CHRONOBIOLOGY OF TREES: SYNTHESIS OF TRADITIONAL PHYTOPRACTICES AND SCIENTIFIC RESEARCH, AS A TOOL OF FUTURE FORESTRY

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Introduction

The subject presented here is linked 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 the internal structure of the growth rings.

This rhythmical characteristic of plants has always had to be taken into account by man, a heterotrophic being, for his subsistence.

On reading works which deal with popular sayings or quote classical authors concerning agricultural practice, or simply talking 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, one is struck by certain common factors, despite the geographical distance of the sources; these similarities in the rules formulated would seem to suggest the existence of possibly 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 (Aichinger 1936), in India, Ceylon and Brazil (Forstmann 1936; Kolisko and Kolisko 1953; Schrödter 1981), or in Guyana, all these traditions seem to be based on matching observations. 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 left behind, as soon as people trusted blindly in traditions, without having 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 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 predominate” (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).

At stake here is the *synodic lunar rhythm* concerning 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.

Empirical knowledge and traditions often mention a second level of influence, that of the ascending and descending cycle of the moon, its *tropical rhythm* concerning the earth-moon relationship from a geocentric point of view (this second rhythm is less obvious to the observer). Indeed, the highest point, compared to the earth’s horizon, of each lunar passage varies systematically and in both directions. The moon’s trajectory takes it higher in the sky for 13 or 14 passages, then the tendency is reversed for the other half of the tropical month, which lasts for 27.32158 days. Here, the general rule is quite close to the previous one:

“As the moon ascends, the sap rises faster in the upper part of plants and improves the quality of its constituents; . . . as the moon descends, the growth of plants above ground is slowed (Gabriel 1988). According to Wohlgenannt’s 1988 synthesis, the ascending moon brings a “separation from moisture and soil,” whilst the descending moon “pulls all things downwards.”

First source of confusion: the ascending moon is sometimes confused with the waxing moon, the descending moon with the waning moon, despite a difference in periodicity of 2.21 days.

Finally, a third, more subtle level of influence has always been mentioned: that of the *sidereal 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 always occurs in the constellation of Gemini, the lowest point in Sagittarius. Here, too, the traditional parallels are sometimes striking: they go as far as relating groups of constellations with certain parts of the plant (root, leaf, flower, fruit). Many rules concerning the date at which trees should be felled in order to obtain certain qualities in the wood take account of the position of the moon compared to the constellations (Hauser 1973; Wohlgenannt 1988; Paungger and Poppe 1991). Such practices are still particularly alive among certain instrument makers, using “resonance wood” of a high quality.

At this level, a source of imprecision arises from the fact that the astronomical constellations observed at a given date no longer coincide entirely in time with the “signs of the Zodiac” of ancient astrology (due to the slow nutation of the earth’s rotational axis).

The Research

Various studies in animal biology and on annual plants seem nevertheless to confirm some of the empirical rules and practises linked to lunar rhythms (Endres and Schad 1997). In trees, Burr (1945, 1947) had indeed observed a rhythm of about 27 days in the “bio-electric potential” measurable along the stem, a rhythm in between the annual and the daily fluctuations, and not directly explicable by the current site or climatic factors. The author suggested at the time a connection with the lunar cycles.

Not being aware of other research or experiments on this topic with forest species, it seemed interesting to us to work with tropical species in their environment, in Rwanda, and with species introduced into that country.

One of the major difficulties of such research *in situ* in temperate zones resides in the continual changing of daylength, temperature and humidity through the seasons. An experiment situated in a region close to the equator allows the elimination of a good part of these factors influencing growth, and an easier identification of a possible influence of lunar phases for example. A supplementary precaution in this domain is regular watering of nursery beds, particularly in the dry season.

Another advantage of this situation was the fact that the trials could be carried out by staff unaware of the working hypothesis being tested, thus excluding any psychological bias (influence of the experimenter).

Materials and Methods

At first, we wanted to concentrate on the first of the 3 cycles mentioned: on the *synodic lunar rhythm*, oscillating between the New Moon (NM) and the Full Moon (FM). The aim was to study the effect of this rhythm on the *germination* and the *initial growth* during 4 to 6 months.

For the precise moment of sowing (after a brief soaking of the seeds), we based our experiment on the work of Kolisko (1927, 1929, 1934, 1935), according to which the maximal effect precedes the phase in question by two days. At the time, this work marked the beginning of the bio-dynamic method of agriculture, founded by Steiner in 1924.

The trials took place in the Forestry Department of the Institut des Sciences Agronomiques du Rwanda (aided by the Coopération Suisse - Intercoopération, Berne), in 1990 and 1991 (with a brief preliminary trial in 1989).

Each sowing consisted of four replications of 50 seeds from the same batch. Each replication was placed randomly in a compartment (20 cm x 20 cm) of a wooden crate with 12 compartments kept in diffuse light by means of shade screens. The seeds, already slightly buried, were thus preserved from a possible direct effect of the moonlight, extremely weak compared to sunlight, which is known not to penetrate further than 5 to 10 mm in the soil, with the red part of the spectrum (authors cited in Egley 1995).

A series consists of 12 successive sowings, 2 days before the full moon (FM) or, 14-15 days later, 2 days before the new moon (NM), and lasts generally 5.5 months.

Species tested:

Maesopsis eminii Engl.
(main tree species - a Rhamnaceous plant from tropical Africa, from Liberia to Tanzania)

Sesbania seban (L.) Merr.
(African shrub cultivated in agroforestry systems)

Acacia mearnsii De Wild.
(introduced)

Acacia melanoxylon R. Br.
(introduced)

The observations consisted of a weekly control of emergence, and counting and measuring heights when being planted out individually into sachets, exactly 4 lunar months after the sowing date.

Results and Discussion

A preliminary trial with *Acacia melanoxylon* in 1989 had strongly encouraged us to study the question more precisely.

The results of the main trial with *Maesopsis eminii* in 1991 appear in three forms (see tables in Zürcher 1992, and statistical treatment):

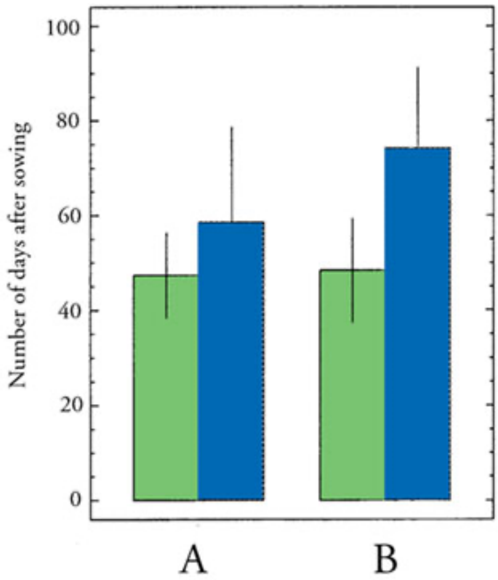
• number of days to first germination in each set of 50 seeds, i.e. speed of emergence;

• germination rate for each set; and

• mean height, maximum height and distribution into height classes after 4 months for each sowing.

The speed of germination or beginning of emergence already shows a significant difference between the FM and NM sowings for all the sowings (A) and especially for those corresponding to the dry season which took place in the middle of the trial (B)

Figure 1. Beginning of emergence, in number of days after the sowing of *Maesopsis eminii*.



A - Mean values with indication of standard deviation for all the results of the series FM and NM.
B - Mean values for 2nd, 3rd, and 4th sowings at FM (0) and NM (●).

Recent experiments on the radish by Fritz in 1994 show the same tendency: faster germination at FM

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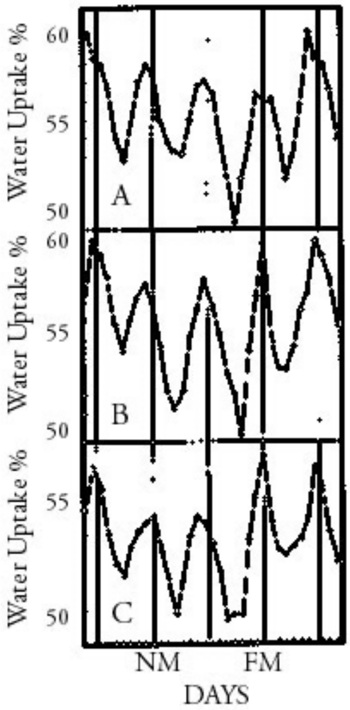
These studies agree with the hypothesis that the *cytokinine* content of plants is linked to the synodic lunar rhythm, with a maximum at full moon (this had been shown by Hofman, Featonby-Smith and Van Stalden on algae in 1986 - quoted by Fritz 1994).

Cytokinine also plays a role in the model proposed by Rossignol, Benzine-Tizroutine and Rossignol (1990) to explain the variations in the relative frequency of three forms of DNA according to lunar phases.

These differences in the speed of germination are probably also partly linked to cyclic variations in the absorption of water by seeds, as shown by Brown and Chow in 1973 working on a large scale: 7931 series of 20 beans. One of the absorption maxima coincides with the Full Moon

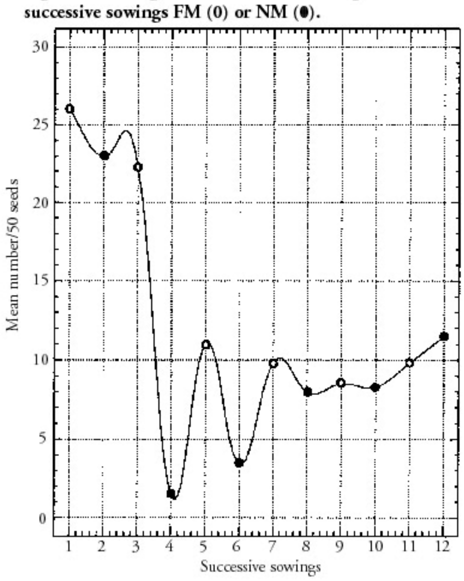
Figure 3. Variation in the apsorption of water by Bean seeds (*Phaseolus vulgaris* L.), compared to the lunar phases.



A - Period of 15.5 to 18.8.1972; B - Period of 25.9.72 to 22.1.73; C - Period of 25.9.72 to 5.1.73. 3 - day mobile means. (Brown and Chow 1973).

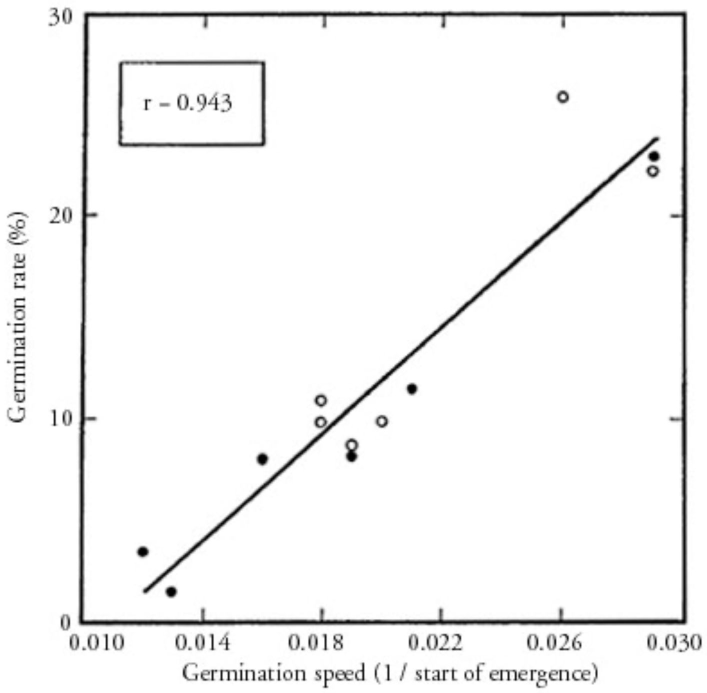
Concerning the continuation of the results obtained with Maesopsis, we were struck by a regular alternation in the mean germination rate, particularly during the dry season (2nd, 3rd and 4th sowings FM and NM)

Figure 4. Mean germination rate of *Maesopsis eminii* for 12 successive sowings FM (0) or NM (●).



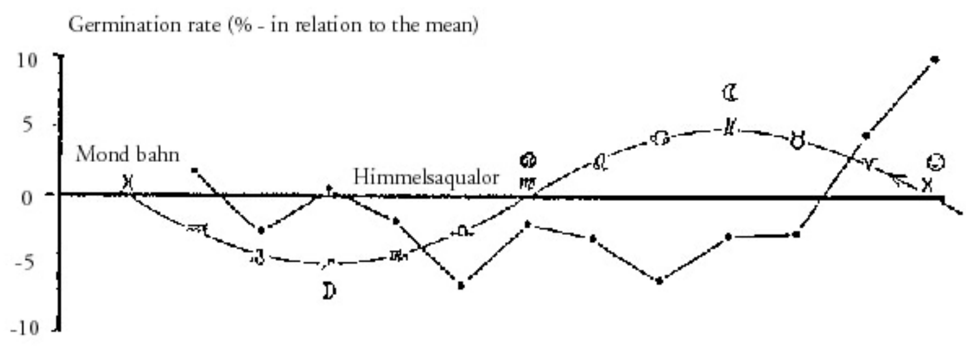
These two first elements (speed of emergence and germination rate) appear themselves to be strongly correlated

Figure 5. Line of regression of mean germination rate with germination speed (inverse of days to start of emergence) for *Maesopsis eminii*.



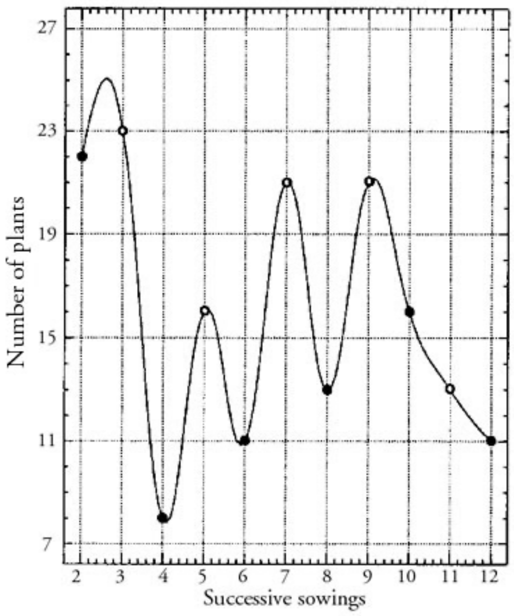
A fine confirmation of this tendency to a higher germination rate around the FM was found by Spiess (1987, 1990), who demonstrated a strong effect of this kind (while the tropic curve with the succession of constellations crossed does not show any connection with the germination rate of rye at the time considered)

Figure 6. Germination rate of winter rye (*Secale cerale* L.), according to lunar cycles in September/October. Mean values over 5 years. (Spiess 1987).



A parallel trial with *Acacia mearnsii* carried out the same year also shows a strong sytematic variation in the number of plants obtained

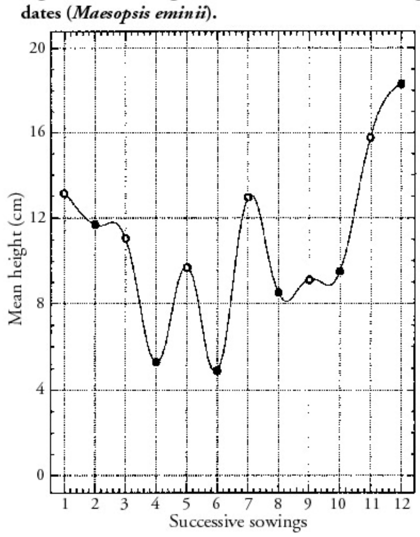
Figure 7. Number of plants for sucessive sowing dates of *Acacia mearnsii* in 1990.



Not only were the speed and rate of germination influenced by the exact sowing date, but also the individual dimensions 4 months later.

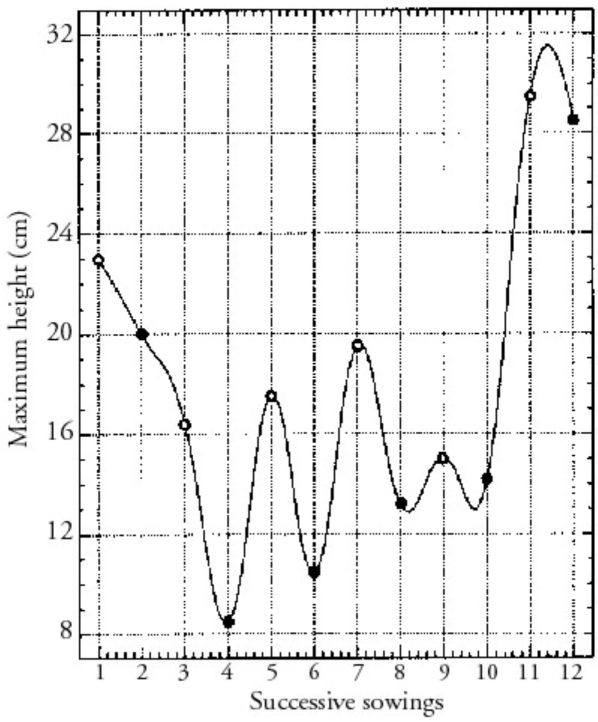
The mean heights at 4 lunar months follow a curve similar to that of the variations of germination rate according to the sowing dates

Figure 8. Mean height at 4 months after the sowing dates (*Maesopsis eminii*).



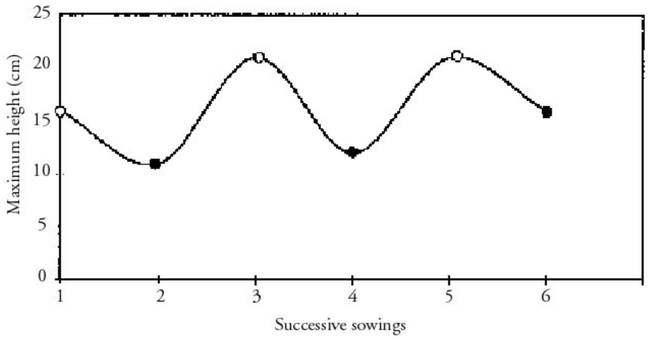
The most striking differences were found with the measurements of maximum heights for each group of sowings at 4 months, with the full moon sowings always coming ahead of the new moon ones

Figure 9. Maximum height at 4 months according to sowing dates of *Maesopsis eminii.*



Such differences had been obtained by Kolisko (1927, 1929, 1934, 1935), working with cereals, vegetables, herbs or flowers in numerous series of trials, with a very homogeneous sowing material (sorted seeds). Four years after the last Rwandan trials, an independent work on germination and initial growth of African tree species from the Soudano-Sahel Zone was carried out in Mali, after the same scheme. The four tested species showed better results with sowings just before full moon (Bagnoud 1995)

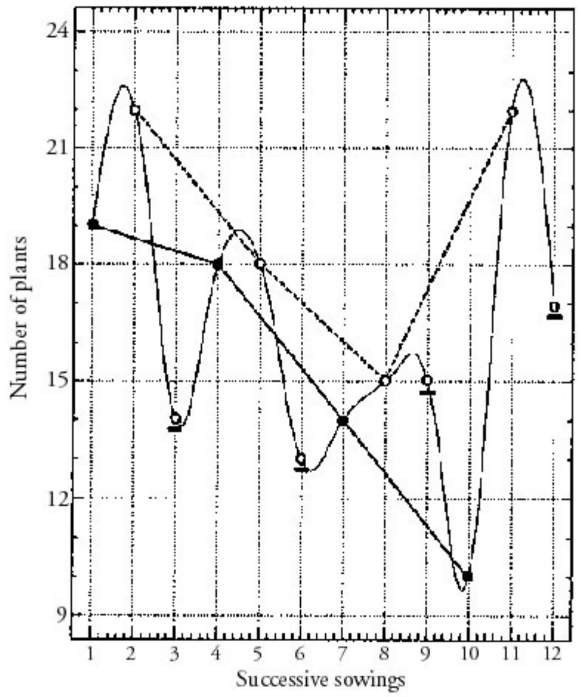
Figure 10. Mean height at 2 months according to sowing dates of *Detarium microcarpum* (Bagnoud 1995).



0 = Sowings 2 days before full moon
● = 2 days before new moon

In this kind of experiment, it is necessary to work in a very precise manner in the choice of dates: at the exact moment of the full moon, the plant seems to react completely differently in terms of viability. The values obtained for *Maesopsis eminii* the following year (1991) show this, as well as confirming the effect of sowing 2 days before the FM or 2 days before the NM which was shown in 1990.

Figure 11. Number of plants at 6 months (2 months after planting out) of *Maesopsis eminii* 1991, with sowing 2 days before the full moon (0), at the full moon (0̲), and 2 days before the new moon (●).



This phenomenon had already struck Milton in 1974, who identified a variation in phase with the synodic lunar rhythm in the growth of maize coleoptiles, in trials lasting 14 months

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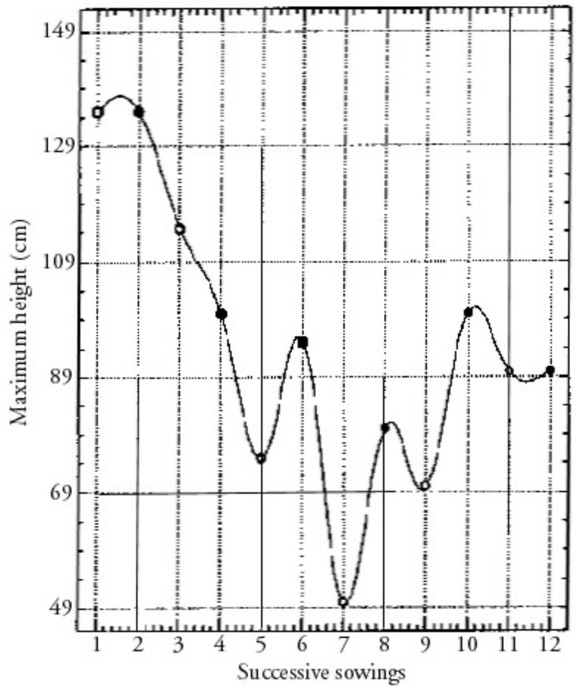
To complicate matters, we found in the trials carried out the following year that one species can also behave in the opposite way to that observed up to then: *Sesbania sesban* produced in 1991 maximum heights systematically in phase with the new moon

Figure 13. Maximum height at 4 months (2 months after planting out), for 12 successive sowings of *Sesbania sesban* 1991.



On this subject, Brown and Chow noticed that sudden inversions in behaviour (water absorption) according to lunar phases sometimes occurred (correlations passing from positive to negative, or vice versa). Similarly, Fritz (1994) finds in *Fatshedera lizei* that the formation of new leaves is strongly linked to the synodic lunar rhythm (positive effect of the FM), and observes “offbeat” periods (formation maxima at NM).

Another phenomenon revealed by these trials was that two neighbouring species could also react simultaneously in a completely opposite manner to the phases of the moon. *Acacia mearnsii* and *Acacia melanoxylon*, also in the following year, give biomass variation curves that are systematically opposed for sowings according to the synodic lunar rhythm. Note that in these double series of 1991, the positive effect of the FM (or of the NM) is less obvious than in the previous trials or than for the two other species.

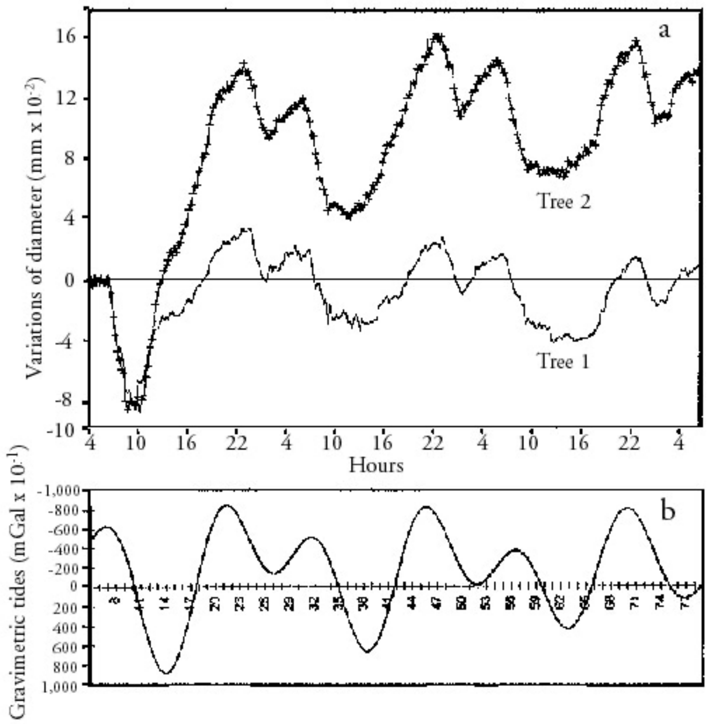
Apart from the *synodic* rhythm studied up to here, recent work by Spiess (1990) shows that the second category of traditions and empirical rules linked to the moon also contain a kernel of truth. It is the moon ascending or descending (*tropical* rhythm), rather than an effect of the constellations (*sidereal* rhythm): the overall level of a category of substances synthesized by the plant (crude protein of Rye grains (*Secale cerale* L.) according to sowing date, analyzed for a period of 6 years) follows a curve parallel to that of the moon in relation to the terrestrial horizon.

Specific effects linked to the signs of the zodiac had been shown by Schultz in the period 1929-1935, using a mobile device (“Tierkreisrad”) designed to test germination from this aspect. Quantitative and qualitative differences were apparent for a series of annual plants (Schultz 1986).

The numerous sayings in this last category about the quality of wood according to the felling date remain at first sight difficult to explain, since wood is made once and for all, and no longer contains living cells in the duramen. Precise experiments should however be carried out in this area.

A recent work in this concern shows that the synodic lunar rhythm is also present in the daily tree physiology: under controlled conditions, the stem diameter of trees fluctuates reversibly in phase with calculable earth (gravimetric) tides (Zürcher, Cantiani, Sorbetti-Guerri and Michael 1998; Figure 14). This phenomenon is even measurable on sealed stem sections; this leads to the hypothesis that water could be moving alternatively from living protoplasts to cell walls of the sapwood, with corresponding diameter changes. This type of short rhythm should also be tested in trials on germination and initial growth of trees.

Figure 14. Reversible diameter variations in spruce and gravimetric tides (Zürcher, Cantiani, Sorbetti-Guerri and Michel).



Conclusion and Outlook

These trials make clear, for the first time in trees or shrubs, the existence of a real phenomenon, often mentioned in traditions or issuing from empirical experience, consisting of a link between the lunar phases (synodic rhythm) and the behaviour at germination and during initial growth. They demonstrate that the phenomenon is not as simple as it might seem at the outset, going beyond the general “cause and effect” model and calling on predispositions or types of reaction specific to plants themselves. These trials in turn raise questions about the exact nature of this phenomenon and of the physiological processes involved.

The importance of such results becomes evident if we consider that, in the future, a main field of forestry will be the establishment of plantations: after the Noordwijk Declaration (1989 - signed by 69 countries), the total surface of plantations must be augmented by 12 Mha per year until the year 2000. In the same sense, the Climate Conference in Kyoto in 1997 and the following conference scheduled for 1998 confirm the necessity of more plantations as “carbon sinks,” combined with emission certificates.

The consideration of “endogen-exogen” rhythms linked to the synodic lunar cycle has two types of practical implications: 1) higher germination rates, followed by a more vigorous initial growth or higher biomasses, and 2) an economically more efficient use of available funds, nursery surfaces, and time alloted to the production of high quality seedlings.

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Finally, he wishes to dedicate this work to the Indian Culture of America, which lived in harmony with the natural lunar rhythm. For the Oglalla, July was for example the “Moon of the Black Cherries.”

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