LUNAR RHYTHMS IN FORESTRY TRADITIONS – LUNAR-CORRELATED PHENOMENA IN TREE BIOLOGY AND WOOD PROPERTIES

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Abstract. For more than 2000 years, certain forestry practices and rules regarding tree felling have been carried out in observance to Moon cycles. A general review of the different types of rules followed (known in Europe and on other continents and stemming from both written sources and current practitioners) shows that special timber uses are mentioned in relation to a specific felling date which supposedly ensures advantageous wood properties.

These empirical forestry traditions apply to a range of wood uses as diverse as building timber, shingles, wooden chimneys, fuel wood, resonance wood for harmony tables of violins, cheese-boxes, barrels and ploughs. In each of these cases, felling at the "right date" is thought to be an important factor to ensure the required properties of the product. Moreover, the rafting of timber used to be limited to certain days of the Moon cycle, when the water was supposed to carry the wood in the best way.

The second part presents scientific studies concerned, on the one hand, with "Moon phases" factor. They deal with elements of tree biology such as germination and initial growth of tropical trees (where strong and systematic variations and their complicating aspects have been observed), insect attacks on trees and reversible fluctuations of stem diameters. On the other hand, some works concentrate on wood properties and the relation between wood and water. They deal with the durability of wood, with systematic density variations after kiln-drying and with variations in the compression strength of the corresponding samples. An overview tries to find a common link between empirical practices and the scientific results.

Keywords: Chronobiology, felling date, Moon phases, traditional forestry, tree biology, wood properties

1. Introduction

The topic presented here is related to the fact that most organic processes and the structures which result from them have a rhythmic character. In the plant world in temperate latitudes, it is immediately obvious that the germination, growth, maturation and perennial structure formation in trees are marked by an alternation between active and resting phases. This alternation is materialized in the morphology of the shoot or in the architecture of the tree, and on an anatomical level, in the succession and internal structure of the growth rings.

Earth, Moon and Planets **85–86:** 463–478, 2001.

Man, a heterotrophic being has always had to take into account this rhythmical characteristic of plants, for his subsistence.

When reading works which deal with popular sayings or quote classical authors concerning agricultural practice, or simply speaking to gardeners, farmers or foresters with an empirical experience based on tradition, one is struck by two things.

Firstly, in addition to the rhythm of the seasons, lunar rhythms are systematically mentioned as having an influence on the growth, structures, characteristics or properties of plants.

Secondly, a number of practices show certain common elements, despite the geographical distance of the sources; these similarities in the rules formulated would seem to suggest the existence of possible objective phenomena. For example, the general rules governing the felling of trees are in accordance right across the continents; whether in the alpine arc (Hauser, 1973), in the Near East, in Africa, India, Ceylon and Brasil, or in Guyana, all these traditions seem to be based on matching observations (Broendegaard, 1985; other sources: See Zürcher, 2000). It should be noted that in the past, people had more time and more peace and quiet to observe: it must even have been of vital importance to them.

These facts and observations certainly had their share of superstitions added on to them, as soon as the precise and objective observations were forgotten, as soon as people trusted blindly in traditions, without having any longer access to an understanding of the phenomena themselves. This appears clearly in certain sayings which make diametrically opposed assertions about the same subject, as can be found, for example, in the very complete book by Hauser (1973) about peasant rules in Switzerland. As for the influence of the Moon, the similarities in the traditional rules can be resumed thus at a first and empirical level:

"The Moon is strongly connected with water; the full Moon brings more water to the plant than the new Moon" (Gabriel, 1988). "During the waning Moon, liquids move towards the roots, the Earth is receptive, it breaths in; during the waxing Moon, on the other hand, the sap tends to rise, and upward growth and breathing out predomine" (Paungger and Poppe, 1991).

Pliny already reduced the phenomenon to its most utilitarian aspect. He advised Roman farmers to pick fruit for market before the full Moon, as it weighed more, but to pick fruit for their own stores at the new Moon, as it would last better. Elsewhere, he recommends felling trees at the new Moon (Storl, 1992).

The determination of "the right felling date", according to ancient traditions or to oral communications referring to the Moon, corresponds to 3 types of rules:

1. According to the *synodic lunar rhythm*, linked to the Sun–Moon–Earth relationship; the passage of the new Moon (Sun–Moon conjunction) through the first quarter to the full Moon (Sun-Moon opposition), then through the third quarter to return to the initial phase represents the lunation and lasts 29.531 days; traditions speak of "waxing Moon/waning Moon" [German "zunehmend/abnehmend"]

2. according to the *tropical lunar rhythm*, related to the Earth–Moon relationship from a geocentric point of view; the Moon's trajectory takes it higher in the sky (compared to the Earth's horizon) for 13 or 14 passages, then the movement is reversed for the other half of the tropical month, which lasts for 27.32158 days; traditions speak of "ascending Moon/descending Moon" [German "aufsteigend/absteigend"]
3. according to the *sidereal lunar rhythm*, whose periodicity is very close to the tropical one; this cycle concerns the constellations of the zodiac before which our satellite passes during a rotation around the Earth, and the cycle lasts 27.32166 days; the highest point of the tropical cycle occurs in the constellations of *Gemini*, the lowest point in *Sagittarius*. Traditions mention specific "signs" [German "Tierkreiszeichen"] or groups from the 12 "signs" as having a special influence on plants.

At stake here from the scientific point of view is the synodic lunar rhythm; much less research has been carried out about the role of the two other rhythms in biological processes.

2. Traditions Still Persisting (see Zürcher, 2000)

Moon-related rules affecting felling are still used by specialists who work with wood today. In this article, certain examples taken from practice which are known to the author at first hand or which come from reputable sources will be quoted, without an evaluation of the resulting statements. The aim of this short section is to demonstrate how this supposed level of effectiveness is put into use when working with wood and in which areas of wood utilization.

2.1. Construction wood

A rule for felling which stems from France is "bois tendre en cours/bois dur en décours", which translated means: soft wood when waxing/hard wood when waning. The second type of wood is considered as adequate for construction. In the Western Alps (Oberland/Pays d'En-Haut) a sawmill owner, who is an influential personage, is advised by an old forester to keep a special assortment of "Moon wood" for building of traditional chalets. In Austria a successful, internationally-known family enterprise near Salzburg is worth mentioning. Here, slow-grown mountain forest trees are felled at new Moon at the lowest point, and, additionally, during a "warm sign" such as Sagittarius. Building timber of highest quality is guaranteed. Reports from development work in Bhutan and Mali also mention the felling of construction wood according to Moon phases. In Mali the rule is "Tu coupes l'arbre pendant la lune vide" (You fell the tree when the Moon is empty – then the wood is thought to be resistent against termites).

2.2. SHINGLES

In Pays d'En-Haut a young, recognised shingle-layer reports interesting experiences related to Moon phases in connection with differences in discoloration and durability. In the Black Forest (Schwarzwald), conifers felled during the appropriate Moon phase provide shingles with a durability several times that of those from trees felled at other times.

2.3. CHIMNEYS

Originating from the Freiburg Pre-Alps (Teutlingen) and the Neuchâtel Jura (La Recorne/La Chaux-de-Fonds) there are two old houses with wooden chimneys which can be visited in Ballenberg/Bern (an open-air museum). According to local reports, when building such chimneys wood from specific felling dates was used, which is supposed to result in extremely fire-resistant material. Ladders for fire-rescue services used also to be manufactured from fire-resistant Moon-phase wood. Larch in particular was often used for these purposes.

2.4. FIREWOOD

In the Western Jura there is an old tradition which is still carried on today, whereby wood for fuel should also be felled according to Moon phases. The opposite stated to construction wood applies to firewood: "Le poinct de la lune est remarquable, pour en croissant tailler le bois de chauffage, et en décours, celui des bastimens" (ancient French rule) – the phase of the Moon is worthy of notice, in order to fell wood for fuel when waxing and for building when waning.

2.5. RESONANCE WOOD

The most valuable wood creations achieved through craftsmen's skills may be seen in the making of musical instruments, such as violins. In the famed alpine forests near Klosters (Prättigau, Grisons), as also in Pays d'En Haut, some wood wholesalers and also some instrument-makers wish to be present on the exact date of felling, in order to guarantee the required quality for harmony tables. Here, not only the Moon phase is important, but also the sign of the zodiac in which the Moon is to be found. The wood thus obtained is supposed to dry particularly well and therefore be especially light, with good acoustic properties.

2.6. CHEESE PACKAGING BOXES

In the Western Jura certain sawmills are specialised in the production of cheese packaging boxes for Vacherin cheese; a use of wood which requires a particularly high level of resistance to fungi for food hygiene reasons. A specialist confirmed that Moon phases were taken into consideration when felling the spruces and spoke

of "notebooks full of observations", although he was not prepared to give away his trade secrets in detail at the drop of a hat.

2.7. WINE-BARRELS

Certain French coopers also use "Moon phase oakwood" – wood from trees felled at special dates gives properly fitting and liquid(wine)proof staves. The maintained difference (compared to "random" wood) may perhaps be analogous to fluctuations in the porosity of oak wood according to the season of the year, which has been experimentally established.

2.8. PLOUGHS

The compliance with cosmic factors when working with wood is not limited to Central Europe. In Bolivia, the Ketshua Indians (descended from the Incas) still fell Thago-/Algarrobo-trees (*Prosopis ferox*) for the making of ploughs during the first waning Moon after the start of spring (shortly before Easter celebrations). The difference in aspects of quality such as durability or hardness is thereby taken for granted.

2.9. WOOD FLOATAGE

Even the transport of treetrunks along waterways used to be carried out according to Moon rhythms, because changing trajectories could be observed during transport. In Prättigau the rule was that wood should be floated at the descending Moon ("nidschigentä"), because then the trunks would stay in the middle of the river.

3. Lunar-Correlated Phenomena in the Biology of the Tree (and the Seed)

The aim of research lies in the critical examination of a possible grain of truth underlying the above statements and in understanding the phenomena which could be responsible for the experiences described. Facts must be separated from superstition.

In this paper, research results concerning trees and wood will be presented in connection principally to the synodic Moon rhythm.

3.1. DURABILITY OF OAK TRUNKS

During the reign of Louis XIV a royal forest order was passed stating that the felling of wood should occur during a waning Moon between the falling of the leaves and the new growth season (Müller, 1993). Between 1733–1735 this ruling was critically examined by M. Duhamel du Monceau, General Inspector of the French Navy and one of the fathers of tree biology, who believed it to be based on

mere superstition. By comparing the decay-resistance of wood felled in the middle of the waning Moon phase with that of wood felled at the middle of the waxing Moon phase, he did contradict the existing rule, but at the same time he revealed an unexpected other Moon-related phenomenon. The result was not merely neutral regarding Moon phase, but rather "favoured the waxing Moon; a repetition of the experiment also favoured the waxing Moon" (Knuchel, 1930). It must, however, be noted that only an extremely small number of trees were included in the experiment (three trees each, oaks approximately three feet thick) and that the sawn trunk sections were kept "at different locations". These two factors strongly question the scientific correctness and objectivity of this research.

3.2. . . . AND OF SCOTS PINE WOOD

Over a period of a complete year the decay-resistance of small samples from standing trees (*Pinus sylvestris*), exposed to three wood-destroying fungi was established. The samples were taken regularly each fortnight from 6 trees, at the exact point of new Moon and full Moon and submitted to controlled fungi attack (Wazny and Krajewski, 1984). When considering the level of destruction for the whole period and the whole experiment, no systematic relation to Moon phases could be recognised; only a (traditional and scientifically known) seasonal trend was established.

If, however, the obtained values for destruction by *Coniophora puteana*, a brown rot with the highest destruction rates for this experiment, are critically examined, it can be seen that over a period of four full months systematic fluctuation was in evidence between full and new Moon (see Zürcher, 2000). A check by the author of this article using a two-way-variance analysis confirms, on the one hand, the seasonal trend in the period from the end of July until the end of November. On the other hand, it also shows that during this period the destruction level for full Moon samples is significantly lower than for new Moon samples. These Moon phase fluctuations are not dependent on the general trend seen here (non-significant interaction). Thus, a general rule could not be confirmed, but a relevant Moon-chronobiological phenomenon occurs, which could be investigated in more depth in future research projects.

It would have been more informative to take the samples in the waning and waxing phases, instead of at full and new Moon exactly. This would have been more appropriate to the content of the traditional beliefs. In addition, research on germination and initial growth of trees has emphasised the importance of such nuances (see following chapter).

3.3. INFESTATION BY BARK BEETLES

A confirmation of old rules regarding infestation by insects was obtained in experiments covering a time period of several years with felled Spruce-trees at the

Institute of Forest Protection of the State Forestry Research Organisation Vienna-Schönbrunn (Jahn, 1982). After a cooler period, the full Moon trees were clearly favoured over the new Moon trees during initial attacks. Further, these differences were connected to variations of "biophysical fields", with a differentiation between day and night at the level of the cambial chemistry.

3.4. Germination and initial growth

Under tropical conditions, as they were present at an experimental tree nursery in Rwanda, an ideal situation for the investigation of Moon rhythms is given. Temperature and daylight duration are more or less constant, and during the dry period the plants can be watered. Over a period of three years a preliminary experiment, a main experiment (12 sowings with 4 repetitions each) and a control- and additional experiment were carried out. Sowing took place two days before full Moon and two days before new Moon (Zürcher, 1992/Figure 1A). For *Maesopsis eminii* germination and initial growth show a decided rhythmic character. Speed of germination, rate of germination, average height and maximum height after four months are thus systematically related to the timing of sowing in relation to the Moon phase (better results were obtained when sowing before full Moon). These results agree with earlier experimental values for annual plants. In this way, an old rule for sowing, applied to trees, could be tested and confirmed for the first time.

A confirmation was also made known shortly after, through an independent experiment using the same methodology with (among others) *Sclerocarya birrea* (Bagnoud, 1995; Figure 1B).

The timing of sowing shortly before full and new Moon was shown to be relevant: in an additional experiment sowing exactly at full Moon even worse results were obtained than shortly before new Moon (Zürcher, 1992).

3.5. Tree tides

An interdisciplinary reworking of previously published, long-term tree-physiological research results has enabled to take the investigation a step further: the synodic Moon-rhythm at a daily level (gravimetric tide-rhythm) could be established for trees held under constant conditions (darkness). The already-known, 24-hour photo- and thermoperiodic modulation of most physiological processes is therefore embedded in a lunar-periodic, 24.8-hour rhythm which appears when light and temperature as pacemakers are shielded off (Zürcher et al., 1998) (Figure 2).

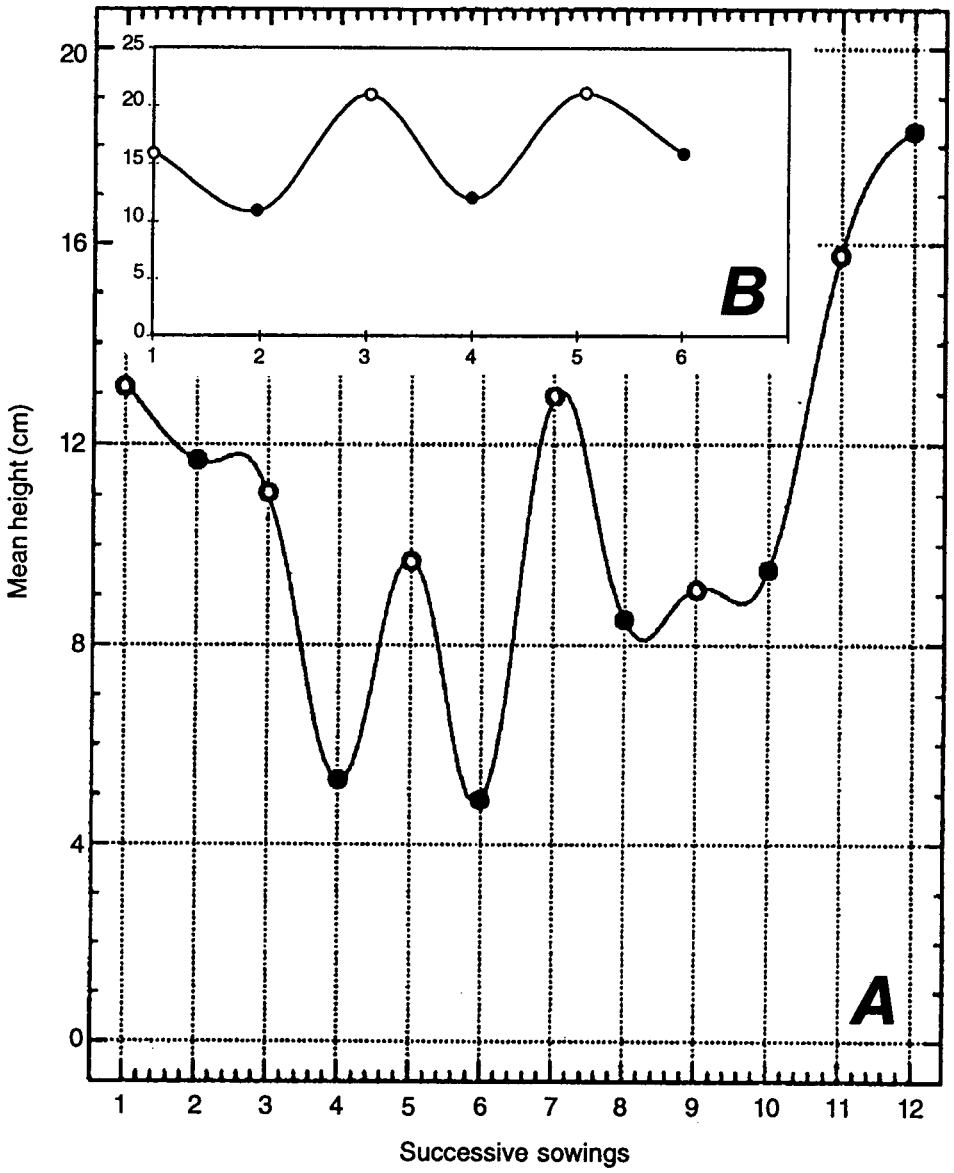

Figure 1. (A) Mean height of Maesopsis eminii at 4 months after the sowing date (Zürcher, 1992). (B) Mean height of Sclerocarya birrea at 2 months after the sowing date (Bagnoud, 1995). 1/3/5/ etc.: Sowings 2 days before Full Moon; 2/4/6/ etc.: Sowings 2 days before New Moon.

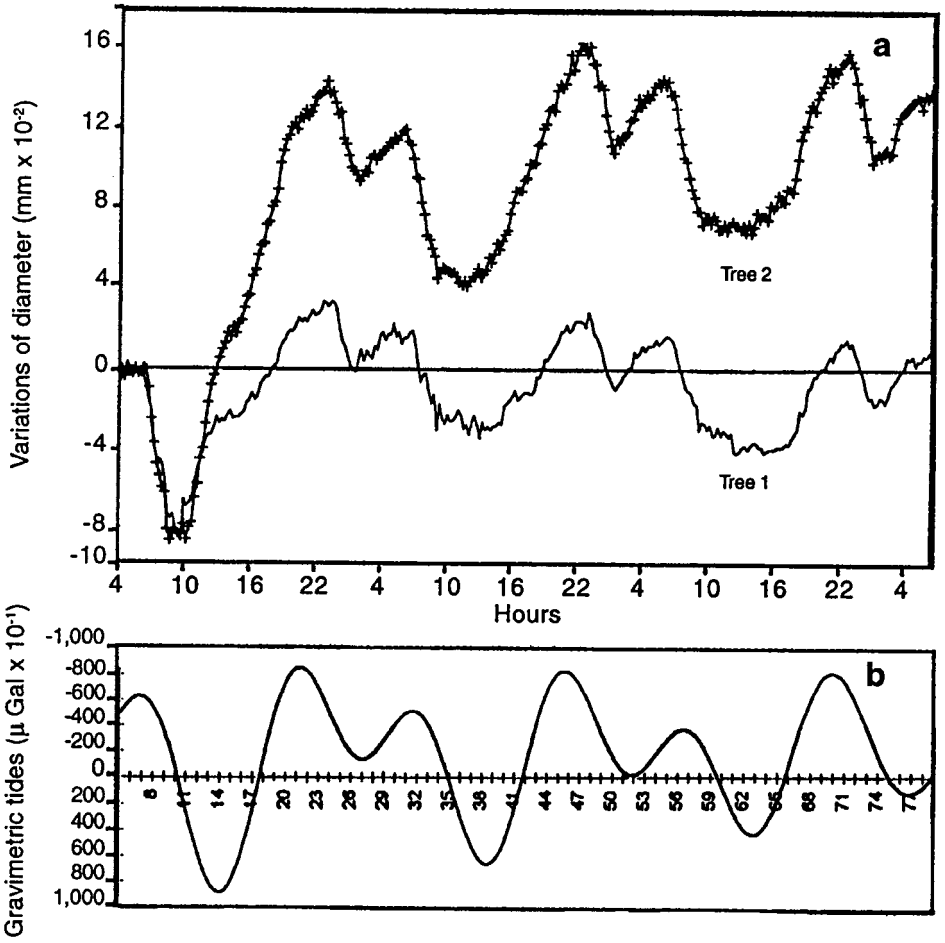

Figure 2. Reversible diameter variations of two young Norway Spruce trees (*Picea abies*) under controlled conditions (permanent darkness/(a) and gravimetric tides for the same period and location (b) (Zürcher et al., 1998) (©*Nature*).

4. Research on the Correlation between Felling-Dates and Wood Characteristics

4.1. Drying-behaviour and density

An overview on the most important studies with regard to the topic 'felling-date' (within the year-cycle) and wood- properties published so far gives an insight into certain correlations between the biology and physics of wood (Gäumann, 1930; Knuchel, 1930; Burmester, 1978). It becomes evident that a felling of trees in the winter period is favourable for balanced drying-behaviour and optimal durability of the wood. At that time of the year, the fibre-saturation point (water absorption through the cell-wall) is at its lowest. In his research, Knuchel paid special attention

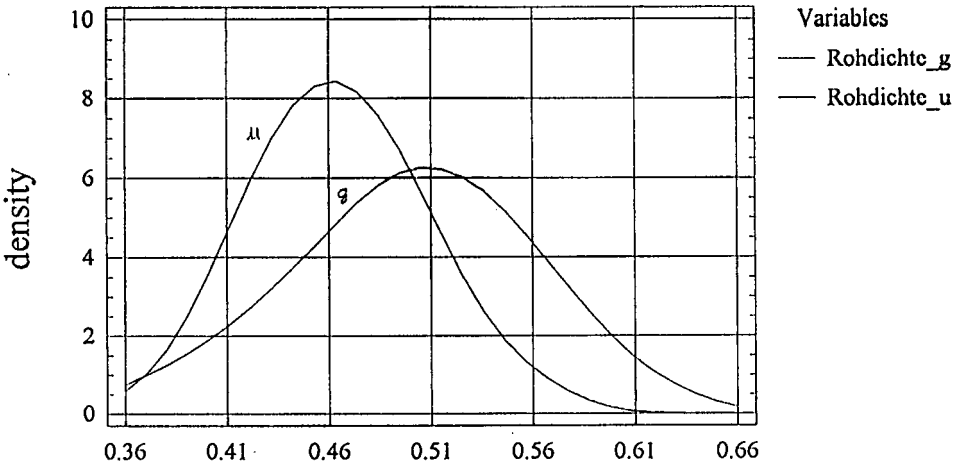

Figure 3. Dry density distribution of sapwood samples of Norway Spruce (*Picea abies*), for the two groups of felling dates: – before full Moon, in ascending period [u]/ – before new Moon, in descending period [g] (Rösch, 1999).

to the fact that the trees were felled during the same Moon-phase within the year cycle, in order to deliberately exclude this factor. He thus left it to others to prove an eventual influence of the Moon. Three investigations with regard to an implication of the Moon phases on wood properties have recently been carried out. In one of these studies – initiated and supervised by the author of this text – a total of 30 Norway-spruce trees originating from 6 felling-dates (3 during waxing Moon and 3 during waning Moon) were divided into sample-series according to the 4 cardinal directions and investigated according to the drying/shrinkage behaviour and oven-dry density in their final condition (Rösch, 1999). Standardized material was taken from the sapwood (the still living, water-conducting outer part of the stem) as well as from the heartwood (the inner, drier part of the stem). For the entire sapwood samples after the two felling situations, from the relatively homogeneous initial material, there resulted for instance the fact that the oven-dry densities varied essentially: mean value ca. 0.46 g/cm^3 for the "unfavourable" cases (at waxing Moon/towards full-Moon: "fm") compared to ca. 0.51 g/cm^3 for the "favourable" cases (towards new-Moon: "nm") (Figure 3). For the heartwood samples, the tendency shown is the same, although to a lesser extent.

The parallel observed between the felling-date-related values of sapwood and heartwood comes to full effect thanks to the calculation of the relation between the oven-dry density and the initial density (as "relative oven-dry density" in %), thus small-scale, material-based initial variations are eliminated. For this criterium, without exception, the nm-values are relatively higher than the adjacent fm-values, especially for the fellings 3–6 (statistical analysis in Zürcher and Mandallaz, 2001; Figure 4A).

Two similarly conceived investigations (Triebel, 1998 – with 120 Norway-spruce trees; Seeling and Herz, 1998 – with 60 Norway-spruce trees) could establish a statistically secured variation in the final oven-dry densities of the outer sapwood samples in 2/3 of the cases, resp. in the entire trial. It is, therefore, interesting that for December and January, all the new-Moon values for sapwood are always significantly above the full-Moon values and correspond to the results of Zurich (Figure 4B). To make the "lunar factor" evident, the seasonal trend can be eliminated by comparing each of the values 2–5 (for relative density) with the mean between the previous and the following value. Here again, the amplitude of the systematic variations is obvious, as well as the similar, but weaker tendency for the heartwood samples (Figure 4C).

4.2. Compression strength

For the determination of the compression strength at each of the four cardinal directions in the sapwood and the heartwood, one each of the defect-free samples (altogether 8 per tree) were investigated. A very close correlation with the value distribution of kiln-drying densities for the sapwood as well as for the heartwood, results. In both cases the systematic differences between fm- and nm-samples of the fellings 3–6 are obvious. Sapwood as well as heartwood show the most significant differences between felling date 4 (nm) and felling date 5 (fm): 17.8% and 22.6% respectively. For the whole investigation, the nm-average value in sapwood (47.2 N/mm^2) surpasses the fm-average value (41.9 N/mm^2) by 12.6%. The heartwood's nm-average value (40.7 N/mm^2) surpasses the fm-average value (36.6 N/mm^2) by 11.2% (Figure 5).

These felling-date-related variations are astonishing at first sight for our current knowledge of wood physics and ask for a formulation of further working hypotheses.

5. Hypotheses

In view of the extremely weak gravitational forces, which came into question as an explanation for circadian fluctuations, it is relatively unlikely that a direct gravitational effect is responsible for these "tree and trunk tides". One argument in support of this view is the fact that other organisms, which move freely in all directions, can also demonstrate such a "tide rhythm". Behavioural scientists have established in their famous "bunker experiment" that the basic physiological rhythm in people allowed full freedom of movement whilst isolated from daily influences follows not a 24-hour cycle but rather a 25-hour cycle (Aschoff and Wever, 1962). This synodic daily rhythm could be connected to faint, constant variations of the Earth's magnetic field, possibly due to weak lunar influence. The detailed work Geomagnetic Biology by Dubrov (1978), from the Soviet Academy of Science, offers more

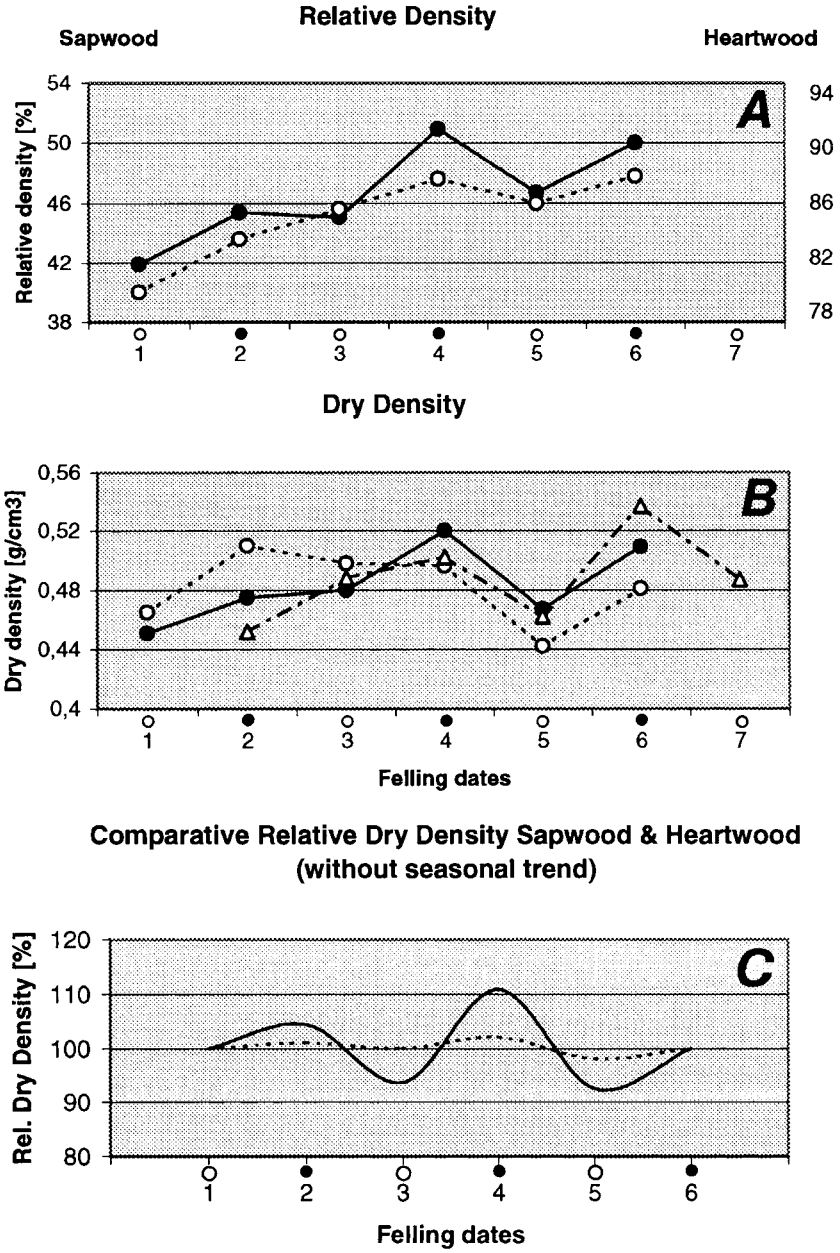

Figure 4. (A) Relative (oven-dry) density of sapwood and heartwood of Norway Spruce (*Picea abies*) after 6 successive lunar-correlated felling dates in Zurich (sapwood: Plain line/heartwood: Dotted line). (B) Systematic variation of oven-dry density after successive lunar-correlated felling dates in 3 sites and 3 years. Zurich 1998–1999: Plain line/Freiburg i.Br. 1997–1998: Dotted line1/Tharandt 1996–1997: Dotted line2. 1/3/5/7: Fellings before Full Moon; 2/4/6: Fellings before New Moon (after Zürcher and Mandallaz, 2001; Seeling and Herz, 1998; Triebel, 1998). (C) Comparative relative density of sapwood and heartwood samples from Zurich, with elimination of the seasonal trend (based on values of 4A).

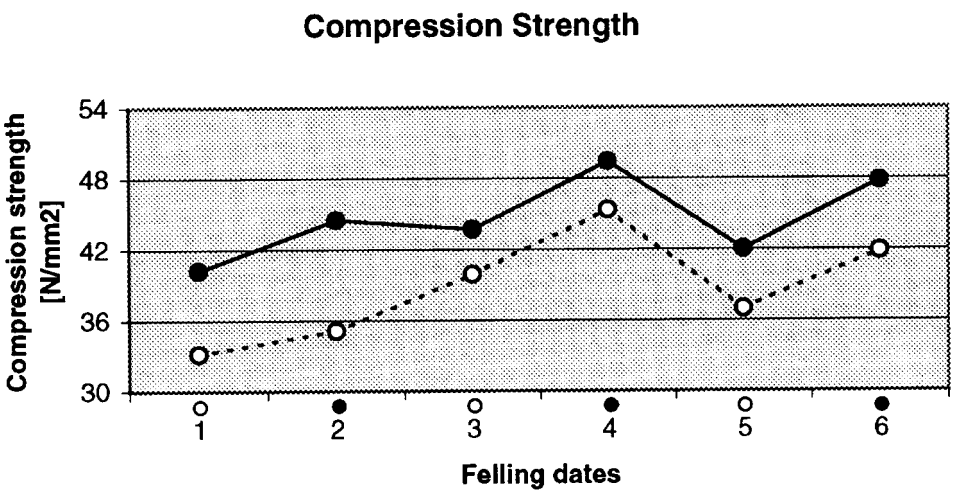

Figure 5. Systematic variation of compression strength of sapwood and heartwood of Norway Spruce (*Picea abies*) after 6 successive lunar-correlated felling dates in Zurich. 1/3/5: fellings before Full Moon; 2/4/6: fellings before New Moon (after Zürcher and Mandallaz, 2001).

information. Perhaps the Earth-atmospheric electric field also mentioned therein, which varies periodically too, could play a role in chronobiological phenomena.

As far as the process which led to the diameter variations measured and to the systematic variation in drying and shrinkage behaviour is concerned, two possible explanations have so far been offered:

I. A process affecting membrane activity in living cells is occurring, which directs the movement of water into the cell wall and back out again into the cytoplasm, coupled with water displacement via the apoplasts (cell wall system outside the plasma membranes);

II. the process occurring is that of rhythmic variations in the wood-water relationship (fixing of water in the cell wall). The relationship between the proportion of free water and the proportion of chemophysically "fixed" water may, due to the formation of variable supra-molecular organisational units, not be constant. The work of G. Piccardi (Dubrov, 1978; Davis, 1995) focused on such fluctuations in controlled crystallisation processes in laboratory experiments covering a period of several years. E. Gäumann (1930), already concluded from his detailed research that "the cause of the differing resistance to fungi in spruce and fir woods lies less in a varying level of substances such as carbohydrate, nitrogen, phosphoric acid, potash and resin in the wood, but rather in the differing colloid-chemical behaviour of the cell walls themselves, in particular that of cellulose and xylan, to a lesser extent of lignin . . . ". For this author, such processes are not only confined to the sapwood, but also occur in the heartwood. "With woods where the water content remains the same year in, year out, for example as with spruce heartwood, the displacement of

water must take place in a purely micellar way, perhaps in the sense that the water molecules are stored in an intramicellar way during the formation of the year ring, whilst being stored in an intermicellar way for the remainder of the time". (The crystalline cellulose chains of the microfibrils are considered as micells, around which the hygroscopic paracrystalline cellulose is accumulated.) Bavendamm (1974), too, takes the view, in his chapter regarding the influence of the timing of felling on the durability of wood, that this is due to varying colloid-chemical behaviour of cellulose and hemi-cellulose in the different seasons of the year. This interpretation was later supported by the work of Burmester (1978), according to which the moisture saturation point of the fibres of the (normally considered as "dead") oak heartwood significantly varied over the course of the year (with one of the highest peaks occurring in March).

6. Conclusion

There is so far a certain coherence between these scientific results and the mentioned felling-date rules:

- Lighter ('full-Moon'-) wood is actually softer (with a lower compression strength) than heavier ('new-Moon'-) wood, the latter being more adequate for construction.
- Lighter wood could be somewhat more inflammable due to a higher water loss and to a better passage of air than dense wood, and produce a better firewood quality.
- Furthermore, it is known that the natural durability in the comparison of species increases tendentiously with density (Rijsdijk and Laming, 1994). Similarly, Norway-spruce wood of the lowland regions grows much faster, is lighter and is more easily attacked by fungi and rot than the wood of mountainous regions. In this sense, dense "new-Moon-wood" could be more resistant to decay than lighter "full-Moon-wood".
- Taking these first available results into account, a specification of the felling-date rules seems to be appropriate: felling should happen around the winter solstice taking into account the synodic lunar rhythm, which in turn is then synchronous with the tropical lunar rhythm (the alleged role of "zodiac signs" has still to be critically tested).

It should also be mentioned that a "favourable" or "unfavourable" felling date for wood in the absolute sense does not exist, but rather a more or less adequate relation between properties and purpose of utilisation. There is "good" wood to be felled at any date of the winter.

These examples provide us with various points of interest for further, practice-oriented experiments in the field of tree- and wood-related chronobiology. The

research results presented indicate a variety of possible benefits when put into practice:

I. Chronobiological practice in tree nurseries would improve the criteria "economy" and "quality", with regard to future requirements (reforestation in tropical regions with the aim of balancing CO2 levels);

II. the confirmed rhythmic variations of drying behaviour, density and mechanical properties could lead to savings in energy and time during kiln-drying processes, and to the formation of high-quality stocks of special woods; furthermore, if linked with a higher durability, there is a potential of using less wood protection chemicals;

III. it seems plausible that even weekly and daily timing criteria could lead to specific wood properties.

It is in any case clear that the phenomena are much more complicated than is often portrayed, and that they overstep many simplified traditional rules.

Without these strange reminders from past cultures we would, however, perhaps never have conceived of these initial and further leading scientific observations in this area.

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