Factors Affecting Rooting of Difficult-to-Root Plants

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INTRODUCTION

Millions of plants of easy-to-root species or cultivars are propagated by nurseries. Each nursery operates its own propagation environment, but all root the plants successfully. This indicates that for easy-to-root species the precise coordination of plant and culture factors is not necessary. A wide range of easy-to-root taxa can be rooted in the same propagation system with the same substrate and the same hormone treatment, often over a long period in the year.

In contrast, difficult-to-root plants need very precise coordination of plant and culture parameters. This is a problem because the whole environment in which cuttings are propagated involves up to 50 factors or conditions that could be altered, including cutting length, setting time, growth hormones, substrate, humidification, light, fertilisation, temperature, and so on. Many of these factors are interdependent (Spethmann, 1990). So it would be necessary to make hundreds of investigations with tens of thousands of plants to develop an optimised propagation method. With forest trees it was possible to undertake complex investigations over many years often with more than 100,000 cuttings and to develop optimised cutting propagation systems, e.g., for *Picea abies* (Kleinschmit et al., 1973), *Quercus robur* and *Q. petraea* (Spethmann, 1986), and some other trees like *Tilia cordata* or *Prunus avium* (Spethmann, 1982; 1990). But this is not practical with rare or expensive difficult-to-root species, such as *Hamamelis*, some *Rhododendron* taxa, or *Kalmia*.

To reduce the number and size of trials needed, it is necessary to be able to rank the relevant plant and culture factors. The most important of these factors can then be optimised while the other factors only modify the result and can be optimised later on. At the same time other factors, the importance of which may have been over-estimated, can also be identified.

RANKING OF PLANT AND PRODUCTION FACTORS

Investigations by The Author over 20 years have cleared up the importance of many propagation factors. The most important factors for cutting propagation success (Table. 1), especially in difficult-to-root species, are:

- Effective age stage;
- Sticking date;
- Humidification method;
- Method of overwintering.

Effective age stage means the combination of effects such as treatments to stimulate juvenility, age of the stockplant, height of the collecting position on the stockplant, and so on.

When factors such as effective age, physiological condition of the cuttings (e.g., degree of stress), and cultural conditions are below optimum, it leads to the following changes in propagation success (Spethmann 1997, Fig. 1, 2):

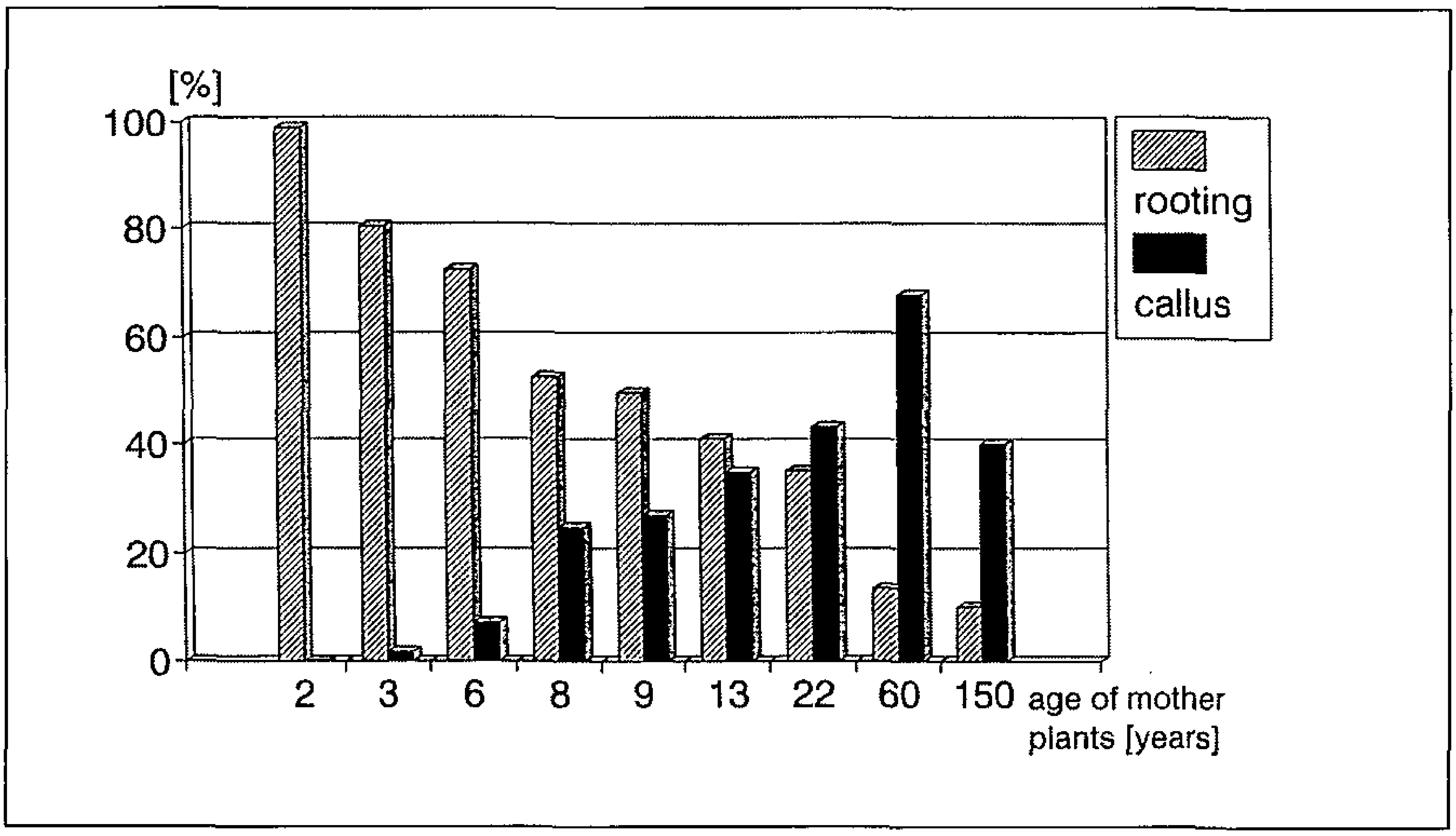

Figure 1. Mean rooting and callus formation of oak cuttings of different aged mother trees.

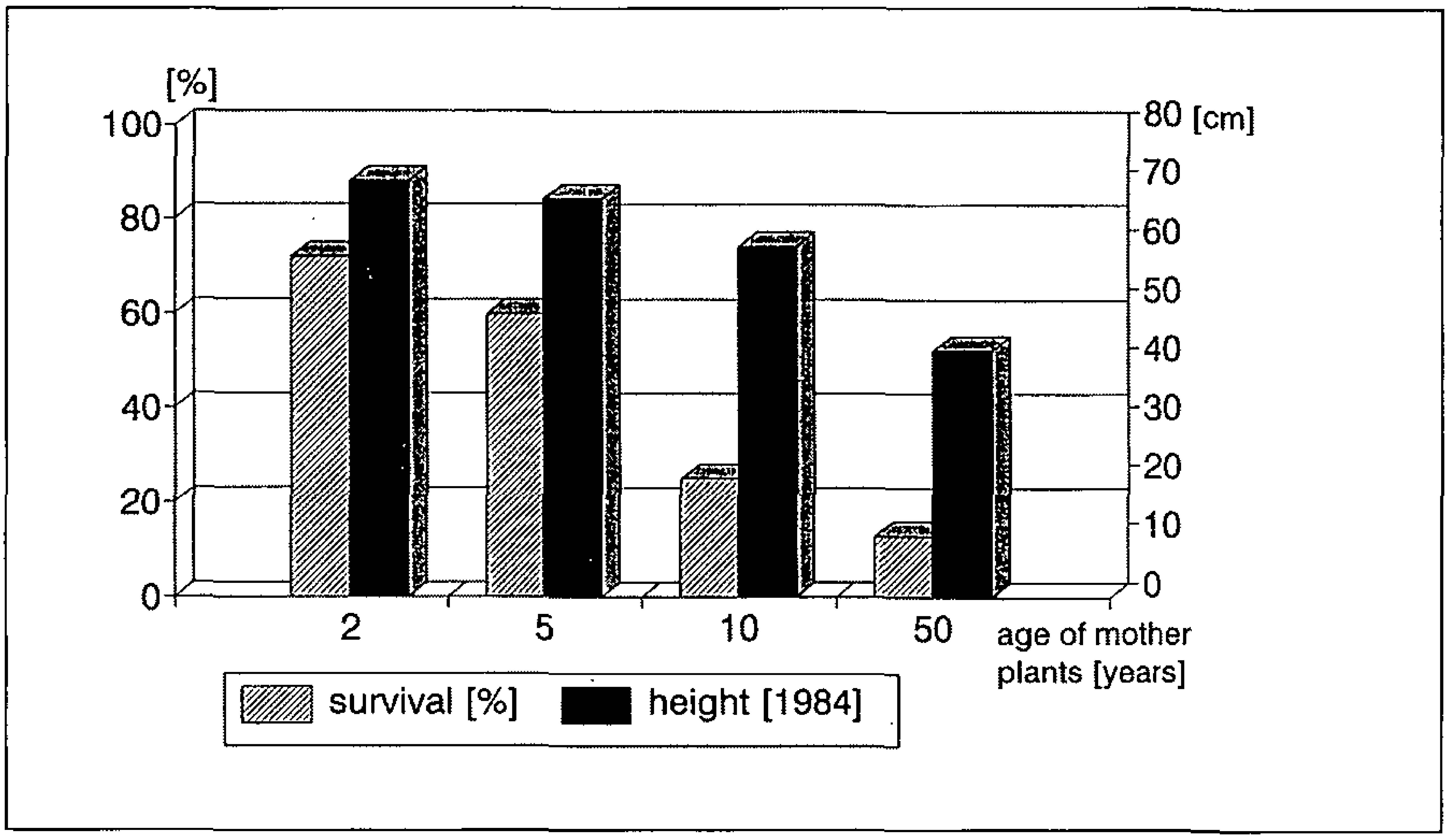

Figure 2. Survival after the first winter and mean height after 3 years of cuttings 1981 of *Betula pendula* as influenced by age of mother plants.

- Decrease in rooting percentage;
- Increase of callus formation;
- Decrease of the main root number;
- Origin of roots at the cutting turned from lateral, acrobasal to basal;
- Decrease of survival after the first winter and in the following years;
- Decrease in total vitality;
- Increase of plagiotropic growth habit especially in conifer cuttings;
- Decrease of the mean shoot growth in the following years.

The optimum time window for sticking is often very short (e.g., 3 weeks in *Quercus*). Trials involving sticking batches of cuttings every month through the year, will determine the optimum period. This shows, in some cases, unexpected results, e.g., *Prunus* (end of June and then again in November), *Fraxinus excelsior* (directly before and then directly after flushing), and *Phyllostachys* (December).

The most intensive and successful humidification system is fog, followed by mist system. Polythene used as a low or contact cover can be used successfully only for easy-to-root plants.

Cutting propagation can only be judged successful after overwintering and resumption of growth. Some tree species, such as oak, cherry, and birch should not be potted in autumn as this can lead to losses up to 80% over winter. Keeping them in the rooting bed in an unheated plastic greenhouse until next spring results in only a few losses and strong hardy rooted cuttings (Spethmann, 1986).

Table 1. Effect of unsuitable plant and culture factors on the success of cutting propagation.

Juvenility	Sticking date	Humidification	Overwintering	Result
juvenile	correct	suited	adapted	best success
adult	correct	suited	adapted	rooting not poss.
juvenile	wrong	suited	adapted	rooting not poss.
juvenile	correct	unsuitable	adapted	no rooting/poor plant quality
juvenile	correct	suited	not adapted	rooting but no survival

QUALITY AND FURTHER GROWTH OF THE CUTTINGS

Important factors influencing the quality of establishment and further growth of the cuttings are: sufficient volume for root development, fertilisation of the substrate, an adapted pH of the substrate (Mlasowsky, 1996), and, in some cases, use of growth hormones.

Ideally the cuttings, especially those of tree-like species, should be set in beds rather than trays or containers to allow plenty of space for root growth. These plants could be transplanted with bare roots to the field after overwintering. Shoot growth after rooting in these conditions is better than that of cuttings set in pots, especially those in cell trays. Fertilisation with 2 kg m^{-3} of medium of Osmocote Plus (3-4 months) tends to stimulate shoot growth effectively, and this results in shorter production time. In our trials we have produced oak from cuttings stuck in June that were more than 1 m tall by October (Spethmann and Harms, 1993).

More recent trials have revealed a significant effect of substrate pH. Surprisingly, the best pH for oak propagation is between pH 3.2 and 4.5 (Mlasowsky, 1996). With increasing pH, rooting percentage decreases, callus formation increases and new shoot growth decreases (Figs. 3 and 4). At pH 6 to 7 cuttings begin to suffer from chlorosis caused by unavailability of nitrogen, iron, and manganese (Table 2). In *Prunus*, pH of 4.5 is the optimum.

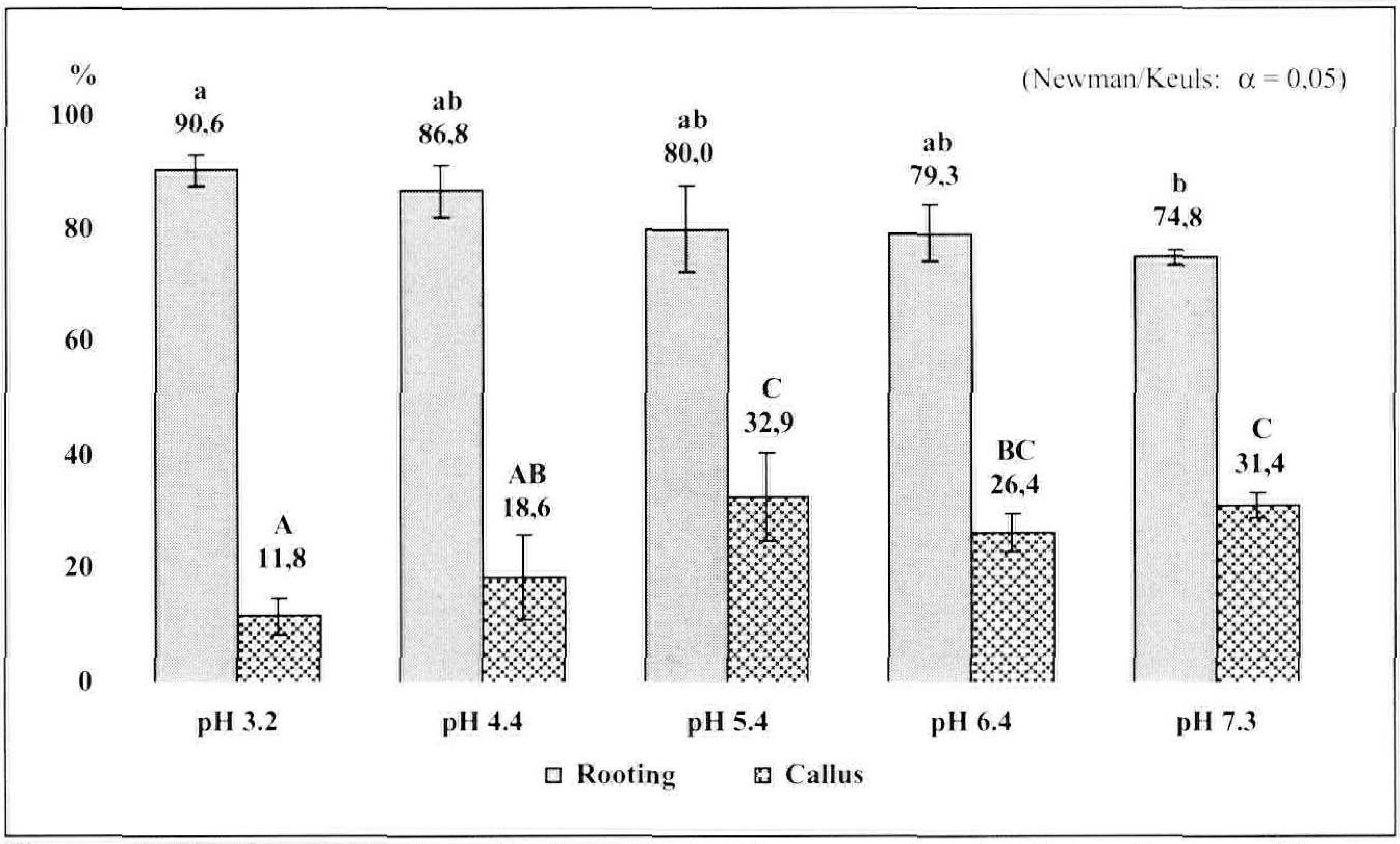

Figure 3. Rooting and callus of oak cuttings (*Quercus robur* L.) depending on pH value (Mlasowsky, 1996).

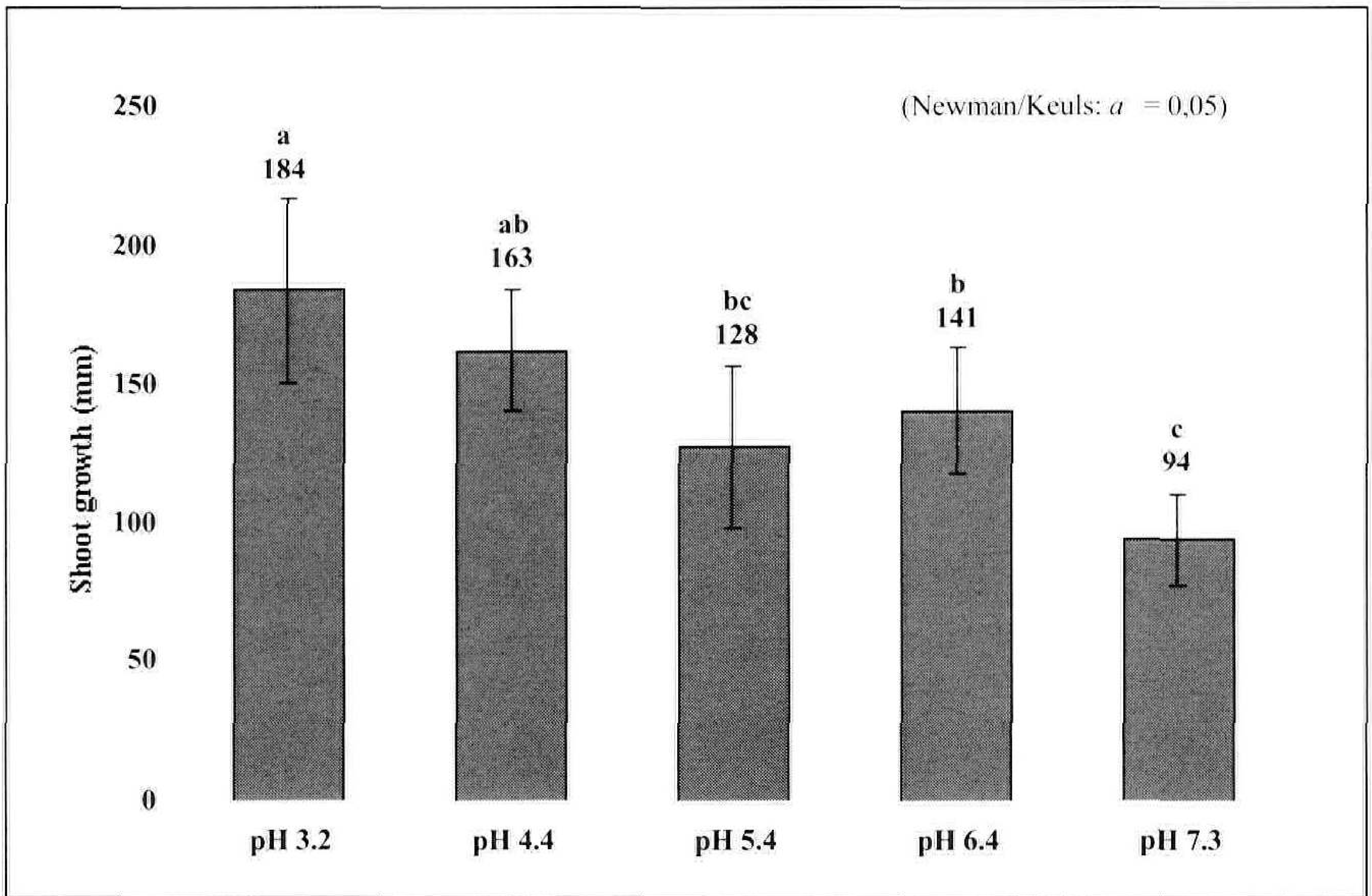

Figure 4. Average shoot growth of oak cuttings (*Quercus robur* L.) depending on pH value (Mlasowsky, 1996).

Rooting is promoted by growth hormones, these are especially effective in reducing rooting time and promoting root quality (root number, rooting position) but do not have much effect on rooting percentage.

Table 2. Nutrient content in dry matter of leaves from oak cuttings rooted in media of different pH (measurements made 23 Oct.).

pH	N (%)	Ca (%)	Mn (ppm)	Fe (ppm)
3.2	1.99	0.88	69	111
4.4	1.88	1.26	60	116
5.4	1.64	1.36	54	80
6.4	1.63	1.6	38	84
7.3	1.56	1.65	39	44
Limiting value	1.65	0.3	35	50

Limiting values based on Bergmann, 1986 and Lyr et al., 1992).

OVERESTIMATED PRODUCTION FACTORS

Some overestimated factors are temperature, light, substrate, a correct cut or wounding of the cutting base, and callus formation.

In particular, a wide range of substrates can be used as long as the key factors described in the previous section are optimised. So, for example, oaks could be rooted in pure peat, different peat mixtures, perlite, or gravel (3 to 8 mm). Even rhododendrons can be rooted with nearly equal success in a peat and sand mix or pure gravel. It is important, however, that the substrate is adapted to the humidification system (Spethmann, 1997).

Wounding of the cutting base often has a negative effect, so that rooting only takes place at the unwounded side, callus formation occurs at the wounded side. In addition, an important commercial consideration is that wounding is an additional handling stage with a cost, which has to be balanced against the likely rooting improvement, which in many cases is less than 5%.

INTERPRETATION OF PROPAGATION TRIALS

To interpret the effect of different propagation regimes it is important to choose the most relevant characters to measure and compare. For years the following characters have been used successfully: rooting success (% of rooted and survived cuttings), lack of callus, position of roots at the cutting, main root number, and shoot growth until autumn. As mentioned earlier, successful propagation can only be judged after the rooted cuttings have overwintered. Often species such as *Fagus* or *Hamamelis* root successfully but the rooted cuttings fail to overwinter.

Callus formation has been regarded as a precursor of root formation by some nurserymen. But in fact callus formation is totally independent from root formation. Cuttings from juvenile stockplants never show callus formation, but it is observed on cuttings from aged motherplants or those stuck in suboptimal culture conditions. Shoot growth of cuttings with root and callus formation is less than that of cuttings which develop roots without callus (Mlasowsky, 1996). In most cases where it looks as if roots have grown from the callus, microscopic study reveals that the roots have in fact developed at the base of the cutting and grown through the callus.

A better type of rooting than basal rooting is acrobasal rooting (over the lower 1 to 3 cm of the cutting) or laterally (along the full depth of the part of the cutting in the substrate). This type of rooting is promoted by the use of rooting hormones with IBA giving better results than IAA (Spethmann and Hamzah, 1987). Cuttings of aged stockplants are likely to root basally under the same conditions that produce acrobasal rooting in cuttings from more juvenile sources (*Quercus, Prunus, Fagus, Tilia, Thuja*, and others). In many species, however (e.g., *Picea*) only basal rooting occurs, despite optimising all conditions.

The number of main roots on a cutting is another important factor in comparing the results of different propagation treatments. After roots have emerged from the cutting bark, the number of main roots of the finished cutting is determined. *Juvenile cuttings and optimised propagation systems result in the highest number* of main roots. The number of roots is independent of the time you allow before evaluation. The root length, however, depends on evaluation time, substrate, and fertilisation — and the long roots are not necessarily the best roots. Root length of more than 15 or 20 cm hinders nursery handling operations such as potting or transplanting. Therefore root length should not be used as a root quality factor (Spethmann and Hamzah, 1987).

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