign of crack appearance (Fig. 3A).

The appearance of similar type of cracks on both cross sections (base, top) of the logs, was recorded in a percentage of 38.9 % of logs, while in 61.1 % of the logs different type of cracks between base and top of the logs was observed (Fig. 3B).

Fig. 3C presents the frequency appearance of the three basic types of cracks in all samplings. Type I of the (cracks passing through the pith) dominates, and occurred in a percentage of 68.7 % for log bases and 70.1 % for log tops. The other two types of cracks (II and III) appeared in much lower frequencies (10.7 – 13.1 % for type II and 7.1 – 2.6 % for type III). Tab. 6 presents the relative crack length to mean diameters of logs.

From Fig. 3D it can be seen that in samplings 4 and 5 the frequency of crack appearance referred to bases was found to be higher than in other cases. Moreover, mean crack length was higher in bases than the tops in all samplings except one (6^{th} sampling).

Finally, Fig. 3E shows clearly that larger diameter of logs are related with higher frequencies of crack appearance. In 50 % of logs with diameter 21-30 cm no cracks were recorded, while in larger diameters (51 – 70 cm), almost all logs appeared with cracks in their ends.

CONCLUSIONS

The crack appearance on cross sections of poplar logs (clone I-214) after felling and bucking of trunks seems to be a general phenomenon (95 % occurrence) in plantations of the prefecture

Serres, NE Greece.

Different types of cracks were observed. According to shape and position of cracks, they were classified to three basic types (I, II, III) including 17 sub-types. Type I cracks were recorded as the most frequently occurred (about 70 %) on both cross sections of logs and for all samplings.

The three treatments, a) different felling time of trees, b) stay of trunks in felling site for 6 weeks, then bucking and measurements and c) circumferential cross cutting of trunks in the positions of bucking and then as b, did not show any effect on the frequency of crack appearance, although in b and c treatments the moisture content of wood was slightly reduced from about 140 % to about 120 % during bucking.

Trunks and logs of larger diameter (d = 40-70 cm) were found to be associated with higher frequency of crack appearance when compared to lower diameter logs (d = 20-40 cm).

Crack appearance in poplar (clone I-214) logs after felling and bucking was found to occur very frequently and it can be described as an undesirable defect with negative effects on wood quality. Further investigations need to study this phenomenon by including parameters such as different sites, application of different felling and bucking techniques, low density of poplar wood, high moisture content of wood during felling and bucking, the presence and intensity of tension wood, rate of growth, accumulated growth stresses in standing trees and trunks, and possibly, other factors which may influence the creation and frequency of crack appearance.

ACKNOWLEDGMENT

This paper is based on MSc Thesis: Giagli, K., 2005: Investigation on the appearance of cracks in poplar trunks (clone I-214) after their felling and bucking in a plantation of Lefkonas, Serres – GR (in Greek). Aristotle University, School of Forestry and Natural Environment, Thessaloniki, Greece.

REFERENCES

1. Alméras, T., Gril, J., Costes, E., 2002: Bending of apricot tree branches under the weight of axillary growth: Test of a mechanical model with experimental data. Trees – Structure and Function 16(1): 5-15.
2. Archer, R.R., 1986: Growth stresses and strain in trees. In Springer Series in wood Science (ed. T.E. Timmel), Springer – Verlag, Berlin, Heidelberg, New York, Tokyo, 240 pp.
3. Clair, B., Alméras, T., Pilate, G., Jullien, D., Sugiyama, J., Riekel, C., 2010: Maturation stress generation in poplar tension wood studied by Synchrotron radiation microdiffraction. Plant Physiology 152(3): 1650-1658.
4. Fang, C-H., Guibal, D., Clair, B., Gril, J., Liu, Y-M., Liu, S-Q., 2008: Relationships between growth stress and wood properties in poplar I-69 (*Populus deltoides* Bartr. cv. "Lux" ex I-69/55). Ann. For. Sci. 65(3): 307.
5. Fournier, M., Moulia, B., Thibaut, B., 1994: Growth, prestresses and regulation of movement in living trees, in evolution of natural structures, principles, strategies and models in architecture and nature. 3rd International Symposium SFB 230 (eds. Universities of Stuttgart and Tübingen), Mitteilungen des Sonderforschungsbereich, Stuttgart 230(9): 157-162.

6. Fournier – Djimbi, M., Sassus, F., Combes, J.G., Grzeskowiak, V., 1997: Growth stresses and reaction wood. In: 2nd International Conference of Plant Biomechanics, Centre for Biomechanics, The University of Reading, Reading. No. 1. Pp 231-238.
7. Garyfalos, I., Koukos, P., 1986: Effect of pruning in relation to spacing on poplar wood production. 18th IUFRO World Congress, Ljubjana, Yugoslavia, September. Pp 7–21.
8. Gatzogianis, S., 1998: Reporting poplar plantation sites (Year 1996). Forest Research Institute Ministry of Agriculture, Thessaloniki, Greece.
9. Jullien, D., Gril, J., 2002: Modelling crack propagation due to growth stress release in round wood. In: Proceedings of EMMC6 Conference on Non Linear Mechanics of Anisotropic Material, Liège. Pp 203-210.
10. Jullien, D., Laghdir, A., Gril, J., 2003: Modelling, log-end cracks due to growth stresses: Calculation of elastic energy release rate. Holzforschung 57(4): 407-414.
11. Kübler, H., 1987: Growth stresses in trees and related wood properties. Forest Products Abstracts 10(3): 62–119.
12. Mattcheck, C., Walther, F., 1992: A new felling technique to avoid end-splitting of deciduous trees. Proceedings of IUFRO V. Nancy, France.
13. Ormarsson, S., Dahlblom, O., Johansson, M., 2010: Numerical study of how creep and progressive stiffening affect the growth stress formation in trees. Trees 24(1): 105–115.
14. Saurat, J., Guéneau, P., 1976: Growth stresses in beech. Wood Sci. Techn. 10(2): 111–123.
15. Sanz, M.C., Oliva, A.G., 2000: Growth stresses in five clones of *Populus* x *euramericana*: I-214, Canada Leones, I-262, and I-MC in Spain. 21st session of the International poplar commission, Portland, Oregon, USA, 24-28 September.
16. Stergiopoulos, G., 1996: Recording tables of poplar wood production from 1966 to 1996 at the prefecture Serres. NW Greece. Serres Forest Service.
17. Thibaut, B., Gril, J., Fournier, M., 2001: Mechanics of wood and trees: Some new highlights for an old story. Comptes-rendus de l'Académie des Science, Paris, Série 2b, 329(9): 701-716.
18. Thibaut, B., Gril, J., 2003: Growth stresses. In: Wood quality and its biological basis. (Eds. Barnett J.R. and G. Jeronimidis). Blackwell Publishing CRC Press. Pp 137-156.
19. Trénard, Y., Guéneau, P., 1975: Relation entres containtes de croissance longitudinales et bois de tension dans le hêtre (*Fagus sylvatica* L.). Holzforschung 29(6): 217-223.
20. Tsoumis, G., 1991: Science and technology of wood: Structure, properties, utilization. Van Nostrand Reinhold, New York, 494 pp.
21. Tsoumis, G., 1992: Harvesting forest products. Stobart Davies Ltd., Herts, England.
22. Wilson, B.F., Archer, R.R., 1979: Tree design: Some biological solutions to mechanical problems. Bioscience 29(5): 293-298.
23. Yamamoto, H., Kojima, Y., Okuyama, T., Abasolo, W.P., Gril, J., 2002: Origin of the biomechanical properties of wood related to the fine structure of the multi-layered cell wall. Journal of Biomechanical Engineering 124(4): 432-440.

Kiriaki Giagli, Elias Voulgaridis
Aristotle University
School of Forestry and Natural Environment
Laboratory of Forest Utilisation
541 24 Thessaloniki
Greece
Phone: + 30 2310 992750
Corresponding author: kgiagli@for.auth.gr