

# Methodological aspects regarding the analysis of beech seedlings crown development

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**Abstract** This article presents some basic methodological challenges raised by analyzing the crown architecture and development of beech seedlings. Since the issue implies both qualitative and quantitative considerations, it is difficult to establish the best methodological approach. Therefore some general considerations about the state-of-the art were necessary, since the problem is quite new in the forestry research field and a it needs a more coherent grasp on the issue.

**Key words**

beech crown architecture,  
3D virtual images of trees

## Importance of crown architecture study

Multifunctional forest management requires a much closer analysis onto the structure of naturally regenerated beech stands and the old-growth forests located west-south Romanian beech old-growth forests located south-west can be regarded as genuine benchmark structures, providing a great deal of information about the multiple connections between tree crown architecture in different development stages.

The beech (*Fagus sylvatica*) is one of the most important tree species that typifies the Romanian forest fund in hilly and mountainous areas, where most of the woods provide a large palette of ecosystem services and also to high quality timber. It is necessary to add that, beech forests must be properly regenerated in order to produce sound vertical and horizontal stand structures able to secure the multiple ecosystem services referred to water, soil and biodiversity protection. Since these stable structures cannot be easily produced by individual tree selection system, a real problem is to name the appropriate regeneration period for the beech stands meant to produce wood and ecosystem services in the same time. In this respect, the natural forests located in the southwestern part of Romania are considered a sort of benchmark structures are worth to be undertaken and applied to cultivated forests in the same region at least.

During the past four decades the European foresters have been quite interested in improving the forest management of deciduous species, among this, oaks and beech are the most prevailing species. The silvicultural techniques tailored for these species require green hands and high skills and the slightest errors could affect the stem quality for good. F. Halle and R. A. A. Oldeman [1] are the first authors who have launched the concept of tree architectural model. This architectural model embodies all growing

meristems in order to produce a sequence of stem expansions. Since then just a few attempts were carried out in this challenge issue, and one of the major impediment to overcome was the lack of a consistent methodological background, common for all species and development stages. For beech, the growth model that fits better the crown development is known as the Troll model, which is being labeled by the name of the author who described it first. Other species have been assigned to other architectural models.

## State-of-the-art studying tree crown architecture

In general, tree architecture is being studied as a distinct stage of tree and stand modeling, addressed for the important role played by tree canopy in reducing the kinetic energy of rainfall [2], carbon gain [3-5] competition between different tree species [6, 7], or tree species adaptive strategies [8]. Summarizing, tree architecture is important for two reasons at least: for horizontal and vertical light partitioning, and for studying the effectiveness of carbon gain in closed forests [9].

One of the first attempts in modeling tree crown development produced a three-dimensional crown architecture model, named YPLANT [4], whose functional unit was the node; a series of nodes are separated by stem segments. The same rationale applied for leaves, each leaf being considered a terminal node, while the petiole was considered a stem. Opposite leaves are produced by a succession of two very small stems, about 0.1 mm. Then each stem is described by length, diameter, elevation angle and azimuth. Leaf geometry was described by surface orientation and a set of shape describing coordinates. For sake of simplicity, each leaf was considered a planar area.

H. L. Späth (1912) carried out systematic investigations on beech growth and development and he was the first who reported that beech has multiple annual growths: a spring one (*Regulartrieben*) and one or even more summer growth, known as St. John growths (*Johanistrieben*)

### Tentative methodological trails

It is difficult to establish differences between the crowns of whatever two statistical populations due to the many features worth being considered due to the physiological connections between apical meristems, the light and stem growth. For research needs, it is important to outline at least two methodological trails, in order to carry out a cost-effectiveness analysis of the possible alternatives which can be followed.

Studying the crown architecture is an alluring research topic because any further model conceived to simulate the individual tree development and growth depends on the main parameters of crown architecture worth to be considered. Therefore two directions have been conceived: one based on a large amount of effective measurements carried out on each unit of growth (length, diameters, angles, azimuths), the latter based on virtual trees, reproduced on the bases of some different photographs further processed by Photomodeler, an up-to-date software which is based on the stereo-photography principles. The advantages and disadvantages of the two approaches are summarized in Table 1.

Table 1

**Possible approaches for analysing the tree crown**

	Advantages	Disadvantages
Traditional approach	Cost-effective and precise Rough results are easy to process Some statistical methods can be applied to better tell the differences	All measurements shall be pair-wise conceived and carried out A lot of information at hand cannot be processed in statistically meaningful way Crown areas and volumes cannot be easily appraised
Stereo-photographical approach	Allows rough assessments for the crown area and crown volume Time-effective data collection	Precise direct measurements cannot be achieved. Quite expensive and require a great deal of labor for data processing. Special training for digital processing is needed More expensive equipment is needed

### Effective approach

Since none of the presented alternative approaches was effectively tested in Romania for beech crown analysis, both methodological trails have been explored, and this section is meant to describe the analytical process which supports the selection of one of these methods.

In case of traditional approach, based on close measurements on different parts of the tree, i.e. branches of different orders, one may expect to be able to find some statistic meaningful differences. Actually, the opportunity to apply some conformity tests is the most important and tempting reason why direct

measurements are to be carried out. But, on the other hand, being stuck in a standard procedure might also be risky because some relevant features might be overlooked since they are not quantitative but qualitative. Having in mind these considerations, we thought that all needed measurements should be oriented to highlighting those traits that make the difference between the two statistical populations: seedlings collected from old-growth forest and seedlings collected from a second-growth forest, similar to the first one in all respects (site conditions and climate) but with a different stand structure, which means different light conditions below the mature tree canopy.



Fig.1 Taking the azimuth for each seedling, before cutting it

The first clue to count was the well-known higher quality of the timber harvested from the old-growth forests, where trees usually have straight stems, without any first-order branches, which would diminish the height growth, resulting a zigzag shape of the stem. When this kind of stem occurs, it indicates, that the height growing process was carried out by different first-order branches, and not by a single apical meristem, as it happens, for instance, with all resinous species. Hence the first traits are worth to take note the dominant stem branched-out and one of the branches undertook the role of dominant main stem (which actually is an assignation of the dominant growth to another branch). Another aspect was the annual unit of growth, identified for each seedling, and its seasonal components (internodes), described in the first section of this article.

Each growth unit was assigned to a given year, within the year 2000 and 2011, and two parallel measurements were carried out: one on the saplings collected from the old-growth forest and one on the saplings collected from second-growth forest. For each annual growth, the number of seasonal growths and their lengths were measured too. Having pairs of measurements, corresponding to each year of the period already referred to, it was further possible to carry out simple statistical tests in order highlight any statistically significant differences between the two populations. Because the signs left by the stipules on units of growth couldn't be seen on the digital pictures, these measurements were done on a special table, using a stripe, as shown in Figure 2 .

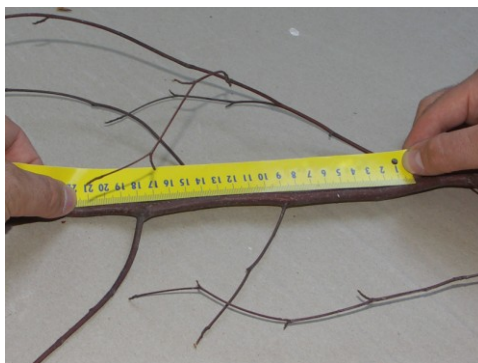


Fig. 2 Measuring an internode within a growth unit of the main stem

In addition to all these lengths and heights, the diameters were also taken into account: the basal diameter, above the ground, and each branch diameter as well were measured with an appropriate tool (a technical beam compass).

Another important aspect was the spatial assignation of the branches, needing a closer look on the position of each crown branch. Before cutting the seedlings their azimuths were measured, according to the procedure described in Figure 1, using a regular compass and a triangle.

In order to produce the 3D virtual image of each sapling, used further for assessing the volume and the total interception area of crown, each sapling fixed in a special device was photographed, presented in Fig.3.



Fig. 3 Fastening the seedlings in preparation for photography

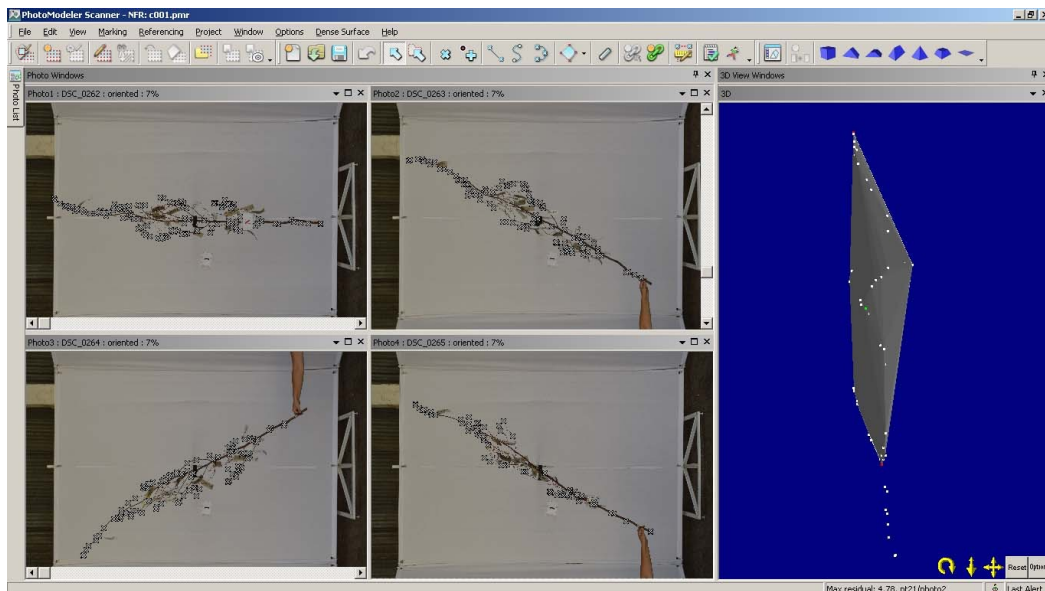


Fig. 4 Reconstructing the 3D virtual image using the 3D relative coordinates identified on each separate picture, using Photomodeler® software

Having four different pictures, taken from different vertical and horizontal angles, it was further possible to re-build the virtual image of each sapling, 'punching' each important node on each digital image,

as shown in Figure 4. The virtual body of the crown allowed us to assess the volume and the total area of each crown. This information is further used to identify which type of rotation body better envelopes the

crown. This aspect is important for further ecological studies, because it allows a more precise assessment of the light interception area produced by a bunch of seedlings with different heights and spatial positions.

Another important considered aspect was the diameter growth. In order to measure the annual growth a basal sample was taken from each seedling and the annual tree rings were further measured on that sample, using standard procedures applied in dendrochronology. That means that each sample was three times grinded with finer and finer abrasive sands and the tree rings were inter-calibrated using the CooRecode 7.1 software. These measurements were possible only with support of Olivier Boiriaux and Stefan Gheorghe from Forestry Research and Management Institute – branch Campulung Moldovenesc.

## Conclusions

Considering the knowledge provided by the studied literature, it is obvious that each species might need a different approach, tailored to the specific pattern of branching the main stem and seasonal growths.

If all efforts are given to precise growth measurements, one may miss the qualitative aspects of outbranching and passing the apical growth between different twigs; highlighting only the qualitative issue, it could be impossible to tell to which extent two different architectural patterns are different or not, and the scope of this study falls into this latter category. The crown architecture of beech seedlings has raised some particular questions to address, due to the multiple growths (or twigs) occurred in a growing season, multiple growths which are supposed to make the difference between the sprouts coming from old-growth and second-growth forest, respectively.

Since the crown itself is being meant to support the main physiological process, which is the photosynthesis, the relationship between the crown interception area and the lighting conditions is another important aspect worth being studied, which implies a broader perspective on the crown itself, perspective which can be provided only by digital photography.

Hence, the two approaches must be eventually combined whenever some is interested in crown architecture study, especially two statistical populations are to be compared.

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