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Considering reversible Variations in Wood Properties: possible Applications in the Choice of the Tree-Felling Date?

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Traditional knowledge, in form of so-called rural rules, indicates that the date of tree felling has an important influence on wood quality. The main factor, after the season of the year, is said to be the position of the moon. The objective of the presented project was to study the variability of some user-related properties of wood, by analyzing measurable parameters. The material stems from four different Swiss sites and is representative of central European conditions. This part of the study involved 576 trees — Norway Spruce (*Picea abies* Karst.) and Sweet Chestnut (*Castanea sativa* Mill.) — felled on 48 dates throughout the fall and spring of 2003–2004 (always on Mondays or Thursdays). Before the start of the experiment, one sample was taken on the same day from each of the tested trees, to serve as reference. Wood properties analyzed are: water-loss, shrinkage under controlled drying, air dry and oven dry density. Smaller series of samples were tested on hygroscopicity. The statistical analysis of the complete data series reveals (in addition to a seasonal trend) a generally weak, but highly significant role of the synodic and of the sidereal moon cycles, to a lesser extent of the tropical cycle. The lunar-related differences are more marked for the central 4 months of the trial.
The results from this study bring some transparency and objectivity into a mainly unexplored field of traditional knowledge, a field subject to controversial discussions. Further research in chronobiology of wood could lead to an ecological technique enhancing specific wood properties.

Key words: Wood properties, Forestry traditions, Moon phases, Drying, Water sorption
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The idea of a relationship between plant growth and moon cycles has often been considered by scientists as due to old superstitions. An interesting corpus of well documented experimental work is yet existing and suggests objective phenomena interacting at different levels. An extensive review of the available data and interpretations has recently been published in a book on botany (Zürcher 2008), based on a series of 88 scientific publications related to this topic. Since we started working on the field of tree chronobiology linked to lunar rhythms, it has been possible to observe significant relationships for different aspects of tree life and wood properties. Here is a short overview:

- The germination and initial growth of some tropical trees show a decided rhythmic character. Speed of germination, percent of germination, average height, and maximum height after 4 months are systematically related to the timing of sowing in relation to the moon phase (Zürcher 1992, 2000).
- An interdisciplinary reworking of previously published, long-term tree-physiological research results (variations of tree diameters obtained by extensometry) has enabled researchers to consider an unexpected aspect: the synodic (time required for the moon to complete a full phase, i.e., usually 29.53 days) moon-rhythm at a daily level (gravimetric tide-rhythm) could be established for trees held under constant conditions (darkness) (Zürcher, Cantiani, Sorbetti-Guerri and Michel 1998).
- Data of trees measured in open conditions, reanalyzed recently with more sophisticated tools, brought spectacular confirmation of the role of lunar tides in tree physiology (Barlow, Mikulecky and Strestik 2010). In the meantime, it had been possible to detect the same type of fluctuations by measuring with a high-sensitivity device the low-potential electric currents along the trees' stems, depending on the physiological phase of the trees (Holzknecht and Zürcher 2006).
- The drying behavior (water loss/shrinkage) and the final density of wood systematically and coherently vary in function of the tree felling date, if analyzed in relation to the season and to the position of the moon (Zürcher and Mandallaz 2001). The observed fluctuations are yet more complex than mentioned in forestry traditions existing all over the world (Zürcher, Schlaepfer, Conedera and Giudici 2010).

Traditional knowledge and practices concerning agricultural and forestry activities - so-called rural rules - are still widely spread in various cultures on different continents. Among them, rules are existing about effects of the tree-felling date on the properties of wood (Hauser 1973, Broendegaard 1985, Oldeman 1999, Cole and Balik 2010). The first written evidence of this knowledge dates back to Theophrastus of Eresos (372-287 BC), who in his History of Plants (V, 1, 3) states that there is an appropriate season for cutting the trees and – within the season - if cutting at the beginning of the waning moon, the wood is harder and less likely to rot. This popular knowledge has passed down to our times and to the local practices of felling trees during different moon positions depending on the specific forms of wood utilization (Zürcher 2000).

Despite such a broad and antique tradition in referring to the moon phases for determining the most suitable date for agricultural (e.g. seeding) and forestry (e.g. tree-felling) activities, there are relatively few scientific research works on this topic. For an extensive scientific review about lunar periodicities in Biology see Endres and Schad (1997).

In wood physics, the wood-water relations have been extensively studied (Skaar 1988; Navi and Heger 2005), but not yet including "time" as a possible initial, rhythmic factor of variation in the sample properties; the role of this factor appears at present mainly in the sorption hysteresis and in the viscoelastic behaviour. Two publications can nevertheless be cited in relation to the apparently fluctuating plant-water relations at issue, where the time factor "Moon" plays an essential role in living vegetals. Experimental based studies with Bean seeds (*Phaseolus vulgaris*) exist on the lunar cycle dependent water uptake during immersion by a dormant reproductive material (Brown and Chow 1973, Spruyt et al. 1987).

Concerning the role of the lunar phase at the felling date, three almost simultaneous, geographically independent research studies investigate selected wood properties of Norway Spruce with 120 trees in Dresden (Triebel 1998), 60 trees in Freiburg i.Br. (Seeling and Herz 1998, Seeling 2000) and 30 trees in Zürich (Rösch 1999, Bariska and Rösch 2000) respectively. None of these three investigations, with 6 felling dates each, could however significantly confirm the influence of the moon-correlated felling date on the main tested wood properties. The data collected from the 30 trees by Rösch (1999) were reanalyzed, regarding oven-dry wood density as a dependent variable in the same sense as water-loss and shrinkage (Zürcher and Mandallaz 2001, Zürcher 2003). This approach led to encouragingly significant results on the criteria water-loss, shrinkage and relative density (oven-dry density in percent of initial fresh / "green" density).
In order to fill the existing gaps in the choice of the previous experimental felling dates and to obtain a suitable data set for a broader statistical analysis, we set up a large (in terms of number of trees, experimental sites and felling dates) and systematic (always at the same days of the week) tree-felling experiment. The aim was to test the existence of a physical phenomenon of lunar-related variations in some selected wood properties as suggested by the mentioned kinds of ancient, traditional rules and practices. In particular, we wanted to examine the occurence of rhythmic, time-dependent cyclic variations in the wood-water-relation in correlation with three different types of moon rhythms or cycles. Moreover, different tree species (Norway Spruce and Sweet Chestnut) and different wood types (sapwood and heartwood) within the tree were analyzed separately.

The wood material tested comes regularly and simultaneously from four different Swiss sites representative for Central European conditions. Per main site, 144 Norway Spruce (*Picea abies* Karst.) trees or Sweet Chestnut (*Castanea sativa* Mill.) trees have been felled. These 576 trees were felled at 48 dates (06.10.2003 - 18. 03.2004, always on Mondays and Thursdays). Before the start of the experiment, one reference sample had been taken in the same day from each of

the main site-trees. Spruce samples were taken both from sap- and outer heartwood (Fig.1), Chestnut samples from heartwood only – the sapwood zone being to narrow in this species.

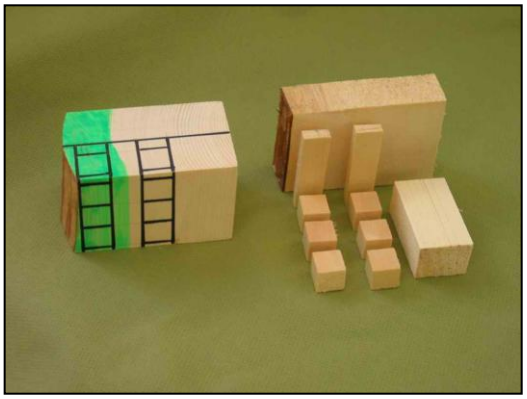

Figure 1: Preparation of test samples from Spruce (left: sapwood / right: outer heartwood)

This report presents the obtained variations in values of water loss under controlled drying, relative density (ratio oven-dry density / fresh density) and hygroscopicity of previously dried samples for the main studied species - Norway Spruce. The data are reported here in a descriptive and graphical way, the statistical analysis being presented in Zürcher, Schlaepfer, Conedera and Giudici (2010). To illustrate the discovered lunar-related phenomena, we will concentrate on one representative site (Château d'Oex) and one type of wood (sapwood).
In all the cases, strong time-dependent and inter-dependant variations are observed. According to variance analyses based on the totality of data (4032 values per criterium), a highly significant part of the changes in the values for water loss, shrinkage and relative density (oven-dry density green density) occurs in tune with the moon phases and its astronomical positions (synodic, tropic and sidereal rhythms). The implication of the time-independent reference-density of each tree allows to confirm the significance of the tested lunar models and to estimate their respective explicative power.

If the synodic lunar month (4 quarters) is subdivided in 8 periods of about 3.5 days each ("syn1" to "syn 8"; "syn 1" beginning with the New Moon NM, "syn 5" beginning with the Full Moon FM), one of the strongest "jumps" is occurring around FM, from "syn4" to "syn 5". The clearly opposite variations in Waterloss (Fig.2 A) and Relative Density (Fig.2B) illustrate the importance of the wood-water interface, which obviously undergoes lunar-correlated reversible changes.

These results confirm therefore the existence of the factor "Moon" as mentioned in traditional knowledge, but in a much more complex form (Theophrastus' rule seeming to be nearest to the synodic phenomena already observed on Spruce).

A **B**

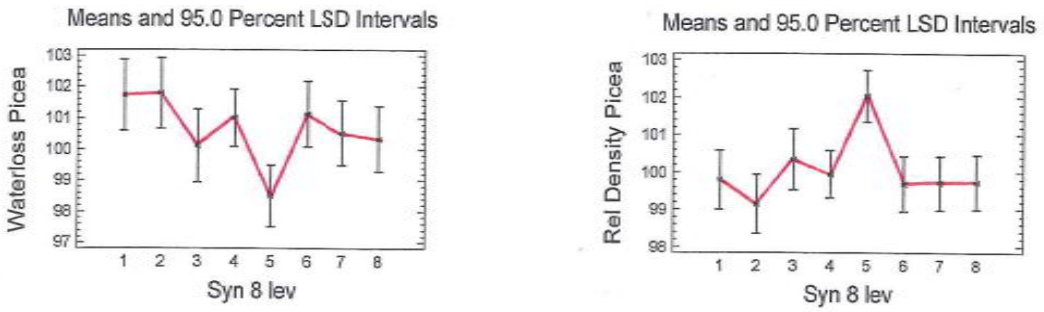

Figure 2: Lunar synodic variations of Water Loss (A) and Relative Density (B) of Norway Spruce (sapwood and heartwood), when dried from "green" to oven-dry state. Mean values with 95 % least significant differences. The vertical bold lines indicate the times of full moon, the dotted lines the times of new moon.

These systematic variations in the course of the synodic lunar month can be illustrated on the variation curve of the criteria "Relative Density" (Fig.3) and Water Loss (Fig.4) along the 48 successive felling dates, for a representative series: Sapwood samples from the site Château d'Oex (even-aged planted mountain Spruce stand). Following table indicates what fellings occurred directly before and directly after Full Moons, with the 6 corresponding dates (Table 1).

Felling dates (before FM / after FM)	Days of Full Moon (FM)
2 / 3	October 10, 2003
10/11	November 9, 2003
19/20	December 8, 2003
27/28	January 7, 2004
36/37	February 6, 2004
44/45	March 7, 2004

Table 1: Tree fellings around Full Moons, and their exact dates.

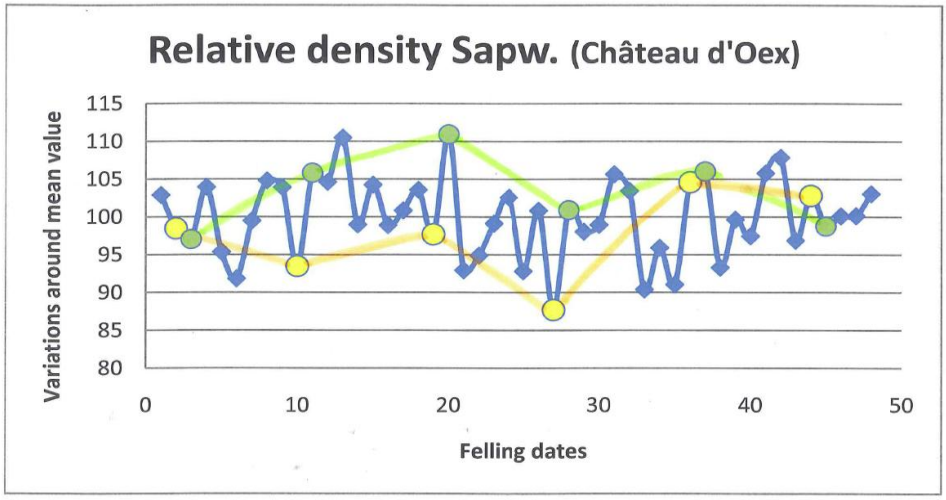

Figure 3: Variation curve of Relative Density of sapwood samples of Spruce from Château d'Oex. Legend of fellings around Full Moon: O = fellings in the 3.5 days before FM / O = fellings in the 3.5 days after FM. Each point represents 12 values (here without std.dev.).

As can be observed, during the four central winter months, from November (felling 10/11) to February (felling 36/37), the values before FM are always lower than the ones after. Before and after this core period in the first and the last weeks of the trial (October and March), the variations do not seem to follow the same lunar-related rule. The corresponding values for the central 4 months around the global site mean (100%) are given in the Table 2, with their differences and an estimation of the mean increase in Relative Density (10%).

Relative density (Sapwood)							
Variation from value before FM (syn 4) to value after FM (syn 5)							
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Mean [%]
bFM (syn4)	-	93.5	97.7	87.7	104.6	-	
aFM (syn5)	-	105.8	110.9	100.9	106	-	Increase
Variation [%]	-	12.3	13.2	13.2	1.4	-	**10.0**

Table 2: Values of Relative Density in the 3.5 days before Full Moon (bFM), compared to the values in the 3.5 days after (aFM) and their difference, for the central winter period November to February.

The cause for these variations in Relative Density lies in similartly fluctuating values in the loss of free and bound water during the controlled drying process, but in an opposite sense (compare also Fig. 2A with 2B). Here too, marked differences around Full Moons occur in the central

winter months only. Table 3 indicates the respective variations aroud FM during this period, the general mean being a reduction in Water Loss of 4.5%.

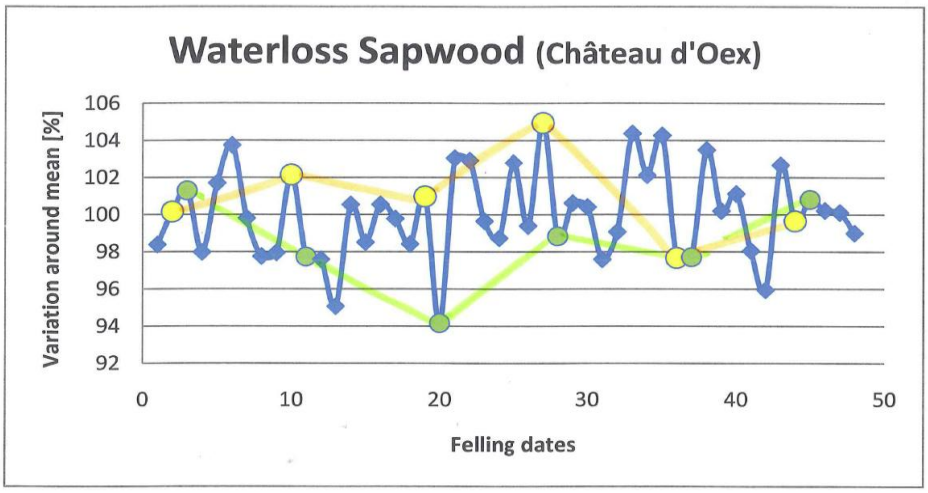

Figure 4: Variation curve of Water Loss of sapwood samples of Spruce from Château d'Oex. Legend of fellings around Full Moon: O = fellings in the 3.5 days before FM / O = fellings in the 3.5 days after FM. Each point represents 12 values (here without std.dev.).

Waterloss (Sapwood)							
Variation from value before FM (syn 4) to value after FM (syn 5)							
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Mean [%]
bFM (syn4)	-	102.2	101	104.9	97.7	-	
aFM (syn5)	-	97.7	94.2	98.3	97.7	-	Reduction
Variation [%]	-	-4.5	-6.8	-6.6	0	-	**-4.5**

Table 3: Values of Water Loss in the 3.5 days before Full Moon (bFM), compared to the values in the 3.5 days after (aFM) and their difference, for the central winter period November to February.

One of the most important physical properties of wood, decisive for weathering behaviour and for decay resistance, is its hygroscopicity. This feature is usually expressed as Equilibrium Moisture Content EMC under a given atmosphere, or as Fibre Saturation Point FSP, below which the loss of bound water in the drying process provokes shrinkage. The test method chosen for estimating the expected variations of hygroscopicity was to expose the samples to direct contact with water. One series was made of air-dried and conditionned sticks with dimensions 16*7*65 mm (see Fig.1). These were fixed all together (12 * 48 = 576 samples per site) at one of the ends to a plate, 5 mm of the other end being immersed for 9 minutes into a basin of water coloured with ink. The capillar ascent of water was estimated by calculation of the relative weight increase. Fig. 5 shows the variations of water sorption by capillarity during the 24 weeks

of tree collection. Both the limitation of the "lunar effect" on the 4 central months and the systematic drop directly after FM ist very similar to what was observed on Water Loss . A noticeable fact is that for capillarity, the mean amplitide of this decrease (25.9%) is much more pronounced (see Table 4).

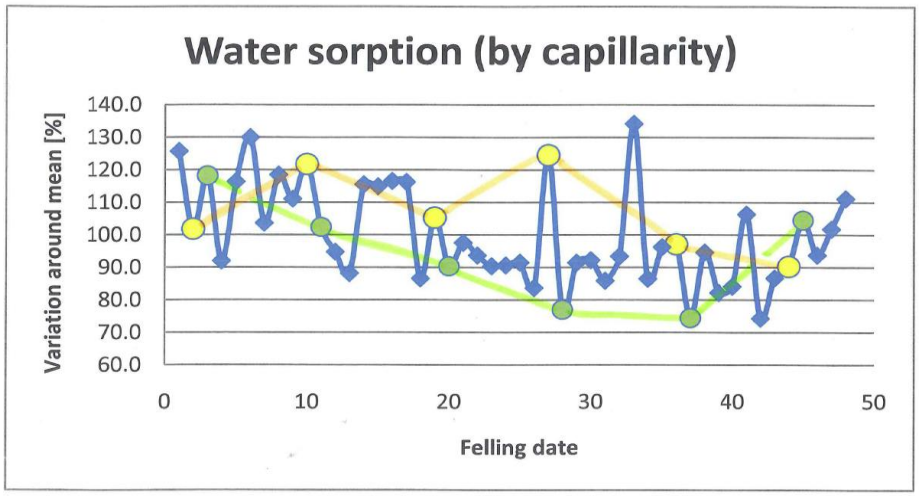

Figure 5: Variation curve of capillar Water Sorption of sapwood samples of Spruce from Château d'Oex. Legend of fellings around Full Moon: O = fellings in the 3.5 days before FM / O = fellings in the 3.5 days after FM. Each point represents 12 values (here without std.dev.).

Water sorption (by capillarity)							
Variation from value before FM (syn 4) to value after FM (syn 5)							
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Mean [%]
bFM (syn4)	-	121.7	105.3	124.6	96.3	-	
aFM (syn5)	-	102.4	90.3	77	74.5	-	Reduction
Variation [%]	-	-19.3	-15	-47.6	-21.8	-	**-25.9**

Table 4: Values of capillar Water Sorption in the 3.5 days before Full Moon (bFM), compared to the values in the 3.5 days after (aFM) and their difference, for the central winter period November to February.

The second test method for hygroscopicity was applied by immersion of the samples previously used for density determination. In a similar way, 576 cubic samples for each site (4 per tree, 12 per felling date) were dipped into water (20°C) for 7 days (168 hours). The sorption ist given by the mass increase in %. The variation curve (Fig.6) is represented relatively to the general mean of the whole series. Here too, the systematic lunar variations of sorption occur in obvious coherence with the Water Loss, and inversely to the Relative Density. Table 5 indicates that the mean reduction in sorption from the days before to the days after Full Moon is 12.6%, half the value obtained for capillar water uptake.

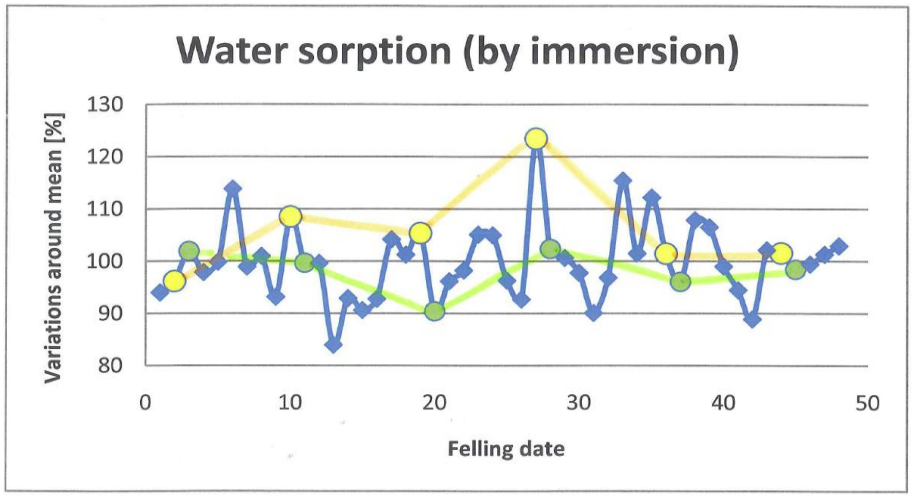

Figure 6: Variation curve of ity of sapwood samples of Spruce from Château d'Oex. Legend of fellings around Full Moon: O = fellings in the 3.5 days before FM / O = fellings in the 3.5 days after FM. Each point represents 12 values (here without std.dev.).

Water sorption (by immersion)							
Variation from value before FM (syn 4) to value after FM (syn 5)							
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Mean [%]
bFM (syn4)	-	108.5	105.4	123.5	101.5	-	
aFM (syn5)	-	99.7	90.4	102.4	96.1	-	Reduction
Variation [%]	-	-8.8	-15	-21.1	-5.4	-	**-12.6**

Table 5: Values of Water Sorption by immersion in the 3.5 days before Full Moon (bFM), compared to the values in the 3.5 days after (aFM) and their difference, for the central winter period November to February.

Following 3 points can therefore be stressed out here:

- Moon-related reversible variations are not limited on Water Loss, Relative Density (and Shrinkage) during the drying process: they are still an even more marked phenomenon at the level of water sorption (capillary and by immersion)
- This systematic and coherent lunar rythmicity occurs clearly only during the 4 months November to February, which indicates that both season and lunar cycles are involved
- These encouraging results need to be completed by durability and mechanical tests before being in position to draw a definitive conclusion in the sense of applicability.

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