International Conference "Wind Effects on Trees"
September 16-18, 2003, University of Karlsruhe, Germany

Planting – a risk for the stability of forest stands?

Robert Nörr
Bavarian State Institute of Forestry, Department „Silviculture and Forest Management Planning ",
Am Hochanger 11, 85354 Freising, Germany; Contact: +49-8161-71-4967, nor@lwf.uni-muenchen.de.

Abstract

The root development of planted trees is mainly shaped through the following factors: method of planting, range of plants, quality of planting and root pruning. The influence of site and species is superceded by this. Improper planting leads to appreciable root deformation, which retards or even prevents the vertical growth of the roots. An extensive regeneration of the deformations cannot be expected, in that even after several decades, a significantly smaller opening up of the root space could be shown on planted spruces. Because of the reduced anchoring ability one can reckon with a higher danger of wind thrust. With the demonstrated methods, root deformations can be significantly reduced.

Introduction

"Wind Effects on Trees", where do these effects occur more clearly than in the large storms, such as "Vivian & Wiebke" or "Lothar"? In both storms the trees were mainly uprooted and thrown; rarely were they merely broken. This shows us, that the key factor for the single tree stability lies less in the proprietary mechanical stability than in the anchorage through the roots. Besides soil conditions, the anchorage, in turn, depends to a great extent on the size and form of the root system in relation to the shoot.

How are size and form of the root system of our forest trees affected?

- On one hand, environmental influences of the soil act directly, such as water economy, aeration (amount of soil air), nutrients and mechanical influences (content of skeleton, layering of soils),
- on the other hand, indirectly acting factors exist, which affect the assimilation, such as light and heat (see Kutschera/Lichtenegger 2002, Köstler et al. 1968, Bibelriether 1966, Braun 1998),
- the social position (Drexhage 1994, Eis 1978),
- the method of establishment, e.g. natural regeneration, seeding, different methods of planting and range of plants (see Schmidt-Vogt 1977, Coutts 1983, Büsgen/Münch 1927, Gruber 1992, Dahmer 1998, Nörr 2000b, Nörr et al. 2002, Huuri 1978, Burth 1994, Pampe 2001, Herget/ Ludwig 1999 v. Lübke 1978, Gürth 1970a, b, Schmidt-Vogt 1969, Leder 1999, Abetz/Prange 1975, Parviainen 1982, Adam et al. 1991, Pampe/Häseker 2003, Moosmayer 1997) and
- the additional stand management and thereby the size of the crowns (see Bolkenius 2003, Nielsen 1990, Wagenknecht 1960, Lembke 1955, Fölster et al. 1991).

I would like to describe the influence of the listed factors on the root development on the basis of dimension parameters and especially through the existence or lack of root deformations in the first phase of root development.

Root deformations had already been reported by the end of the 19th century (see Dücker 1883, Reuss, 1907); their effects have been discussed controversially. No negative longterm effects were found by Köstler et al. (1968), Bibelriether (1962), Schmidt-Vogt/Zimmer (1995), Hocevar (1980), Schnurbein (1973) and Heikinheimo (1941). A restriction of the rooting was proven by Rudolf (1939), Specht/Au (1967), Huuri (1980), Eccher (1975), Deleporte (1982), Grene (1978), Schönberger et al. (1990), Dahmer (1997a, 1998b), Tomiczek (1984) and Nörr (2000b, c), among others.

Changes in the root system can be described and assessed by root deformations[1]. Of special interest thereby are deviations of the vertical roots, because the anchorage of our trees on medium to deep sites occurs mainly through the vertical root system. Through a differentiation of the deformations in kind and development, their causes can be determined and the course of regeneration and their effects on stability can be estimated.

Method

For more than 13 years the Bavarian State Institute of Forestry (LWF) examined the root development on more than 7500 trees. With a total excavation of

- two to ten year old deciduous trees (Part A) and of
- approximately 40 year-old deciduous and coniferous trees (Part B)

the spatial structure of the thick roots (fine roots were registered only to some extend) could be extensively analyzed.

Part A:

Choice of the examination areas
After the storms “Vivian” and “Wiebke” of the year 1990, the LWF established 52 examination sites in regularly planted, storm-cleared areas in the primary damage regions of Bavaria, in order to examine the root development of young deciduous trees (beech, oak, sycamore maple and ash).
Several sites, methods of establishment (natural regeneration, seeding as well as the common methods of planting „Buchenbühler method“, „angle planting“, „hollow spade“, drilling methods with drill diameter of 10 to 30 cm, as well as subsequently the „Rhodener method“) and several ranges of plants were included in the study. Through the root excavations in the year 1992 and the follow-ups in the years 1995/96 and 2000 on the same sites (sample size 5821 roots), the root development of the first 10 years could be documented and analyzed.

Choice of sample
The choice of the test trees was made with the strip sample method. According to a random principle, a straight guide line was set up on every examination area diagonally to the planting rows, to exclude the influence of the individual planter. For the follow-ups, the test lines were moved parallel by some meters, whereby one was careful to observe, that the initial conditions for the excavations remained comparable.

Data survey
On the test areas, all above-the-ground parameters for the test trees were collected first. After the excavation, the roots were cleaned, measured and classified. The main focus of the examinations lay in the quantification of the root deformations as well as the analysis of their causes and effects. Thereto the roots were classified according to the kind of the deformation (10 kinds of deformation, table 1), their development (5 strengths of deformation, table 2) and the actual opening up of the root area (vertical and horizontal in 5 steps).

[1] Definition: Deformation of the root, which showed a fundamental deviation of the initial growth direction at the moment of the examination.

Table 1: Definition of the kinds of deformation

Kind of deformation	
Crookedness of the main root	Deviation of the vertical roots from their initial growth direction in the depth
Crookedness of the side root	Deviation of the horizontal roots sideways or upwards
The following kinds of deformation are contained in the total picture of the crookedness of the main and side root. They serve for the further differentiation.	
Formation of tuber	Untypical thickened section in the area of the main root
Perpendicular compression	Alteration in direction by mounting the main roots at the base of the planting hole or planting gap
Root connation	Inseparable connection of two or more roots
Root twisting	Equal circular growing of several roots
Untypical surface root development	Root concentration above 20 cm
Story or secondary root development	Development of adventitious roots by plantings, which are too deep
"Flowerpot effect"	Only with hole planting: Concentration of the main root mass in the area of the drilling hole. For more precise collection, the portion of the sprouting roots can also be considered: - 0 - 25 % of the roots has sprouted - 26 – 50 % - 51- 75 % - 76 – 100 %.

Table 2: Definitions of the strengths of the deformations

Strengths of the deformations	
Without deformations	Small kinks or arched growth represent no deformation, as long as the direction of growing is not changed permanently.
Light deformations	Some roots are deformed. The effects on the root spreading however are insignificant.
Distinctive deformations	Already distinctive change of direction, but a certain depth and side development is not yet guaranteed.
Strong deformations	Strong change of direction with starting regeneration of the deformed root or with starting regeneration through new root formation.
Extreme deformations	Strong change of direction, no significant regeneration of the deformed root, no regeneration through new root formations.

Part B:

To examine the long-term effects of the root deformations, 138 spruces, Douglas firs, sycamore maples and beeches with an age of more than 30 years were excavated additionally. Old trees, which were planted with the “angle method“, were compared with natural regeneration or another planting method under corresponding initial conditions.

Beside the social position and the dimension parameters, the root cross-section areas were collected in defined depth and side sections[2].

Causes of root deformations

The root development of **natural regeneration/seeding** is controlled only through "natural" influence factors. The analysis of the data shows, that depending on tree species, location and social position, such root systems are built, which are described in the literature. Hence, natural regeneration/seeding can serve as reference for a root development that is not influenced by man.
An **artificial formation of stands** inevitably causes a change of the root system. Breeding of plants, transport, root pruning and planting affect the root development (see Parviainen 1982, Mullin 1963, Hoffmann 1966, Rupf 1948, Sauer 1984, Grene 1977, 1978, Arnott 1978, Schmidt-Vogt 1979, Abromeit et al. 1999). With increasing number of work steps, the risk of long-lasting detrimental effect on the root development increases through an improper treatment. Figure 1 shows the results: The natural regeneration exhibited significantly much rarely and weaker root deformations, in comparison to the examined plantings. It had an overwhelming good to very good development of the vertical root space and a smaller portion of shallow root systems.

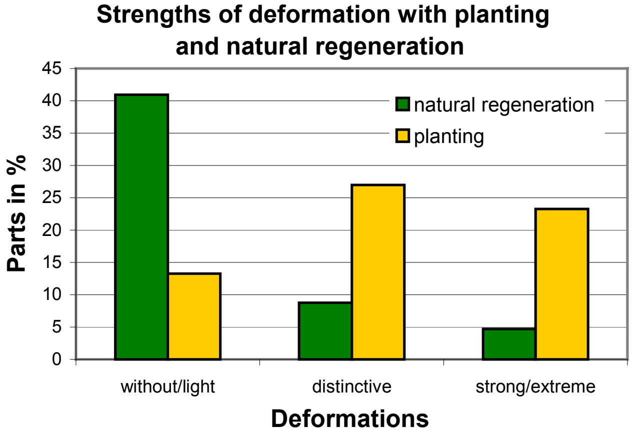

Fig. 1: Strength of main root deformations at 10 year old deciduous trees after natural regeneration and planting

Causes for the highly significant, more frequent and stronger root deformations of the examined plantings:

- Planting method
  Roots are inevitably deformed, if root length or width exceeds the depth or width of the planting hole. With some methods, such as "angle planting" or drilling methods with a drill diameter of 10 and 15 cm, root deformations were pre-programmed on larger ranges of plants.

- Planting quality
  Unsatisfactory results also were achieved with planting methods, with which a sufficiently large hole for the range of plants can actually be formed. The numerous root deformations could be traced back to an improper application of the methods. In two comparative areas (drilling method with drill diameter of 30 cm, deep ground loam, oak) the influence of the planting quality could be proven (Fig. 2).

---

[2] In that the diameters of all roots thicker than 2 mm were measured in the depth levels of 30, 60 and 90 cm and in the side section in 100 cm and summed up as root areas per depth level afterwards.

Fig. 2: Root deformations according to planting quality
(drilling method, comparable soil location conditions)

With correct planting extreme root deformations, which are so problematic for the stability, could then be avoided. In particular, compressions – as a clear indicator for a bad planting quality – rarely existed.

- Ranges of plant
  In general, smaller ranges showed significantly less root deformations than bigger ranges (oak was an exception). With increasing size of ranges, the development of the vertical root space decreased (Fig. 2), tap roots became more rare and shallow roots increased. Smaller ranges grew almost completely out of the original drilling hole, if they were planted by the drilling methods (no flower pot effect); by comparison, tall plants only grew by half or by two thirds out of the drilling hole.

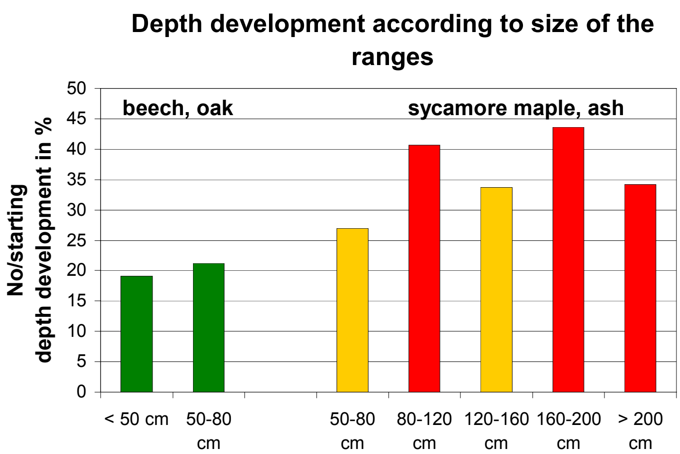

Fig. 3: Portions of roots without or with starting depth development of
10 year old deciduous trees, depending on size of range

- Soil location
  With natural regeneration/seeding, overwhelmingly the share of skeleton and to a lesser extent the water economy determined frequency and strength of the root deformations. With plantings, by contrast, the effect of the soil location for the frequency of deformations could not be proved (Fig. 4).

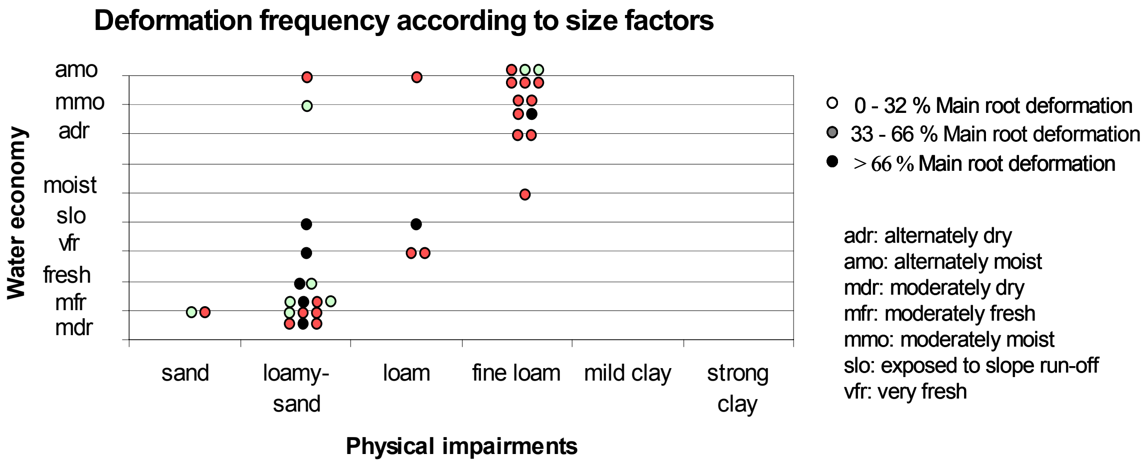

Fig. 4: Frequency of main root deformations of 10 year old, planted deciduous trees according to water economy and physical obstacles.

Only in extreme locations which lack suitability of the soil location for the tree species, the root development was additionally restricted.

- Tree species

  Root systems developed out of natural regeneration/seeding root systems, as described in the literature. However, the given values for the maximal root depth were not reached for any of the tree species.

  Upon planting, the effect of the tree species on frequency and strength of root deformations could not be proven. Only oak and beech had a regeneration potential, which was above average. Ash and sycamore maple showed above-average, strong root deformations and a minimal regeneration potential. The causes lay less in the tree species than in the ranges of plants and planting methods, which were used.

- Root pruning:

  One year after planting, root pruning was recognized in 97 % of the plants, 9 years later in 10 %. With an above-average frequency (in 25% of the plants after 10 years), the root pruning could be determined with ash and with all other species greater than 120 cm.

Summary of the influence factors:
With the plantings, the “natural influence factors” (tree species, soil location) are superceded by human influences (planting methods, planting method, ranges of plant, root pruning). An improper planting leads to numerous and strong root deformations.

Effects of root deformations

Root deformations have a long-lasting effect on the anchoring ability of the trees. With increasing strength of deformation, the maximum vertical root development (Fig. 5), the vertical development of the root space and the parts of depth-oriented root systems (tap root and heart root systems) of 10 year old planted deciduous trees decreased. This led to a clear leveling out of the entire root system.

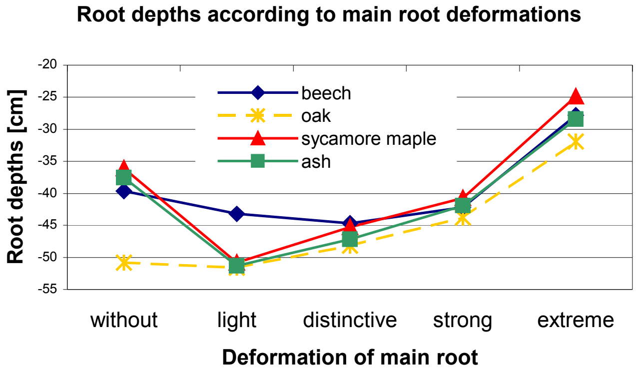

Fig. 5: Maximum root depth of 10 year old planted beech, oak, ash, sycamore maple with increasing strength of main root deformations

A regeneration of the root deformations could be seen only to some extent. During the examination period of 10 years, the frequency of the deformations on the planted deciduous trees decreased only marginally.

On old trees, root deformations can be seen only, when they are extremely developed. Therefore long-lasting effects from an improper planting can be proven only with a comparison of natural regeneration and planting under comparable conditions.
30 to 40 year old spruces, which were planted by the “angle method”, rooted significantly more shallow (19-35 cm) than the natural regeneration, had (highly) significantly smaller root areas in 60 and 90 cm depth and clearly had more frequently shallow or shallow-sinker root systems.

Fig. 6: 32year old spruce „angle planting; light depth development, shallow root system;

Fig. 7: 32year old spruce natural regeneration; good root depth, many strong roots in depth;

32 year old Douglas firs, which were planted with the “angle method”, grew significantly more shallow (11 cm) than the natural regeneration and no longer had tap roots. The following consequences can be derived therefrom (according to Nielsen 1990, Coutts 1983 a, b, Polomski and Kuhn 2001):

- The wind powers, which work on the stem, must be encountered and evened out on the planted trees trough a smaller root bale;
- On smaller root bales, the anchoring contribution is minimized through the root bale (the so called root bale component, composed of cohesion, strength of movement and weight of the root bale);

- Decreasing diameters of the side roots decrease the size of the root lever. This leads to a smaller effective anchoring ability of the root bale and of the roots on this windward side;
- Through a smaller amount and strength of the side roots beyond the root bale, the strength of traction on the wind-ward side of the tree is reduced;
- The shallow root systems on the surface direct the storm forces towards the external, weaker side of the root areas. Therefore they have a smaller resistance than tap or heart roots, which direct the wind burden through their vertical roots deep down into the earth.

One cannot expect, that the differences between the 30 to 40 year old plantings and the natural regeneration will correct itself in the following years to a relevant extent. According to RACHTEJENKO (1952 in KÖSTLER et al. 1968), the vertical root system of spruce in higher age admittedly thickens through the development of more sinker roots, but with 30 to 40 years the entire depth will be essentially reached later. Similar information is found at POLOMSKI and KUHN (2001).

Therefore, the decreased depth development of planted trees can admittedly be improved through an intensive new formation of sinker roots, but a complete regeneration can not be expected.

Summary of the effects of root deformations:
All in all the fundamental components for the anchoring ability of the roots at the examined planted trees were reduced. One can then expect a long-lasting reduced anchorage in the soil.

Avoidance of root deformation

The vertical root development, which is primarily responsible for the stability of a tree, cannot be seen above the ground. Non-deformed and extremely deformed sycamore maples and ashes demonstrated significantly, while beeches and oaks had lightly lower shoot heights. Therefore, an active support of well rooted trees during the pruning is just as improbable as to hew out trees with strong to extreme root deformations. Hence root deformations can only be avoided directly upon the formation of stands:

- **Establishment methods:**
  - Where possible, prefer natural regeneration or seeding to planting.
  - Choose planting methods in accordance to root size.
- **Ranges of plant:**
  - Use small ranges of plant.
  - Use high-quality plants.
- **Planting quality:**
  - Use planting methods properly.
  - Plant carefully.
  - Cut roots moderately and correctly.
  - Optimize the quality management for the planting: among other things by intensive training, controlling, regular root digging.
  - Avoid pressure of time through enough buffer time.

References

A substantial list of references can be requested from the author.

More detailed information about the effects of root deformations as well as measures to avoid them can be obtained in the newly issued LWF-report No. 37, “Planting – a risk for the stand stability?”, as well as in the leaflets No. 4 “It depends on the roots!“ and No. 4a “Care decides about planting success!“.