Chronobiology of trees: Synthesis of traditional phytopractices and scientific research as tools of future forestry

Ernst Zürcher[22]
Hochschule Holz Biel, Switzerland

Introduction

The question of the influence of moon phases upon the organic world, and particularly upon vegetation, has always been of interest to man. In different countries (especially in the old cultures), this has lead to agronomical and forestry practices ('phytopractices') that consider these phases in the different operations.

The phenomenon is presented here in its general aspects, considering empirics, traditions and more recent research. Sowing trials and measurement of the subsequent growth of several tropical tree species in Rwanda have shown obvious rhythmic variations. In particular for *Maesopsis eminii*, the speed of emergence, the rate of germination, the mean height and the maximum height at four months thus depend systematically on the date of sowing in relation to the synodic lunar phases.

These results agree with experimental data available on cultivated annual plants. Simultaneous trials with other tree species and other trials made in the following year partially confirm these rhythms. Independent trials in the Soudano-Sahel zone with different tree species also confirm the main results.

In addition, another form of lunar rhythm and its implications is briefly mentioned in this chapter: the recent discovery of the tidal dimension of reversible daily diameter fluctuations on trees brings an interesting hypothesis concerning the status of water in woody tissues. Recent work on electrophysiology of trees equally highlights tidal rhythms under certain physiological conditions. This type of short-period lunar rhythm could play a role in addition to the monthly synodic effect.

The importance of such results to the large-scale international forestry plantation programmes is emphaisized. These need an optimum use of available resources, nursery surfaces, funds and time. The findings show that traditional practices can inspire research and lead to new unexpected applications.

The subject of this chapter comes from the fact that most organic processes and the structures that result from them have a rhythmic character. In the plant world in temperate latitudes, it is immediately obvious that 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

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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 that deal with popular sayings or quotes in classical authors concerning agricultural practice, or when simply talking to gardeners, farmers or foresters with an empirical experience based on tradition, one is struck by two things. First, 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. Second, one is struck by certain common factors, despite the geographical distance of the sources. These similarities in rules 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, Sri Lanka 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 and as soon as people trusted blindly in traditions, without having access to an understanding of the phenomena themselves. This appears clearly in certain sayings that 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 formulation of the traditional rules can be interpreted thus: 'The moon is strongly connected with water; the full moon brings more water to the plant than the new moon' (Gabriel, 1988). According to Paungger and Poppe (1991):

> 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.

The famous German astronomer Johannes Kepler wrote in 1602: 'From experience is sure, that everything which is formed by humidity starts strongly growing with the waxing moon, but diminishes with the waning moon' (cited in Rohmeder, 1938).

Plinius, a Roman writer (23-79 AD), 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 recommended 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 formulated quite closely to the previous rule. According to Gabriel (1988), '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'. According to Wohlgenannt's 1988 synthesis, the ascending moon brings a 'separation from moisture and soil', while the descending moon 'pulls all things downwards'.One source of confusion is that the ascending moon is sometimes confused with the waxing moon, and 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; Paungger and Poppe, 1991; Wohlgenannt, 1988). Such practices are still particularly alive among certain instrument makers, using 'resonance wood' of a high acoustic 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 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. 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 three 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 germination and initial growth during four to six 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 maximum 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 5–10 mm in the soil, with the red part of its spectrum (Zürcher, cited in Egley, 1995). A series consisted of 12 successive sowings, two days before the FM or, 14–15 days later, two days before the new moon NM, and lasted generally 5.5 months.

The species tested were:

- *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 four 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 1990 appear in three forms (see tables in Zürcher, 1992, and statistical treatment):

- number of days to first germination in each set of 50 seeds, that is, speed of emergence;
- germination rate for each set;

- mean height, maximum height and distribution into height classes after four 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 and especially for those corresponding to the dry season, which took place in the middle of the trial. In mean values for the whole trial, the FM seeds germinated after 47.5 days, 19 per cent faster than the NM seeds, which appeared after 58.5 days. Experiments on the radish (*Raphanus sativus*) by Fritz (1994) show the same tendency: faster germination for sowings shortly before FM.

These studies seem to 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 Staden on algae in 1986 – cited in Fritz, 1994). Cytokinine also plays a role in the model proposed by Rossignol et al (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 (1973) working on a large scale: 7,931 series of 20 beans. One of the absorption maxima coincides with the FM or shortly before (see Figure 1).

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) (see Figure 2). These two first elements (speed of emergence and germination rate) appear themselves to be strongly positively correlated. A parallel trial with *Acacia mearnsii* carried out the same year also showed a strong sytematic variation in the number of plants obtained. A fine confirmation of this tendency to a higher germination rate for sowings before the FM was found by Spiess (1987; 1990; 1994), who demonstrated a strong effect of this kind, especially for carrot (*Daucus carota*).

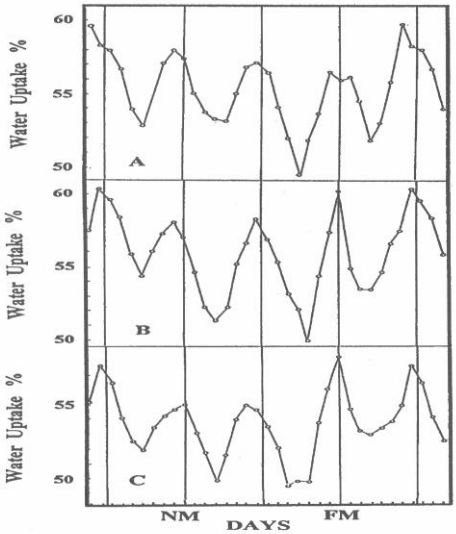

Figure 1 Water absorption by bean seeds (*Phaseolus vulgaris*) and lunar phases.
Note: A, B and C are the three different periods in 1972 and 1973. 3-day mobile means.
Source: Brown and Chow, 1973

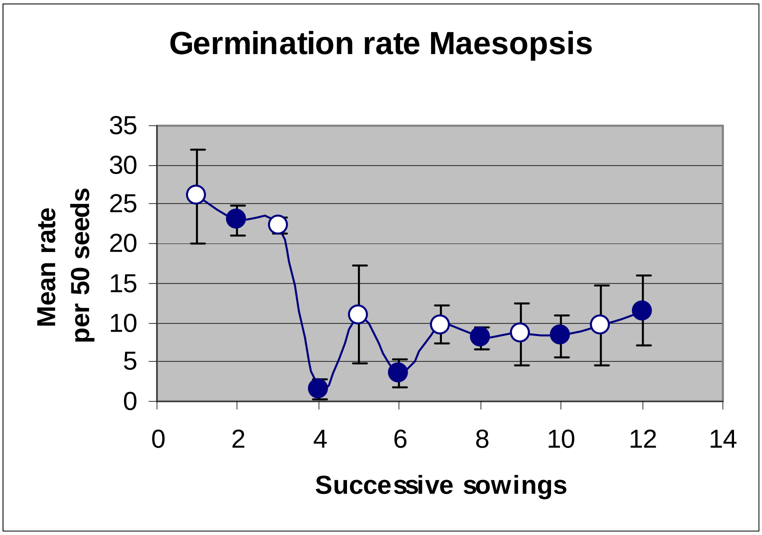

Figure 2 Mean Germination rate of 12 successive sowings (*Maesopsis eminii*).
Note: Sowings at dates two days before FM (◯), alternate with dates two days before NM (●).
Period: May to October 1990. Means with standard deviations.

Not only were the speed and rate of germination influenced by the exact sowing date, but also the individual dimensions four months later. The mean heights at four lunar months follow a curve similar to that of the variations of germination rate according to the sowing dates (see Figure 3).

The most striking differences were found with the measurements of maximum heights for each group of sowings at four months, with the FM sowings always coming ahead of the NM sowings (see Figure 3). 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, independent work on germination and initial growth of four African tree species from the Soudano-Sahel Zone was carried out in Mali, after the same scheme. According to the values, two months after sowing, the four tested species showed better results with the dates just before full moon (Bagnoud, 1995). Here, a kind of equalization seemed to occur during the two following months.

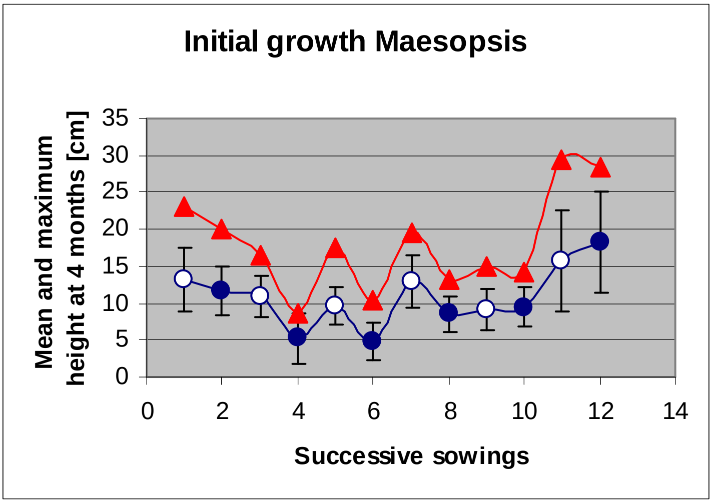

Figure 3 Plant height at four months (mean and maximum) of 12 successive sowings (*Maesopsis eminii*)

Note: Sowings at dates two days before FM (□), alternate with dates two days before NM (●). Period: May to October 1990. Mean heights with standard deviations.

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 FM, the plant seems to react completely differently in terms of viability (dramatic drop). The values obtained for *Maesopsis eminii* the following year (1991) show this, as well as confirming the effect of sowing two days before the FM or two days before the NM, which was shown in 1990. 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 15 months, with parallel systematic sowings on three platforms (stationary, rotating clockwise, rotating counter-clockwise) under constant conditions (see Figure 4).

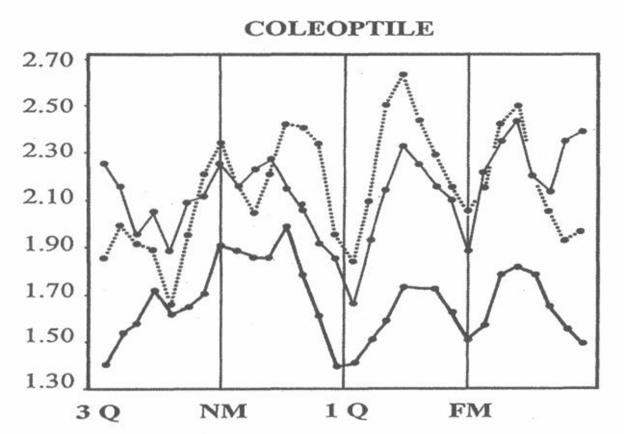

Figure 4 Length of Maize coleoptiles (*Zea mays*) in cm, seven days after sowing for three different experimental configurations.
Note: 1Q, 3Q: first and third quarters.
Source: Milton, 1974

Our critical reexamination of the data and negative conclusions of Rohmeder (1938), who worked on the lunar-phase correlated germination of European spruce (*Picea abies*) with an impressive number of seeds, and utilizing now modern statistical methods allows us to find small, but significant differences in the germination rates (Zürcher, forthcoming). As for the other mentioned species, the sowings of spruce before FM germinate better than the ones before NM and the ones of the exact day of FM, but also better than the sowings between NM and the first quarter (see Figure 5).

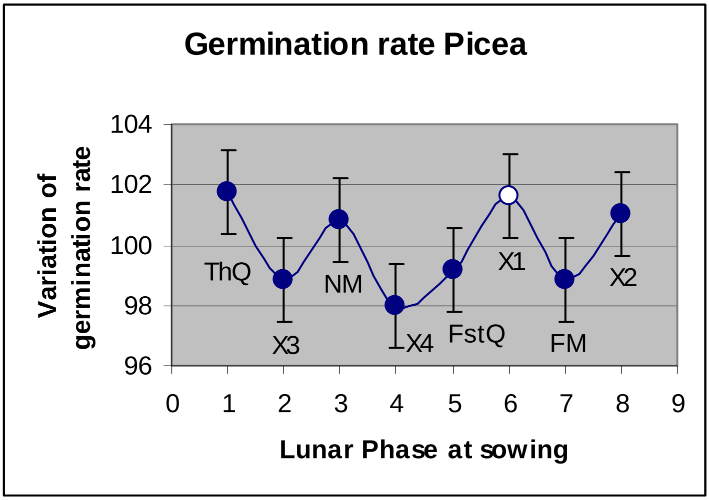

Figure 5 Variation, related to the general mean, of the germination rate of European spruce (*Picea abies*), 21 days after sowing according to lunar phases (1936, 1937)
Note: Mean values with 95 per cent confidence intervals.
Source: Zürcher, forthcoming, after data of Rohmeder, 1938

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 previously observed: in 1991, *Sesbania sesban* produced maximum heights systematically in phase with the NM. This type of tendency was also described by Spiess (1994) for potatoe (*Solanum tuberosum*), which had the lowest yield for plantations between the first quarter and the FM. On this subject, Brown and Chow (1973) 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) found 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 close 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 thise 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, 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 cereale* L.) according to sowing date, analysed for a period of six years, follows tendentially a curve parallel to that of the moon in relation to the terrestrial horizon.

Specific effects linked to the constellations 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 related to the synodic lunar cycle and also related to this last type of rhythm 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 heartwood. Precise experiments have also been carried out in this area (Zürcher et al, in preparation).

International pluridisciplinary work on this concern shows that the synodic lunar rhythm is also present in the daily tree physiology: under controlled conditions (darkness, constant temperature), the stem diameter of trees fluctuates reversibly in phase with calculable earth (gravimetric) tides (Zürcher et al, 1998). This phenomenon was even measurable on sealed stem sections and led to the hypothesis that water could be moving alternatively from living protoplasts to cell walls of the sapwood, with corresponding diameter changes.

These last mentioned reversible, circadian (daily) lunar synodic fluctuations of stem diameters (for trees held under constant conditions) provoked a controversial discussion, no such rhythms having been found on Scots pine trees (*Pinus sylvestris*) growing in open conditions (Vesala et al, 2000), thus seeming to contradict the possibility of tidal rhythms in trees.

An interesting differentiating synthesis has recently been forwarded by Holzknecht (2002) and Holzknecht and Zürcher (2006), through long-term measurement of (bio-)electric potentials on European spruce and Swiss stone pine

(*Pinus cembra*). While during the growth season the measured electric potentials followed a diurnal rhythm (responding to the known diurnal changes of climatic factors), the potential variations were in correlation with the calculated circadian gravimetric tides during the decreasing lunar phases in the winter period. At that time, the global curve exhibited a lunar and semi-lunar course. Interestingly, there are periods of rest during the growth season where the tidal correlation briefly becomes evident too. This type of short-period lunar rhythm should also be tested in trials on germination and initial growth of trees.

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 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. The Kyoto Protocol (1997) and the following resolutions confirm the necessity of more plantations as 'carbon sinks', combined with emission certificates. In this context, astonishing potentials of agroforestry systems (including for example *Sesbania sesban*) have been recently presented by Verchot et al (in Robledo et al, 2005).

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

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