



PROCEEDINGS

**International Conference
"Beech silviculture in Europe's largest beech country"**

IUFRO WP 1.01.07 Ecology and silviculture of beech

4-8 September 2006, Poiana Braşov, Romania



Forrest & Landscape Denmark



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DROUGHT AND BEECH SILVICULTURE - WHAT WILL BE THE RELEVANT REGENERATION STRATEGIES AND TECHNIQUES?

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Introduction

European beech (*Fagus sylvatica* L.) is one of the main tree species in the ongoing conversions of coniferous plantations to deciduous forests, since beech dominates the potential natural vegetation (PNV) in large parts of Central Europe. However, the reputed drought sensitivity of beech has led to discussions about the growth and regeneration of beech on dryer sites in southern Germany in the context of climate change predictions (Rennenberg et al. 2004, Ammer et al. 2005).

Summer 2003 was one of the warmest and driest periods in Central Europe for almost 100 years. The air temperature between June and August was anomalous, deviating from the 30 year average (1961-1990) by +5°C (Schär et al. 2004). In northeastern Central Europe (north-eastern Germany and western Poland) a deficit in precipitation of 180 mm resulted from the 2003 drought. In this year the precipitation rate amounted to 440 mm p. a. only (Rudolf 2004).

In eight pure and mixed European beech forests in northeastern Central Europe the growth response of natural beech regeneration during the 2003 summer drought and the additional effects of shading was investigated. According to the results, adequate strategies for the natural regeneration of beech forest under conditions of frequent drought events are discussed.

Materials and Methods

The selected stands, comprising four to six year old natural beech regeneration situated on sites with similar sandy soils, spanned a 600 km geographic gradient from Northeast Germany to Northeast Poland (Masuria).

During the extended drought period from end of July to mid August 2003, the water status of beech regeneration was assessed by measuring the predawn potential (ψ_{PD}) of 17 to 22 randomly selected saplings with a Scholander pressure chamber (Scholander et al. 1965). All stands were then classified into class (1) without water stress ($\psi_{PD} > -0.4$ MPa), class (2) with moderate water stress ($\psi_{PD} - 0.4$ MPa to -0.8 MPa) or class (3) with high water stress ($\psi_{PD} < -0.8$ MPa, Czajkowski et al. 2005). Inventories of natural regeneration took place on permanently marked plots 0.12 ha to 0.25 ha in area. On six to eight subplots (20m² area), up to 20 beech saplings were labeled and total aerial shoot length, root collar diameter, and terminal shoot length were recorded. A second inventory in September 2004 enabled relative length and diameter increment in 2003 and 2004 to be calculated in relation to plant size at the beginning of the growth period.

Hemispherical photography was used to consider additional effects of below-canopy irradiance on plant performance by deriving the diffuse site factor (DIFFSF) of each subplot (Wagner 1994).

Results and discussion

Results showed that plant water status during July and August 2003 had a considerable effect on the relative increment of saplings during 2003 and 2004. Increased water stress, indicated by decreased predawn plant potential, correlated to lower relative length and diameter increment (Figure 1). A carry-over effect of the summer drought on beech sapling performance was evident as a decrease in relative growth was observed during the 2004 wet growing season compared to sapling growth during the 2003 drought year.

An analysis of covariance (ANCOVA) identified both water stress and diffuse site factor (DIFFSF) as parameters affecting relative growth increment of the saplings (Table 1). Water stress had a stronger effect on plant performance than shading. However influence of canopy stress was more evident when water stress was increased. For the relative length increment in 2004, climatic water shortage and diffuse site factor (DIFFSF) were found to have an interactive effect. The latter may reflect the impact of soil resource depletion in addition to the impact of shelterwood competition on regeneration performance by limiting light availability. In addition, the limited ability of shaded beech regeneration to adapt to water stress can also play a role. This may be due to the lower osmotic potential and lower root/shoot ratios of these plants (cf. Eschrich et al., 1989, Löf et al. 2005). The lower adaptation potential of shaded beech exacerbates the impact of competition from the overstorey (Aranda et al. 2001).

The predicted increase in summer drought events in Central Europe suggest that an optimization of soil water resource management in future silvicultural planning will be crucial for successful beech stand regeneration. In this context, a marked reduction in canopy after the successful establishment of young beech plants will reduce the risk of water stress, provided competition from ground vegetation is controlled. Irregular shelterwood systems creating gap openings with an initial area of up to 20 meters in diameter will provide those conditions, particularly in gap centers.

Figure 1: Relationships between plot means of predawn potentials and relative increment of the natural beech regeneration (RL): relative length increment, RL_L: relative increment of root collar diameter).

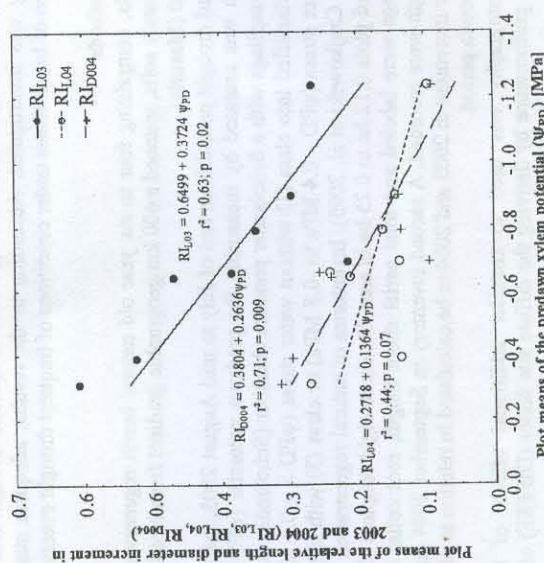


Table 1: Analysis of Covariance (ANCOVA), univariate tests using relative increment parameter (Type III decomposition, models with highest coefficients of determination); RL₀₃: relative length increment 2003, RL₀₄: relative length increment 2004, RL_{D004}: relative increment of root collar diameter 2004; SQ: sum of squares, MQ: mean of squares.

	FG	SQ	MQ	F	P
RL₀₃ (r² = 0.45)					
Water stress class	2	0.674104	0.337052	18.2	<0.01
DIFFSF	1	0.120818	0.120818	6.5	<0.05
Error	55	1.020502	0.018555		
Total	58	1.840314			
RL₀₄ (r² = 0.41)					
Water stress class	2	0.128944	0.064472	10.5	<0.01
DIFFSF*water stress class	3	0.126513	0.042171	6.8	<0.01
Error	53	0.326543	0.006161		
Total	58	0.555955			
RL_{D004} (r² = 0.46)					
Water stress class	2	0.225830	0.112915	18.4	<0.01
DIFFSF	1	0.060702	0.060702	9.9	<0.01
Error	55	0.337438	0.006135		
Total	58	0.632050			

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SHADE TOLERANCE OF SAPPLINGS OF BEECH IN COMPARISON WITH MAPLE AND ASH

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Introduction

Since long German forestry is aiming at mixed species stands. This is reinforced by the change of the silvicultural paradigm to close-to-nature silviculture and at the same time impeded by the principles of continuous cover forestry involved with the former (Lüpke 2004). This is particularly true in beech (*Fagus sylvatica* L.) stands. Beech is well known as a very shade tolerant and heavy shade casting species. Both features contribute to high competitiveness resulting in pure beech stands on many sites. However, the need to mix in other species gained increasing importance the last decade. Besides the above mentioned more philosophical aspects additional reasons turned up: a) Climate change threatens the stability even of beech stands which are regarded as very stable ecosystems up to now. Mixed species of deviant ecological characteristics can enhance stand stability by distributing the risks of climate change (Petercord 1999). b) Many mixed species produce particularly valuable timber and grow naturally in early successional stages where beech is lacking or rare. In late successional beech stands they are competitively inferior. On nutrient rich sites, maple (*Acer pseudoplatanus* L.) and ash (*Fraxinus excelsior* L.) are the most important species of this category.

Pursuing the continuous cover concept, a forester typically has to grow a mixed regeneration of beech, maple and ash underneath a dense beech overstorey for many years. This is a new situation. In the past, the beech overstorey normally was removed within 10-15 years after having started the regeneration. This provided sufficient light to ensure an initial height lead of maple and ash over beech. In the new situation, the outcome is not foreseeable. In order to mitigate this uncertainty we carried out an investigation on shade tolerance of beech, maple and ash saplings under such conditions. We concentrate on height and diameter growth under low light because we regard these as decisive features for successful survival, or with other words, for shade tolerance.

Materials and Methods

The study area is located in the Göttingen Forest on two sites with rich nutrient supply, differing in water balance: 1) "Hünstollen" on shallow limestone plateau with rendzina and terra fusca soil, frequently with poor water supply during dry periods in summer. 2) "Hengstberg" on clayey downslope with deep terra fusca or cambisol/pelosol with constantly fairly good water supply. The altitude ranges from 301-400m, the mean annual rainfall is 680 mm (340 mm in the growing season) and the average annual temperature is 7,8°C. Shelterwoods of beech with few maple and ash trees, approximately 120 years old and with heterogeneous canopy densities cover both sites. 20-30 years ago natural regeneration started. Today it forms a dense thicket comprising maple, ash and beech as major species, underneath a fairly dense shelterwood.

Tree growth and light data were recorded within circular plots of 2,5 m², evenly distributed on both study stands and covering the whole range of canopy densities. From these plots saplings of the three species were stratified in three tree classes - dominant, codominant and suppressed - and equal numbers of each stratum were randomly selected as samples (in total 192 saplings at Hünstollen and 236 at Hengstberg). For every sapling, the following data were

recorded: light intensity at the uppermost leaves by hemispherical fotos, total height, length of the last five annual terminal shoot increments and diameter at 10 cm above ground. After cutting the saplings, a stem disc was taken from 10 cm above ground for determining age and annual ring width for the last 10 years. As a measure of light intensity we used the indirect site factor (ISF, in % of above canopy light), and grouped the values in three light classes.

Results and Discussion

All the sample trees were about the same mean age (Tab. 1). Differences between sites and light classes were not significant. Beech was on the average with 16 years two years older than maple and three years older than ash. The minimal age ranged from 5 years for ash to 8 years for beech, the maximal age from 18 for ash and 25 for beech. From these values, a time window of 20 years for the natural regeneration on both sites can be derived. Regeneration started with beech, followed 2-8 years later by maple and ash. The last seedlings established were ashes. Züge (1986) found a comparable age lead of beech over maple and ash in a similar natural regeneration on the same site.

Table 1: Number, size and age of the sample saplings, grouped by study site, species and light class.

Species	Light classes	n	Indirect Site Factor (% full sun)	Diameter (mm)	Height (cm)	Age
Hünstollen n=192						
Beech	3-9,9%	26	7,7 (3,5-9,9)	8,8 (4,0-19,0)	142,2 (67,0-288,0)	15 (8-21)
	10-16,9%	25	13,8 (10,0-16,9)	17,3 (8,0-32,0)	278,9 (143,0-490,0)	18 (12-24)
	17-24%	19	18,6 (17,0-22,3)	26,4 (10,0-48,0)	381,9 (150,0-632,0)	17 (13-24)
Maple	3-9,9%	23	12,7 (3,6-22,6)	16,5 (4,0-48,0)	254,3 (67,0-632,0)	17 (8-24)
	10-16,9%	26	13,4 (10,0-16,4)	15,4 (6,0-29,0)	152,6 (86,0-307,0)	12 (7-17)
	17-24%	24	18,9 (17,0-23,7)	28,3 (13,0-54,0)	420,4 (222,0-579,0)	16 (12-21)
Ash	3-9,9%	23	7,4 (3,9-9,7)	17,9 (6,0-54,0)	276,5 (86,0-579,0)	15 (7-21)
	10-16,9%	21	12,9 (10,0-16,5)	12,0 (5,0-18,0)	131,3 (75,0-228,0)	13 (8-20)
	17-24%	6	19,3 (17,2-20,5)	17,3 (11,0-23,0)	233,9 (109,0-395,0)	14 (5-21)
Hengstberg n=236						
Beech	3-9,9%	27	6 (3,2-9,9)	7,4 (4,5-14,0)	123,6 (76,0-290,0)	14 (9-25)
	10-16,9%	29	12,8 (10,3-16,5)	16,0 (9,0-41,5)	263,8 (142,0-513,0)	16 (11-24)
	17-33%	28	20,8 (17,2-30,9)	34,6 (10,0-56,0)	436,7 (200,0-738,0)	18 (12-23)
Maple	3-9,9%	84	13,3 (3,2-30,9)	19,5 (4,5-56,0)	276,4 (76,0-738,0)	16 (9-25)
	10-16,9%	27	6,3 (3,9-9,4)	8,6 (5,0-11,0)	141,8 (90,0-446,0)	12 (6-20)
	17-33%	29	20,9 (17,1-30,8)	37,9 (17,0-61,0)	487,6 (206,0-707,0)	16 (8-21)
Ash	3-9,9%	81	13,6 (3,9-30,8)	21,4 (5,0-61,0)	308,6 (90,0-707,0)	14 (5-21)
	10-16,9%	29	6,0 (3,3-8,7)	7,6 (4,0-12,5)	129,9 (50,0-320,0)	12 (5-19)
	17-33%	17	22,6 (17,3-31,2)	30,1 (16,8-42,0)	491,2 (312,0-700,0)	13 (9-18)
Hengstberg n=236						
Beech	3-9,9%	71	12,5 (3,3-31,2)	16,5 (4,0-43,0)	276,9 (50,0-700,0)	13 (5-23)

For the following analysis, it is important that mean ages of the light classes did not differentiate significantly. However, there is a clear tendency of being more younger saplings in the low light class (3-9,9 % of above canopy light), most of them forming the understorey of the thicket. But differences between the medium and high light classes (10-16,9 % compared with 17-24 respectively 33 % of above canopy light) were negligible.

Annual terminal shoot growth, averaged over the last 5 years, of all three species rose with light (Fig. 1). Significant differences between beech and maple/ash occurred only in the high light class, with beech showing 35 (Hünstollen), respectively 43 cm (Hengstberg), and maple/ash about 37 % (Hünstollen), respectively 40 % (Hengstberg) more. Maple and ash showed no difference among themselves under the whole range of light conditions. All species reached larger height increments at the study site Hengstberg, presumably because of better water supply. But in deep shade (3-9.9 % of above canopy light) there was no significant difference, with all species growing about 10 cm annually. Light was the only limiting factor, without interacting with other growth factors like e.g. water supply.

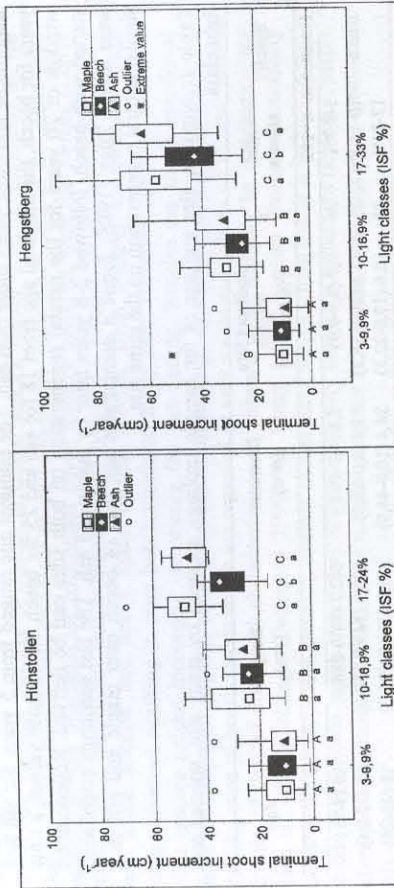


Figure 1: Annual terminal shoot increment as average over the last 5 years for light classes and tree species. The significant differences between species within light classes are marked by lower case letters and those between light classes within each species by capitals (Mann-Whitney-U-Test $p < 0.05$).

Annual radial increment, also averaged over 5 years, showed more or less the same picture, with one exception: even in the high light class beech was not inferior to maple and ash. No significant species differences could be detected. The rise of annual increment with increasing light was more pronounced with radial than with height growth. Whereas radial increment gained 4.2 fold (Hünstollen), respectively 6.0 fold (Hengstberg) from low light to high light class (as a mean of all three species), the respective values for height growth (3.3 and 5.4) were smaller. As observed in previous studies (Pacala et al. 1994, Lin et al. 2002, Gratzler et al. 2004) the more shade-tolerant species (i.e., beech) have less height growth at high light levels than less shade-tolerant species (i.e., ash and maple). However, unlike to their findings, in our study beech did not exhibit higher growth in deep shade.

The course of the annual diameter increment over the last 10 years is exemplarily shown in figure 2 for beech at Hünstollen. The steep rise from 2000 to 2001 and the subsequent fall to 2002 are conspicuous, particularly pronounced in the high and medium light class, but still detectable in low light. The other two species and the second site Hengstberg showed more or less the same increase, but the subsequent fall was much weaker, or missing as in the case of maple. We assume the reason for the increase being a cutting and opening up of the shelterwood in winter 2000/2001, while the dry season in 2003 and a mass outbreak of the louse *Cryptococcus fagisuga* in summer 2004 might explain the fall with beech in Hünstollen. The reaction of maple and ash can be interpreted as less sensitivity to drought. Contrary to diameter growth, height growth increased one year later after opening the canopy, what is similar to the results of Collet et al. (2001). With this lag, it showed the same pattern during the following years.

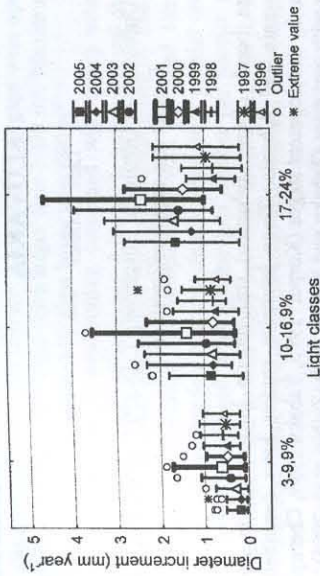


Figure 2: Annual diameter increment for the last 10 years for beech at Hünstollen.

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STAND STRUCTURE AND GAPS OF VIRGIN BEECH FORESTS IN SLOVAKIA

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Introduction

Virgin forests with pure beech (*Fagus sylvatica*) still remain in reserves in Romania, Ukraine, Slovakia, Slovenia and Albania. Three intensive studies have described stand structure in these reserves by development stages (Korpeš 1995, Tabaku 1999, Chernyavskyy 2005). Two studies dealt with gap sizes (Tabaku and Meyer 1999, Zeibig et al. 2005). Here a further study is presented, conducted in two forest reserves in eastern Slovakia.

The aim of the study is to describe the natural disturbance regime. It will be assessed by the proportion of gap area in the forest and gap size frequencies.

Gaps might be also considered as the first development stage in the forest. The second aim of this study is to describe the further stand development. The sizes of further stages are determined by the number of neighbouring trees belonging to a stage defining dbh class.

Materials and Methods

Both reserves are located in eastern Slovakia. The Havešová Reserve has very good growth conditions for beech: stand height is 45 m. The south slope is 10° on average. The Kyjov Reserve also has good growth conditions: stand height is 30 m. The northeast slope is 10°.

Both sites are described in detail by Drößler and Lüpke (2006a).

A gap is defined as interruption of the canopy in the upper stand layer (Havešová: 30-45 m, Kyjov: 20-30 m). According to height curves, a tree growing into the upper stratum has a DBH of approximately 30 cm at Havešová and 20 cm at Kyjov. These DBH values were used to distinguish between gaps with regeneration and closed forest. In addition 7 cm DBH were also used as distinction, because stand structural analysis is based on trees with DBH \geq 7 cm. Gaps were recorded by line transect sampling according to Runkle (1992). In each gap the number of dead canopy trees (gap makers, visible up to ~40 years after tree fall) was determined. Gap frequencies were corrected according to selection probability of differently sized gaps. More detailed information given in Drößler and Lüpke (2005).

To describe stand structure on 20 plots, 0.4 ha each, live trees (minimum 7 cm DBH) were recorded and coordinates determined. Additionally tree height and crown radius were measured for 60 trees per reserve to determine correlations with DBH. Thus a tree distribution map with circular crowns could be drawn for each plot. The next step was a grouping of trees of similar size: All trees were assigned to diameter classes, which were trees between 7-20 cm (initial stage), 21-40 cm (early), 41-60 cm (medium) and 61-100 cm (late optimum). The number of trees in each DBH class with crown contact was determined. Thus the crown radius provided a boundary limit in defining neighbouring and non-neighbouring trees. The frequency of single trees and differently sized tree groups was then derived.

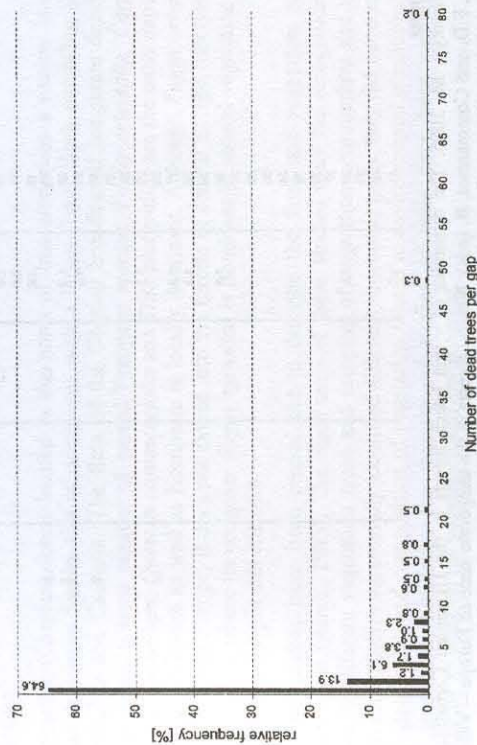
Results and Discussion

Gaps: Gaps comprised 15% of the forest area. Half the area of gaps was covered by trees with 7 cm or greater DBH. In both reserves the gap size distribution was very similar: 2/3 of gaps were formed by single tree fall. 25% of gaps were formed by 2-4 trees and 9% of gaps by 5-10 trees (Figure 1). Only 1/5 of dead trees formed a new gap, while 4/5 extended a gap.

The number of gaps decreased exponentially with increasing gap size. More than 85 % of the canopy gaps were smaller than 250 m². Around 10 % of gaps were openings between 250 and 1000 m², and 1-3 % of the gaps were larger than 1000 m². Maximum gap size was 0.4 ha. Half of gap area was comprised by gaps larger than 600 m².

The results suggest single tree cutting combined with group selection seems to be the appropriate harvesting method in managed forests to imitate natural disturbances very closely. Unfortunately, gap number per hectare can not be determined by line transect sampling. This number would be interesting for comparisons with managed forests (e.g. shelter wood cutting). Digital height models of forest stands, generated by aerial photographs and elevation height models, can be used to determine gap number per hectare (Nuske and Nieschulze 2004). This method and around 5000 ha virgin beech forests in Romania offer a promising opportunity to investigate gaps on a larger scale and with less effort than terrestrial surveys.

Figure 1: Frequency of gaps in Kyjov in relation to the number of dead trees per gap.



Stand structure: Projected on 10 ha 269 single trees and 93 groups with 2 trees occurred in the first DBH class in Kyjov (Table 1). In both reserves the frequency of tree groups was very similar. In each DBH class single trees dominated with exponentially decreasing number of groups with increasing group size. The largest tree group in the late optimum stage consisted of 22 trees with an area of ~0.2 ha. But maximum size is limited by the edge of 0.4 ha sample plots. Nevertheless the clear relationship between group size and group frequency was also observed for other DBH class divisions done by Drößler and Lüpke (2006b). They determined similar tree group frequencies on a 13 ha plot in Kyjov. Differences with managed forests were shown and the method recommended to assess close-to-nature structure silviculturally.

Table 1: Number of tree groups with trees of similar size in Kyjov (projected on 10 ha).

Number of trees per group	DBH class/development stage			
	7-20 cm (initial stage)	21-40 cm (early optimum stage)	41-60 cm (medium optimum stage)	61-100 cm (late optimum stage)
1	268.8	158.7	99.8	57.6
2	83.4	65.3	25.6	24.3
3	53.8	24.3	12.8	10.2
4	34.6	11.5	15.4	3.8
5	16.6	9.0	7.7	2.6
6	9.0	3.8	5.1	2.6
7	7.7	2.6		1.3
8	7.7	2.6		3.8
9	11.5	1.3	2.6	2.6
10	6.4	1.3	1.3	1.3
11	5.1	1.3	1.3	1.3
12	3.8			1.3
13	2.6	1.3		1.3
14	1.3	1.3		1.3
15	1.3	1.3		1.3
16	2.6	1.3		
17	2.6			
18	2.6			
19		1.3		1.3
20	1.3			1.3
21	1.3			
22				
23				
24	1.3			
25				
26				
27	1.3			
28	1.3			
29				
30	1.3			
31				
32				
33				
34				
35				
36				
37	1.3			
38				
39				
40				
41	1.3			

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RELATIONSHIPS BETWEEN BEECH TREE TYPES AND SOIL PROPERTIES IN THE FORESTS OF NORTH OF IRAN

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Introduction

The Hyrcanian (Caspian) forest located in the north of Iran comprises a narrow band of temperate deciduous forests that is contiguous with a larger forest block extending across eastern Turkey and Caucasia. The flora of the Caspian broadleaved temperate deciduous forest comprises a large number of central European species. *Fagus orientalis*, *Carpinus betulus*, *Acer velutinum*, *Quercus castaneaeifolia* and *Tilia platyphyllos* are the most important tree species and Beech as well as Hornbeam is locally dominant. Although *Fagus orientalis* occurs in southern Europe, it does not extend into the forests of central Europe described by Ellenberg (1988), where its congener *Fagus sylvatica* is dominant in natural vegetation on a wide range of soil types and climates.

Many recent studies have been carried out to describe the flora and vegetation of the Hyrcanian forest (Asadi, 1985). The main aims of these studies were the recognition and definition of different vegetation types and mapping of vegetation communities and types. Although these studies successfully identified different vegetation types, they did not consider how the distribution and composition of vegetation related to environmental conditions such as soil properties. Similarly, the majority of studies of soils have been carried out independently of work on the vegetation and environment.

The main aim of this research was to investigate the relationships between the distribution and composition of tree species, especially Beech trees in relation to soil properties in one district of the Hyrcanian forest.

Material and methods

The study site is the Kheirood-Kenar forest (51° 32' N, 36° 27' W) of the Caspian in northern Iran and classified as mountain forest with an altitudinal range from about 650 to 1400m a.s.l. The highest mean monthly temperatures of 29° C occur in June and July and the lowest of 7.1° C in February and the mean annual rainfall of 1354.5 mm.

325 rectangular square plots of 50 * 50m-(2500 m²) were chosen in the forest. On each plot, the diameter of all trees more than 7. 5-cm diameter at breast height were measured and identified. Slope, elevation and aspect were recorded for each plot. In order to select sites for soil sampling the forest was stratified into about 300 landform units based on differences in altitude, slope and aspect. In each landform unit, each tree plot was compared with its two nearest neighbour plots on the base of their species compositions using the Sorenson index. In this way, 85 sample plots were selected for soil profile from the original 325 tree plots.

Inside each selected plot, soil profile was dug, soil horizons were identified and characteristics of each horizon recorded. A soil sample was collected from each horizon of the profile and for all of the soil samples, the soil texture, soil pH, soil bulk density, total nitrogen, organic carbon and available phosphorus were identified.

Numerical and statistical analyses

Basal area for each tree species in all of the plots and the total basal area for all of the trees species within each plot were calculated. Two-way indicator species analyses (TWINSPAN) (Hill, 1976) method for classification and one-way ANOVA (Analysis Of Variance) method was also used to test differences amongst tree groups identified by TWINSPAN.

Soil variables and topographic factors comprising altitude, aspect and slope for all 85 soil samples, as well as total basal area were prepared in the form of matrices for the other multivariate analysis. Relationships between tree composition and measured environmental variables were examined in the output of DCA. For testing differences amongst soil properties and topographic variables in four tree groups, one-way ANOVA was also used. Correlation coefficients between environmental variables and relationships between these variables and tree groups resulted from ANOVA were calculated by Minitab program, version 13/1. For all of the above mentioned multivariate analysing "PC-ORD" program version 3.17 was also used.

Results and discussion

The results of TWINSPAN classification for the 325-tree sample plots identified four tree groups or tree types at the second level of division. At the first level of TWINSPAN high basal areas of *Fagus orientalis* and *Carpinus betulus* are the key features for the division. Tree groups A and B were dominated by *Carpinus betulus* and tree groups C and D by *Fagus orientalis*. *Acer cappadocicum* and *Quercus castaneaeifolia* were the other abundant tree species inside group A. The main tree species distinguishes group B from the other groups was *Alnus subcordata*. Inside group C, although there were several tree species, *Fagus orientalis* was the dominant species within this tree group. The abundance of *Fagus orientalis* is also high inside group D, but *Tilia platyphyllos* was the tree species, which distinguished this group from the other groups.

Distribution of tree samples on the DCA axes in the places, where soil sample were collected, showed distribution of *Fagus orientalis* and *Carpinus betulus* is in contrast to each other. The value of basal area of *Fagus orientalis* for the plots distributed on the left side of DCA diagram is significantly more than the plots which have been located on the right side of DCA diagram covered by distribution of *Carpinus betulus*.

Correlation coefficient between the environmental variables and two axes of DCA showed that percentage of organic carbon in A horizon ($r = -0.310$), C/N ratio in A horizon ($r = -0.319$), content of silt in B1 horizon ($r = -0.239$) and altitude ($r = -0.396$) had a significant relationship to the first axis of DCA. Content of clay ($r = -0.309$) and silt ($r = 0.320$) in B1 horizon had a significant relationship to the second axis of DCA. The direction of the arrows of C%, C/N ratio and altitude and correlation coefficient between these variables and the first axes of DCA show that these variables trend toward the left side of the first axis of DCA, where *Fagus orientalis* is dominant, and in contrast of the place where *Carpinus betulus* is dominant. These results identified that the content of C%, C/N ratio and altitude increase as basal area for *Fagus orientalis* increases amongst tree plots located on the left side of DCA diagram.

Fagus orientalis/*Carpinus betulus* gradient is the most important vegetation gradient in the site study. The distribution form of *Fagus orientalis* and *Carpinus betulus* along the forest stands is in contrary to each other, with *Carpinus betulus* being dominant in the forest stands located at low altitude and gradually replaced by *Fagus orientalis* at high altitude.

The results of different analyses in this study define except the altitude, percentage of organic carbon (C %) and carbon to nitrogen ratio (C/N) in A horizon was significantly correlated with the forest composition compared to other soil variables and they referred to organic materials and the rate of their decompositions. The results of the study demonstrated that by increasing of altitude, and increasing of domination of beech in the forest, content of these soil variable increases. The percentage of organic carbon and C/N ratio in the soil depends on decomposition of organic materials, then it is clear that the variations of these factors in the soil, which is affected by the altitude-induced climatic differences. Bonito et al. (2003) in their research in broad leaved forest in United State described mineralization of nitrogen significantly affected by altitude. On the other hand although many environmental factors affect the rate of litter decomposition, the rate of litter fall is remarkably uniform among tree species growing under similar soil and climatic conditions (Fisher & Binkley, 2000). In the comparison of leaf decomposition rates among different plant species identified that litter of *Carpinus betulus* was decomposed faster than *Fagus orientalis* (Cornelissen, 1996), so that the presence of beech in this study may augment the content of nitrogen and carbon in higher altitude. Overall there are complex relationships between tree compositions, altitude and soil organic matter in the study area, but it is clear that C/N ratio was directly related to altitude and C%.

Although the variations of altitude, C/N ratio and C% can explain the main gradient of tree composition (*Fagus*/*Carpinus* gradient), the results of ANOVA and DCA showed that the amount of silt is higher compared to clay content in the area covered by *Fagus orientalis*. In fact the results confirmed beech tree type placed in area by lighter soil texture classes compare to hornbeam tree type covered the areas by heavier soil texture classes.

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THE STRUCTURE AND DYNAMICS OF VIRGIN BEECH FOREST ECOSYSTEMS FROM "IZVOARELE NEREI" RESERVE - INITIAL RESULTS

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Introduction

The natural forest is the most complete and rich information source regarding the organization and functioning of the forest ecosystems. The forest ecosystems with a high degree of naturalness are an important reference point for forest management (Peterken, 1996).

Beech (*Fagus sylvatica* L.) natural forest ecosystems are of strategic importance for both European and Romanian forestry, due to the importance of beech forests in Europe (roughly 12 million ha), representing a large resource for both timber production, biodiversity conservation and environmental protection. The highest degree of naturalness is encountered in virgin beech forests (von Oheimb et al., 2005). These forests are situated in Central and South-eastern Europe, covering surfaces from a few hectares to a few hundred hectares (Leibundgut, 1993; Korpel, 1995; Bândiu, 1995; Tabaku, 2000). According to the 2001-2004 inventory, Romania has over 200000 ha of virgin forests, 40% of which are represented by pure and mixed beech mountain forests.

In the "Izvoarele Nerei" Scientific Reserve one of the largest European remnant virgin forests was preserved. It covers a surface of approximately 5000 ha of pure beech virgin forest in different developmental stages. This paper aims to give a general presentation of the characteristics of this unique forest: a highly diversified structure and its variation along 700 m altitudinal gradient, a nearly monospecific composition - dominated by beech with very few exemplars of fir and elm and sycamore, impressive trees dimensions (the largest trees having diameters over 1 m and heights over 50 m) and large standing volume (frequently over 1200 m³/ha).

Materials and Methods

The structure of the forest was investigated in ten permanent circular experimental plots of 1 ha each, randomly established at 4 altitudinal levels (800, 1000, 1200 and 1350 m). The vegetation layer was divided in the following study layers: standing trees, regeneration, herbaceous flora, and deadwood.

The spatial position (x, y, z), diameter (dbh), height (h), crown projection and crown length for all standing trees (dbh ≥ 8 cm, h ≥ 3 m) was measured. Additionally some qualitative characteristics were recorded: presence of forked or broken trees vitality (healthy, damaged or dead), bark characteristics, and presence of T fiber and frost damages.

All saplings (h < 2 m) and trees higher than 2 m, with the dbh < 8 cm where counted and considered "regeneration points". Areas covered with seedlings of approximately same age and height (3 height classes, 0 - 0.5 m, 0.5 - 1.3 m, > 1.3 m), dbh < 8 cm where measured as "regeneration polygons" (surface and description of seedlings - height, age and vitality).

The deadwood was measured and mapped. The height and dbh for standing deadwood (dbh ≥ 15 cm, h ≥ 1.3 m), the length and diameter at ends for fallen deadwood (logs and fallen parts of the trunk and branches with a diameter ≥ 15 cm and a length ≥ 3 m) where registered. Stumps

higher than 1.3 m where recorded when at a height of 20cm the diameter was ≥ 15 cm. The decomposition status was described (solid wood, partially rotten or rotten).

For each of the ten experimental plots specific regression equations where calculated in order to observe the correlation between dbh and height of the trees. The volume was calculated using the following regression equation:

$$\log v = a_0 + a_1 \log d + a_2 \log^2 d + a_3 \log h + a_4 \log^2 h$$

for beech the coefficients are:

a_0	a_1	a_2	a_3	a_4
-4,11122	1,30216	0,23636	1,26562	-0,07966

Results and Discussion

The mean density of living trees ≥ 8 cm dbh amounted to 387 ha⁻¹, from which more than half where healthy trees (244 ha⁻¹). The mean basal area amounted to 50,7 m²ha⁻¹, with a maximum of 57,8 m²ha⁻¹, with the following mean and maximum values for the healthy trees: 39,5 m²ha⁻¹ and respectively of 46,5 m²ha⁻¹. The average and maximum values for the standing volume where 831,0 m³ha⁻¹ and of 1139,8 m³ha⁻¹ respectively, with 697,6 m³ha⁻¹ and 986,8 m³ha⁻¹ values for the healthy trees. The diameters distribution curve has a typical reversed "J" shape, while the heights distribution curve has a bimodal form with a peak in the 5-10 m height class and a second larger one in the 25-30 m class. A strong correlation between diameters and heights was observed in all plots (a *p*-value between 0,85 and 0,95). Some of these important structural characteristics are present shortly in Table 1.

Table 1: Structural characteristics of trees (≥ 8 cm dbh) in the 10 permanent plots

Characteristic	Average
Healthy trees percentage	62,98
Average diameter (cm)	33,31
Maximum diameter (cm)	126,40
Average basal area - all trees (m ² ha ⁻¹)	50,70
Average basal area - healthy trees (m ² ha ⁻¹)	39,50
Average height (m)	21,58
Maximum height (m)	51,68
Average crown length (m)	12,39
Average crown projection (m ²)	33,38
Broken trees percentage	15,57
Average volume - all trees (m ³ ha ⁻¹)	831,0
Average volume - healthy trees (m ³ ha ⁻¹)	697,60

In the case of deadwood, a large variation between plots was observed, with a visible decrease of the volume at higher altitudes (Table 2).

As expected the regeneration layer was present in all plots, but only in those whit extended gaps, larger areas where covered by continuous regeneration polygons.

The observed structural characteristics of the Nera forest are comparable with those observed by Tabaku (2000) in the Albanian beech forests and Leibundgut (1993) in Serbia. The monospecific composition, higher structural diversity and higher volumes and tree dimensions reflect the optimum growing conditions found by the beech in the Nera reservation (Peters, 1992).

DIRECT SEEDING ON FORESTLAND AND THE INFLUENCE OF RODENT PREDATION ON BEECH NUTS

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Introduction

During artificial regeneration of beech (*Fagus sylvatica* L.) on forest land, the common practice is to plant 2–3-year-old bare-rooted seedlings at a stock density of about 2,500–5,000 per ha (Madsen and Löf 2005). Regeneration costs are high, and in southern Scandinavia, the costs may reach 7,000 Euro per ha even when the fencing is excluded. Therefore, the development of alternatives is needed. Direct seeding is an old method that has attracted renewed attention (Küssner and Wickel, 1998; Willoughby et al., 2003). The costs are lower compared to planting and may range between 750–2,000 Euro per ha all included except fencing. Something that means fifty per cent or less compared with the costs of conventional planting. However, predation by rodents on beech nuts is a major problem for regeneration (Armour 1963, Ashby 1959, Löf et al. 2004).

Little is known concerning silvicultural measures for improved direct seeding. The specific objectives of this study were to: (1) evaluate the effects of various timing of direct seeding, (2) evaluate the effects of the size of granivorous rodent populations on predation, and (3) with the assistance of camera surveillance try to find out exactly what species of animals that remove the seeds from the site.

Materials and Methods

The experiments were set up with four blocks (6×4,5 m²) at each of three sites (Söderåsen 1, Söderåsen 2 and Krageholm) in southernmost Sweden during May 2005. A randomized block design with two treatments in each block was used. The treatments were direct seeding of beech nuts in May and in June. Soil scarification was carried out manually in May using a planting spade. In the treatments there were two rows of seeds, with 30 seeding points in the rows. The beech nuts were sown two at each seeding point together with a piece of white paper, to make it easier to locate the seeds at the end of the season. The distance between the seeds in the row was 15 cm. All sites were fenced against larger herbivores.

The population sizes of rodents were determined before the direct seeding in May and in June. Rodent live traps (type Ugglan, 10 x 9 x 25 cm) were set out in grids of forty or forty-two traps at all sites. The distance between the traps was 15 m, and the traps were baited with oats, apple and hay. On both occasions the traps were out for two nights and the rodents caught the first night were marked and counted. The following night the marked animals caught were counted separately from the animals caught for the first time.

A digital camera (SB – 282CWH, Loke) with a motion detector and infrared light was set up in one block and site following the seeding in June.

Table 2: The volume of standing and fallen deadwood

Plot number	Total deadwood volume (cu.m)	Percent from the total deadwood volume (%)	Fallen deadwood		
			Standing deadwood (cu.m)	Solid wood (cu.m)	Partially rotten Rotten wood (cu.m)
102	62,7	6,9	18,9	6,2	12,4
103	46,4	5,8	14,0	0,2	23,2
104	79,4	9,0	17,4	24,5	17,4
110	79,2	7,2	16,2	5,1	14,3
112	104,5	8,6	29,2	0,0	0,0
114	108,7	11,7	31,3	0,0	0,0
116	105,6	10,5	30,3	0,0	0,0
118	50,4	7,8	17,6	0,0	0,0
119	52,9	7,2	9,9	6,7	3,7
120	53,6	8,6	21,6	3,5	2,1

At this stage of the research, a variation of the structure and dynamic of beech along altitudinal gradient forest can be observed. These patterns and the mechanisms behind the altitudinal variation will need further research.

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Results and Discussion

Four to five months after the direct seeding of beech nuts there were very few seeds remaining at the sites unharmed. Neither the percent of seeds remaining, nor the percent of seedlings established differed much between May and June on either site (Table 1). Rodent populations were generally larger later during the summer than in the spring (Pucek et al. 1993), why seeds could be expected to disappear at a higher rate in June than in May. On the other hand the availability of other food sources than sown seeds is greater in June than in May, which may explain the small difference between the two times of direct seeding. The difference between the percent of seeds remaining and the percent of seedlings established was mostly the result of nonviable seeds.

Table 1: Percent seeds remaining and seedlings established in October following seeding in May and June at three sites in southern Sweden. Mean \pm SE

	Södersåsen 1		Södersåsen 2		Krageholm	
	May	June	May	June	May	June
Remaining seeds, %	9.6 \pm 2.8	14.2 \pm 9.3	6.7 \pm 2.7	7.1 \pm 3.9	3.3 \pm 1.2	3.3 \pm 1.2
Established seedlings, %	3.8 \pm 1.6	2.1 \pm 2.1	0.4 \pm 0.5	1.3 \pm 1.5	1.3 \pm 0.4	0

Another important factor for the disappearance of seeds was the size of the experiment. The blocks were not very large and there were not that many seeds sown in each treatment, which means that a few rodents easily could eat all the seeds. That was likely the reason why it was hard to see a relation between the number of rodents caught (Table 2) and the disappearance of seeds (Table 1).

To make a good estimate of rodent population size with the mark-recapture method a rather large number of individuals need to be recaptured during the second trapping night. Since that was not the case in this study, the occurrence of rodents is presented as total number of individuals caught on each trapping occasion instead of as individuals per hectare (Table 2).

The most common rodent species on all three sites and on both trapping occasions was the bank vole (*Clethrionomys glareolus* Schreber) (Table 2). Other species caught were yellow-necked mouse (*Apodemus flavicollis* Melchior) and wood mouse (*Apodemus sylvaticus* L.). The total number of rodents caught was largest at Södersåsen 2 on both trapping occasions (Table 2), but the percent of seeds remaining was not the lowest at this location (Table 1). As discussed above that might be due to the small size of the experiment.

Table 2: Number of trapped individuals of mice and voles at three sites and two times divided by species.

Species	Södersåsen 1		Södersåsen 2		Krageholm	
	May	June	May	June	May	June
<i>Clethrionomys glareolus</i>	2	13	14	19	6	10
<i>Apodemus flavicollis</i>	1	7	1	4	0	0
<i>Apodemus sylvaticus</i>	2	5	8	4	0	2
Total	5	25	23	27	6	12

Another explanation for the nonexistent correlation between the number of rodents caught and the disappearance of seeds would be that the seeds were removed by some other animal than mice and voles. Birds are for example known to eat a lot of beech nuts (Watt 1919). To get an idea if that could be the case the camera was set up to monitor the rows of seeded beech nuts.

Since the infrared light unfortunately was not strong enough the pictures taken during the night were all black, and during the day no animal was seen eating from the beech nuts.

Two things that could be determined due to the camera were that the seeds disappeared during the dark hours, and that they, to a large extent, disappeared almost immediately after the seeding. The white paper that was buried together with the seeds made it possible to see on the photographs if the holes where the seeds were put had been dug up. The last picture taken in daylight on the day of sowing showed no pieces of paper on the ground, but the first picture taken the morning after revealed that practically all seeds had been removed from their initial position since a lot of white paper pieces were laying on the soil surface.

Birds for example mostly seek for food with their eyes, while rodents use their olfaction (Vander Wall 1998). This enhances the belief that the seeds were taken by rodents since animals looking for food with their eyes would not find the buried beech nuts. Rodents are also known to be active during night, while seed-eating birds are often foraging during the day.

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COMPARISON OF PLANT SPECIES DIVERSITY OF DIFFERENT PLANT COMMUNITIES IN CASPIAN FORESTS, IRAN

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Introduction

Biodiversity is defined as the kinds and numbers of organism and their patterns of distribution (Barnes 1998). The focus of biodiversity measurement is typically the species and species diversity is one of the most important indices which is used for evaluating of ecosystems in different scales (Ardakani 2004).

Plant communities are defined as an assemblage of functionally similar species populations that occur together in time and space. Plant communities are separated from each other based on indicator species and each community has distinctive species composition. Therefore, plant species diversity would be different among the communities. The more diverse community, the more stable environment (Ardakani 2004).

The smallest share of wooden species and species diversity could be found both in spruce (*Picea abies*) and beech (*Fagus sylvatica*) forests. Oak (*Quercus robur*) forests show the richest species diversity (Hauk 2005). Hycranian vegetation zone is a green belt stretching over the northern slopes of Alborz mountain ranges and covers the southern coasts of Caspian Sea. The specific environmental conditions in this forests have been led to occurrence of different forest communities (Sagheb-Talebi 2004).

In order to practice silvicultural methods in different communities, we must learn about plant species diversity in them. This knowledge helps the forest manager to evaluate performed silvicultural treatments.

The aim of this study was firstly to recognize the forest communities in the study area, then identify and compare the plant species diversity in that forest communities.

Materials and Methods

This study was being carried out in the experimental forests of university of Tehran (located in northern Iran, total area ca. 7000 ha). These forests are natural deciduous hardwood forests which have been under low intensity management.

The study area was sampled by randomized-systematic method. Sample sites were located by overlaying a 200 x200-dot grid on a 1/10,000-scale topographic map of the study area. Potential sample sites occurred on the map at the intersection of a row and column selected from a table of random numbers.

Floristic sampling was made on a floristically homogeneous surface area of 400 m² sample which was identified according to the minimal area procedure. At each sample, floristic list and an estimate of percent cover abundance of each vascular plant (in the tree, shrub and ground layers separately) were being recorded with using of Braun-Blanquet scale (Mueller-Dombois 1974).

The vegetation data was analyzed using TWINSpan classification and complementary DCA analysis resulted in the recognition of different communities.

Species richness was calculated as the average number of species per sample. Shannon and Simpson indices were applied to quantify diversity and equitability of samples of different recognized communities.

A Tukey test was used to test whether there were significant differences in the species richness, diversity and evenness indices among the different communities.

Results and Discussion

152 samples were established and 104 species were recorded in the study area in different layers including 12 trees, 9 shrubs and 83 herbs.

Four communities including Querceto-Carpinetum betulii, Carpineto-Fagetum Orientalis, Rusco-Fagetum Orientalis and Fagetum Orientalis were recognized in the study area.

Table 1: Descriptive statistics of different diversity indices in the different communities

Indices	Community type	Number of Samples	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Species	Fagetum Orientalis	21	18.95 ^a	4.20	0.92	9.00	28.00
	Querceto-Carpinetum	30	27.97 ^b	6.80	1.24	16.00	39.00
Richness	Carpineto-Fagetum	59	27.00 ^b	5.42	0.71	16.00	38.00
	Rusco-Fagetum	37	22.19 ^a	6.92	1.14	10.00	36.00
Evenness	Fagetum Orientalis	21	0.64 ^a	0.12	0.03	0.30	0.84
	Querceto-Carpinetum	30	0.76 ^b	0.09	0.02	0.56	0.91
	Carpineto-Fagetum	59	0.71 ^b	0.07	0.01	0.48	0.83
	Rusco-Fagetum	37	0.65 ^a	0.10	0.02	0.36	0.80
Shannon	Fagetum Orientalis	21	1.86 ^a	0.41	0.09	0.86	2.62
	Querceto-Carpinetum	30	2.49 ^b	0.27	0.05	1.89	3.15
Simpson	Carpineto-Fagetum	59	2.32 ^b	0.24	0.03	1.63	2.74
	Rusco-Fagetum	37	1.96 ^a	0.44	0.07	0.94	2.74
Simpson	Fagetum Orientalis	21	0.70 ^a	0.14	0.03	0.32	0.89
	Querceto-Carpinetum	30	0.84 ^b	0.07	0.01	0.67	0.94
Simpson	Carpineto-Fagetum	59	0.84 ^b	0.06	0.01	0.57	0.91
	Rusco-Fagetum	37	0.74 ^a	0.13	0.02	0.37	0.91

* (a,b) Means followed by a different superscript (a, b) are significantly different at the 0.05 level.

According to Table 1, the highest level of all diversity indices belonged to Querceto-Carpinetum and the least level could be found in Fagetum oriental. Diversity indices of Carpineto-Fagetum were close to those of Querceto-Carpinetum while all Rusco-Fagetum indices were as less as Fagetum Orientalis communities. The mean differences between (Carpineto-Fagetum, Querceto-Carpinetum) and (Fagetum Oriental, Rusco-Fagetum) were significant in all diversity indices at the 0.05 level but there were no significant differences in the different indices between themselves.

The results illustrated that *Querceto-Carpinetum betulii*, *Carpineto-Fagetum communities* were significantly more diverse than *Rusco-Fagetum* and *Fagetum Orientalis communities*. Therefore, it is concluded that the plant diversity in mixed forest communities would be more than that of pure ones.

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A SURVEY ON CHANGES OF GROWING STOCK OF BEECH (*FAGUS ORIENTALIS*) NATURAL FOREST STAND AT ASALEM IN GUILAN PROVINCE

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Introduction

Stock volume of tree species in different sites is subjected to change. The level of changes depends on sites factors. Knowing the level of changes in different sites are very important to plan forest management and any other forestry plans (Asli & Etter, 1963). Knuchel(1950) divided the Swizerland beech forest sites into three groups of bad, medium and good sites. The combination of tree species in this area is different from the northern Iran. Growing stock in Swizerland beech forest sites was 500 sylve/ha in good sites, 350 and 250 sylve/ha in medium and bad sites respectively. Considering the changes of the stock volume in various sites, it is necessary to study the stock volume in different conditions and sites.

The objective of the present study is determination of ideal growing stock of beech (*Fagus orientalis*) in different sites. It seems that growing stock in natural forest stand does not vary significantly from ideal growing stock. In this study the untouched or slightly exploited natural forests were considered. The study area is Asalem which is situated in west of the Guilan province. In this area 10 sites were selected and studied.

Material and Method

The study area was beech (*Fagus orientalis*) natural forest stand at Asalem in the Guilan province, northern Iran. These sites were situated in 700-1700 meters above sea level. The mean annual rainfall and temperature in the Piceason climatology station (situated at 1244 meter above sea level) are 1286.5 mm and 8.5 °C (Sheikholeslami, 1998). On the base of Ambreget formula(Q2), climate of northern Iran at beech forest stand is very cold and wet. The mean temperature in the coldest month of the year is 8.1 °C and hottest month is 21 °C with very rainy summer. The climate of the studied area is Eurasiatic type (Assadollahi, 1987). Soil of the Asalem area are lying on the alkaline & acidic igneous bedrock(Habibi kaseb, 1984). The pH of these soils are 4.5 through 5.5 and sometimes accedes to 6. The textures of the soils are sandy-loam, silty-loam, clay-loam and sandy-clay-loam. These soil types are well drained. The forest stands in the studied sites include: pure fagus type(over 90% of fagus and other species including *Carpinus betulus*, *Acer velutinum*, *Acer cappadocicum* & *Sorbus torminalis*) and mixed fagus type including about 75% fagus together with *Carpinus betulus*, *Acer velutinum*, *Acer cappadocicum*, *Alnus sp.*, *Tilia begonifolia*, *Ceracus avium*, *Fraxinus excelsior* & *Sorbus torminalis* (Hassanzad Navroodi, 2000).

In this study the untouched or slightly exploited natural forests of the Asalem area were surveyed. The method of study was selective sampling(Zobeiry, 1994). In this area 10 sites and 3 plots in each site with area of one hectare(Korpel, 1982) located at different conditions were selected and the following parameters were studied: tree species, diameter at breast

height(DBH), trees height and stem quality analysis. The altitude from sea level, slope in percent and aspect were also determined.

Local Tarif Table of Chooka are used to calculate growing stock per hectare. In order to study the growing stock changes, stock volume per hectare were calculated for all species in each site separately. Stock volume per hectare in each site were also evaluated on the base of volume distribution at three diameter classes that are 15-30, 35-50 & >50 cm (Prodan, 1965). The sites with growing stock less than 300 sylve/ha, 300-400 sylve/ha, 400-500 sylve/ha & over 500 sylve/ha, were defined as poor, medium, good & very good growing stock, respectively. Significant differences between mean growing stock in studied sites were evaluated by ANOVA and multiple rang test.

Results and Discussion

Studies show that forest stands in this area are uneven aged high forest. Minimum altitude was 700 meter and maximum altitude was 1700 meter above sea level. In these sites, slope was 30-70% and aspect were western, north-western, northern, north-eastern and eastern. Soil depth was low through very deep. The mean number of trees, basal area and stock volume were 369 per ha, 37.7 m²/ha and 479 sylve/ha respectively. Minimum stock volume was 302 and maximum stock volume was 607.5 sylve per hectare. In order to display the growing stock statement, stock volume distribution per hectare in this area are shown in table 1 and stock volume mean in table 2. As shown in these tables, sites with high growing stock over 50% volume are concerned as high diameter classes. Similar pattern were observed in Switzerland sites (Knuchel, 1950). This shows that trees in productive sites have higher increment and reached higher sizes, but in poor sites, increment of trees were very low and trees did not reach higher diameter and height (Asli & Etter, 1963). However, differences of growing stock between poor and productive sites were very significant. Results of ANOVA and multiple rang test showed a significant difference between mean stock volume of 10 studied sites and those having north direction proved to be a very good growing stock (>500 sylve/ha). The sites with western, eastern and north-eastern aspect had a good growing stock (400-500 sylve/ha) and the north-eastern aspect had a moderate growing stock (300-400 sylve/ha). Soil depth exerted great impact on the growing stock. The influence of altitude from sea level had a significant influence on the growing stock in this area.

Table 1: Distribution of growing stock per hectare at different diameter breast height classes in studied sites

No. Sites	Diameter classes(cm)			Total sylve/ha
	Class 10 - 30 (sylve/ha)	Class 35 - 50 (sylve/ha)	Class > 50 (sylve/ha)	
1	45.6(10%)	100.6(22.1%)	308.5(67.9%)	454.5
2	99.4(25.2%)	192.9(49%)	101.7(25.8%)	394
3	32.8(5.9%)	75.3(13.5%)	448.4(80.6%)	556.5
4	35.2(6.6%)	61.5(11.5%)	438(81.9%)	534.7
5	73.5(16%)	107.9(23.4%)	279.1(60.6%)	460.5
6	54.8(12.1%)	80.1(17.8%)	316.1(70.1%)	451
7	74.3(24.6%)	118.7(39.3%)	109(36.1%)	302
8	67.7(15.5%)	123.3(28.1%)	247.4(56.4%)	438.4
9	33.9(5.6%)	108.3(17.8%)	465.3(76.6%)	607.5
10	20.3(3.4%)	50.5(8.6%)	520.1(88%)	590.9
Mean	55.8(11.2%)	101.9(21.3%)	323.3(67.5%)	479

Table 2: Mean of growing stock of species per hectare in studied sites

Species	Mean (sylve/ha)	Percentage (%)	Total (sylve/ha)	Percentage (%)
Fagus orientalis	394.8	(82.4%)	479	(100%)
Carpinus betulus	25.68	(5.4%)	1.04	(0.22%)
Acer velutinum	27.34	(5.7%)	1.72	(0.4%)
Acer capadocicum	7.16	(1.5%)	0.962	(0.2%)
Alnus sp.	12.06	(2.5%)	1.54	(0.3%)
Tilia begoniifolia	6.87	(1.4%)	0.87	(0.18%)
Ulmus glabra	1.54	(0.3%)	0.22%	(0.04%)
Cercus avium	0.962	(0.2%)	0.22%	(0.04%)
Sorbus torminalis	1.04	(0.22%)	0.22%	(0.04%)

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PATTERNS AND PROCESSES OF NATURAL REGENERATION IN UNMANAGED FORESTS

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Introduction

Roughly two main types of unmanaged forest can be distinguished in Europe: so called primeval or virgin forests which have (almost) never been managed and strict forest reserves (SFR), which are left to develop freely - in most cases after intensive human impact. In the nemoral zone of Europe true virgin forests amount to less than 0,1 % of the forested area (Blüking et al. 2000). Research in these remnants of Europe's original forests has increased in the last decades resulting in several compilations of the existing knowledge (e. g. Falitinski 1986, Korpel 1995, Peterken 1996, Vrška et al. 2002).

In contrast to primeval forests dynamics in SFRs are still governed by past management for a considerable time span (Meyer 2005). Therefore they can not be regarded as an "instant" substitute for missing virgin forests. Nevertheless they can show how nature works in absence of direct human impact.

In order to reduce input near to nature forestry aims at integrating natural processes into management concepts. Thus, the scientific interest in unmanaged forests is closely linked to its application in forest management.

Regenerating forests is one of the most cost-intensive measures in forestry. Therefore monitoring and analyzing patterns and processes of regeneration in unmanaged forests is of major interest for forestry research.

The presented paper deals with regeneration in unmanaged beech (*Fagus sylvatica* L.) forests in Europe. On the basis of results from SFRs in Lower Saxony, Germany and Albanian virgin beech forests the following hypothesis are addressed:

Typically, regeneration of unmanaged beech forests

1. is restricted to canopy gaps
2. is impeded significantly by several negative factors, e. g. disadvantageous soil conditions, competition of herbs and/or grasses or browsing
3. shows a broad-scaled spatial pattern.

Conclusions for forest management are drawn.

Materials and Methods

In order to analyze regeneration two indicators are applied. The sum of shoot lengths (= SSL; in m^{-2}) serves as indicator of regeneration biomass production. The probability of regeneration above 2 m height at a certain plot (= PADR) serves as indicator of regeneration success. SSL was applied in a comparative analysis of regeneration in two beech SFRs and Albanian beech virgin forests. The SFRs represent oligotrophic beech forests situated in the Solling mountains, Lower Saxony, Germany. They were set aside from management in 1972. Both SFRs are covered with almost pure beech stands. Underneath the even-aged overstory (age: 155 and 167 years) regeneration has developed after gap-formation caused by windfalls and stem breakages. On two monitoring plots in each SFR (sized 1.0 and 1.5 ha) dbh and tree positions of the stand ≥ 7 cm diameter were measured on three successive occasions from 1972 to 1999. Regeneration (trees < 7cm dbh, without seedlings < 1 year) was recorded per height-class on systematically distributed subplots at the last inventory.

For the Albanian virgin forests data on sample areas of 3.6 to 5.0 ha with a full survey of dbh and positions of trees ≥ 7 cm dbh carried out in 1997 are available (s. Tabaku 1999).

Regeneration (trees < 7cm dbh, without seedlings < 1 year) was sampled on a systematic grid network. The Albanian sample areas represent mesotrophic beech forests. They are assumed to be roughly comparable to Mid-European beech forests (Tabaku & Meyer 1999).

PADR was applied in 9 SFRs in Lower Saxony and the Albanian virgin forests. The true probability of regeneration > 2 m height in three basal area classes (low, medium and high basal area) was compared to the expected probability in case of a random distribution. Additionally a literature review was conducted in order to address the hypothesis in a generalized way.

Results and discussion

If regeneration is confined to gaps there should be a pronounced decrease of SSL with increasing basal area of the living stand. Thus basal area per ha was computed in circles with a radius of 10 m surrounding the regeneration sample plots. Subsequently values derived were classed into 4 ranks and the mean values of the 4 groups were related to mean SSL (Fig. 1). Whereas the range of SSL is comparable between SFRs and Albanian virgin forests, the relationship to overstory density differs considerably. Mean SSL shows a distinct decrease with increasing basal area in the SFRs. In the virgin forests either no clear relationship is detectable (Munella) or an optimum at fairly high densities is followed by a decreasing phase. Even at very high densities > 60 m^{-2} high levels of SSL are maintained in the virgin forest.

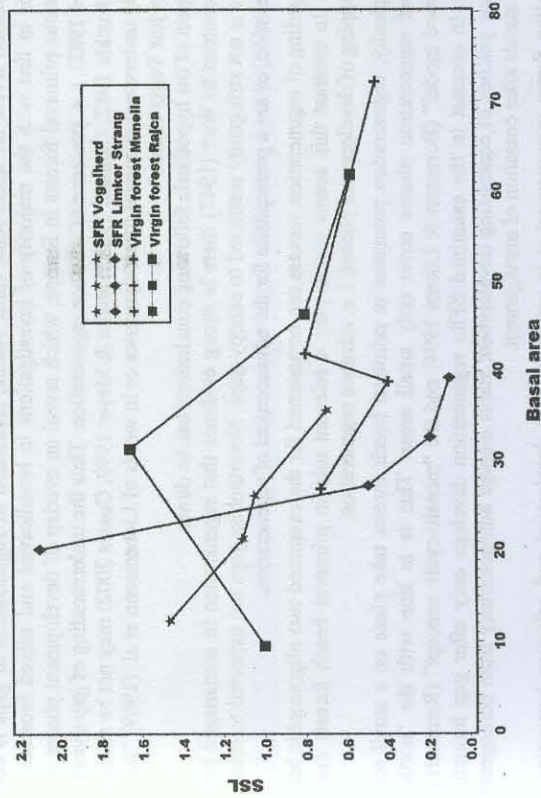


Figure 1: Mean sum of shoot lengths (SSL; $m m^{-2}$) in relation to small scale basal area ($m^2 ha^{-1}$) in strict forest reserves (SFR) of Lower Saxony and Albanian beech virgin forests. In the virgin forests regeneration (without seedlings < 1 year, mainly beech s. Tabaku 1999) was found at each sample point. Regeneration > 2 m height was recorded with a frequency of 67 % (Munella) to 79 % (Rejca). Hence, advance regeneration seems to be a typical feature of the examined beech virgin forests.

At much lower levels of basal area in the examined SFRs frequency of regeneration was found to be 61 % to 89 % and of regeneration > 2 m height 20 % to 59 %. Regeneration

developed after a wind storm in 1972 and was favored by ongoing disturbances thereafter (Meyer 2005). Maximum age indicates a lack phase of 5-10 years until regeneration started to develop (age determined by traces of bud scars).

30 years of free development of SFRs have led to regeneration processes clearly restricted to gaps. The probability of regeneration > 1,5 m height in gaps was recorded in the SFR "Limker Strang" in 2004. The investigation of 60 canopy gaps revealed a probability of 77 %.

Applying the indicator PADR to 9 SFRs in Lower Saxony yields results comparable with SSL. Regeneration success is significantly higher where stand density is low (Chi Square test statistic; results not shown here). However, this applies only to beech basal area. Admixed species like oak (*Quercus petraea* Matt., *Quercus robur* L.), maple (*Acer pseudoplatanus* L., *Acer platanoides* L.) or ash (*Fraxinus excelsior* L.) enhance regeneration success. In the Albanian virgin forests PADR shows a non-significant decrease with increasing basal area.

There is no doubt that basic ecological principles apply equally to all kinds of ecosystems, including primeval forests. Therefore regeneration should generally be affected by competition of overstory trees (e. g. Angestam et al. 2003).

In virgin forests this relationship may be masked by maturity- and age-effects. On the one hand competitive strength of overstory trees decreases with age. On the other hand a full development cycle with many seed years offers numerous opportunities for regeneration, especially in small-scaled textures with edge-effects between development phases. Furthermore regeneration of shade-tolerant beech can stand low radiation and high competition levels for quite some time. Hence, restriction of regeneration to gaps is eased. This is in line with the majority of investigations in broadleaved and mixed broadleaved-coniferous primeval forests in Europe, which reveal an overlap of development phases (e. g. Korpel 1982), i. e. presence of advance regeneration. Thus the understanding of gap dynamics (e. g. Runkle 1982, Canham 1988, Tabaku & Meyer 1999, Coates 2002) may not be sufficient to fully understand primeval forest dynamics or in words of Liebermann et al. (1989) "forests are not just Swiss cheese".

In respect of the hypothesis following conclusions can be drawn:

1. In contrast to Watt (1947) there is strong evidence that regeneration in unmanaged beech forests is not stringently restricted to canopy gaps. Nevertheless gaps are expected to enhance regeneration, or are a prerequisite for the advancement of regeneration.
2. Impeding of regeneration success can be assumed for the examined two oligotrophic beech SFRs. In contrast this seems not to play a relevant role in primeval beech forests due to overlapping of development phases, i. e. advance regeneration.
3. Typically, regeneration processes in primeval beech forests take place on a small scale. Distinct regeneration phases cover only small areas. This is in line with the "northern hardwood model" (Bormann & Likens 1994) and the "mosaic-cycle concept" (Remmert ed. 1991). In contrast in the examined SFRs regeneration develops only after gap formation. Separate patches of contrasting development status emerge autonomously from homogenous beech stands after cessation of management.

Regarding forest management it is concluded that decelerated and selective harvesting of canopy trees over as long periods of time as possible provides the highest probability for successful natural regeneration.

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THE EFFECT OF STAND DENSITY AND SOIL PREPARATION ON SEEDLING EMERGENCE AND EARLY GROWTH OF NATURAL REGENERATION OF BEECH

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Introduction

European beech (*Fagus sylvatica* L.) is one of the most important forest-forming species in Poland. It covers over 4% of total forest area, building valuable stands, particularly in the north, and in the mountain areas in the south of the country (Leśnictwo 2004).

The main factors determining the silvicultural quality of beech regeneration include: stand preparation for seed production and seeding, proper soil conditions allowing initiation of self-seeding and its development, light felling and, in the older age, improvement felling.

In the years 1976-1995, the Silviculture Department of the IBL carried out research aimed at the improvement of the adequate silvicultural methods to create optimum conditions for fruit bearing, seeding and germination, as well as growth and development of natural regeneration of beech stands.

The research included:

- determination of the impact of stand density on seed crop and on the emergence and growth of beech seedlings in the first years of life
- impact of soil preparation on the emergence and growth of natural regeneration

Material and methods

The research started in the year 1976. Four pure beech stands were selected, growing in similar habitat conditions (fresh forest) but differing in density (Table 1). The age of stands ranged from 95 to 130 years, and the experimental sites measured 0,75 hectare. Every site was divided into three 0,25 ha plots.

Table 1. Characteristics of experimental sites

Site No.	Trees per ha	Age	Density
1. (Gryfino)	304	123	1.08
2. (Gryfice)	136	120	0.80
3. (Ślawno)	95	130	0.72
4. (Golub Dobrzyń)	234	95	0.95

Tree location was determined on all plots. Every tree was measured for DBH, total height and length of crown and crown horizontal projection in eight directions, on the basis of which crown projection area was calculated. The insolated area of the crown was calculated according to the formula proposed by Assman (1968).

Soil was prepared prior to seeding, using the following tools:

1. LPz-75 Double-Furrow Plough
2. PTL-2 Disc Plough
3. PR-W Spreading Plough
4. Part of every experimental site was left with soil unprepared, as control.

The main plots were divided into 10m-wide strips on which, randomly selected, individual tools were applied.

Seed crop evaluation was carried out in every stand on the basis of 15 model trees selected from 3 plots. Seeds were collected from three (3m²) points under every tree and subjected to health and germination capacity evaluation.

The inventory of young natural regeneration was carried out in summer 1977 at measurement stations (1m² in size) in the number of 25 per plot. For the next 5 years, measurements were taken every year. They included: determination of the quantities and measurement of the height of self-seedlings. Data were collected for every soil preparation method to determine its impact on the growth and development of self-seedlings. The ($p=0.05$) variance analysis was used to analyze the measurement results.

Results

The research showed that the crown formation parameters had a positive effect on seed crop which oscillated between 1,475 kg of seeds per ha on Site No.3 with the lowest stand density and 709 kg/ha on Site No.4.

Soil preparation with tools prior to seeding produces several-fold regeneration effects in terms of seed germination and young natural regeneration, and assures competitive advantage for them over herbaceous plants in the first years of growth. The best regeneration results are obtained on the soil being ploughed and harrowed.

The research also showed the negative impact of stand density on the survival and growth of beech seedlings in the first five years of life.

The research results were the basis for formulating the principles of natural regeneration of beech in Poland.

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NATURAL REGENERATION OF BEECH (*Fagus sylvatica*, L.) IN THE VIRGIN FOREST LOM IN THE WEST PART OF THE REPUBLIC OF SRPSKA

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Introduction

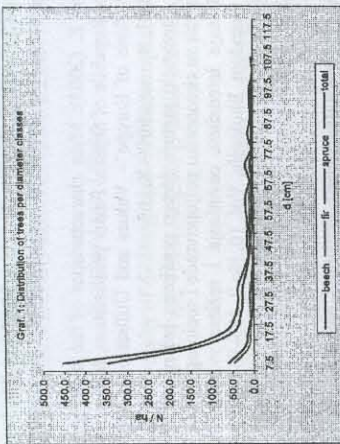
Virgin forest Lom (297.80 ha) is located in western part of Republic of Srpska. Beside well known virgin forest Perućica (1388 ha), and virgin forest Janj (295.00 ha), it is one of rear untouched natural forests in Republic of Srpska. Abundant of species and preservation of stands in virgin forest Lom are significant basis for research of natural regeneration of Beech tree (*Fagus sylvatica*) in mixed stands of Beech, Fir, and Spruce.

Materials and Methods

Virgin forest is located at 44°27' - 44°28' N, and 16°27' - 16°30' E, on mountain Klekovaca, and its ridge Lom. According to Thornthwait - Matter (1955) hydro bilans in researched area dominant climate is per humid - A (Ik = 287), and in vegetation period moderate - humid climate - B2 (Ik = 105.22). Average annual air temperature is 4.7°C, and in vegetation period 9.6°C. Annual participation is 1597 mm, and in vegetation period 746 mm. Data collection has been done on permanent research plot (P = 1.0 ha). Research plot is located on flat terrain, 1320 m above the sea level. Geology in researched stand is tear limestone, and shallow soils are dominant (kalkomelanosol, kalkokambisol) and combinations - mosaics with other soil series. Stand belong association group *Vaccinio - Piceion* Br. / Br.- Bl. (1938) 1939 and association *Piceo - Abieti - Fagetum* (Treg.1941) Čolić 1965. Emend. Gajić et al. Research plot is based on centre virgin forest in stand prest and woodland. On research plot one all trees measured diameter (taxation limits 5.0 cm) and thain hight. In all research plot that one taken two research plots (20x20 m). One is taken in density crown (0.8 and 0.9). On systematically based on elementary plots 1 m² wich one based characterise of young growth (species trees, hight, number of trees). Analise site quality (Drinić, et al., 1980) and hight which one caustimted used Prodans function. Regime light is fortify stationary izohel systems analysis (Kolić, 1975). Treatment influence regime light and characteristic seedlings assessed is analysis varijanse 3x2x3 - factorial experiment (Hađživuković, 1991).

Results and Discussion

Total number of trees in stand is 996/ha (live trees 965/ha, and dead trees 31/ha). By the number of trees, Beech is dominant with 69.0 %. In lower dbh classes (up to 30 cm), Beech tree is 60.0 % of total number. This domination has been caused by socialization (Mlišek, 1968) of Beech tree in stand down floor. This phenomena could not be understand as final process (Šafar, 1953, 1955; Fukarek, 1965), but as natural process of species succession in stand natural regeneration. Distribution line of tree number per dbh classes is very similar to distribution line characteristically for uneven age stands. It is possible to make conclusion that stand is in optimal faze, uneven age faze. The highest frequency of tree number is in high class of 7.5 m, where Beech is dominant, but is also obvious one secondary maximum in high class of 28.5 m. In first five high classes contains 74 % of trees. That shows process of Beech tree growth in stand down floor.



Tariffs for Beech are IV/III, while for Fir and Spruce is I/II (Matić, et al., 1980). Total volume in OP1 stand is 1216.0 m³/ha, from which volume of dead trees is 113.2 m³/ha (the most dead tree is Fir, about 50%) or 9.3% from total volume. Mix volume species ratio Fir : Spruce : Beech tree = 42 % : 29% : 29%. Stand annual yield (live trees) is 10,12 m³/ha and yield ratio among species Fir : Spruce : Beech tree = 37,8% : 20,5% : 41,7%. Percentage of volume growth is very low with value of 0.92%.

Stand has 674 juvenal plants of Fir, Spruce, and Beech tree which height is over 130 cm, and dbh under inventory minimum (5.0 cm). Mix of species juvenal plants Fir : Spruce : Beech = 18,1% : 13,8% : 68,1%. In this juvenal plants category Beech is most frequent in Height class 4.3 - 5.3 m (109/ha or 23.75%), and its quality is generally bad (54.0%), while with excellent quality only 14.2% and good quality 31.8%. Juvenal plants are spread in small groups or individually.

Light regime, that has been measured by stationary isohels method (Kolić, 1975), shows that light intensity in high crown density (0.9 - 1.0) is 895 Lx/m², and permeability coefficient is Kp = 2.7%. In condition of total crown closure (0.8) light intensity is 1500 Lx/m², and permeability coefficient Kp = 3.8%. The highest frequency of juvenile Beech tree is in area where is light intensity between 1000 and 2000 Lx, and light permeability, compare to open space between 3% and 4%.

Based on the result of analyses of variance, it has been concluded that is statistically significant impact of both studied factors on size of Somer Beech tree hight growth on level of significance 0.05. Impact of light permeability on size of Somer Beech tree hight growth in dens and closed crown canopy has mostly linear effect.

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NATURAL REGENERATION AND NATURE-BASED SILVICULTURE - DOES THE SPONTANEOUS REGENERATION WORK WELL?

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Introduction

The title contains three terms which need definitions. I propose the following:

- Natural regeneration: it mimics regeneration in unmanaged, primeval forests with some important differences. Time of regeneration and ecological conditions, particularly light intensity and seedbed features, are controlled by the forester in order to achieve certain management goals. As an example, the forester will synchronize tree harvest and mast bearing whereas naturally a tree dies and gives space for regeneration without caring for seed production. Or a forester will use soil preparation, vegetation control and fertilization to improve conditions for germination and growth of tree seedlings.
- Spontaneous regeneration: after some human impact like cutting and timber harvest, regeneration follows spontaneously without any technical support like seeding, soil preparation or vegetation control. Contrary to natural regeneration, spontaneous regeneration is not planned. Particularly there is no temporal harmonization of seed production and cutting.
- Nature-based silviculture: this concept is the core of the main certification rules and widely accepted in Germany, especially by public forest owners. The following characterization is based on certification requirements of the German PEFC group (Programme for the Endorsement of Forest Certification Schemes, PEFC 2006). From a silvicultural point of view, the following aspects are important: in principle forest owners have to refrain from clearcutting. Small-scale cutting types have to be preferred; particularly single-tree selection, target diameter cutting and group selection are regarded as ideally suitable. Thereby, regeneration is bound to small areas and more or less uneven-aged, which are important prerequisites for an essential goal, namely the structural enrichment of the forest. Another essential goal is the promotion and maintenance of mixed-species forests. By these means, forest stability shall be improved substantially.

In practice, target diameter cutting is by far the most widespread cutting type in Germany to achieve the above mentioned goals. As far as we know from recent investigations in Slovakian and Albanian old growth beech forests (Tabaku and Meyer 1999, Tabaku 2000, Meyer et al. 2003, Drößler and Lüpke 2005), it emulates well the disturbance regime and regeneration conditions in primeval beech forests. As an example, Drößler and Lüpke found in two Slovakian beech forest reserves that more than 85% of all gaps were smaller than 250 m², and most of them were created by death of single overstorey trees. Despite the very shady conditions on the forest floor (mean diffuse site factors of 2.5 and 9.4 respectively), beech regeneration could be found all over, but grew substantially in height only in gaps. Mixed-species were scarce because of higher light demands.

Materials and Methods

The data source for this compilation is based on different studies carried out at the Institute for Silviculture of the University of Göttingen. Besides the above cited work of Tabaku (2000) and Drößler and Lüpke (2005) on the structure and dynamic of Albanian and Slovakian

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primeval beech forests, partly compared with managed forests (e.g. Single tree selection forest, Tabaku 2000), they comprise unpublished analyses of regeneration development under target diameter cutting regimes in beech stands near göttingen on acid and limestone soils.

Results and Discussion

Three examples of spontaneous regeneration in managed forests illustrate the widespread practical experience that small-scale cutting types like target diameter cutting produce satisfactorily dense beech regeneration.

1. *Natural regeneration following target diameter cutting:* Tab.1 contains a typical example of a 145 years old beech stand near Göttingen. The light intensity above the regeneration layer after the second target diameter entry is given in Tab. 2.

Table 1: Density and species composition of natural regeneration, triggered by target diameter cutting 7 years ago, in a 145 years old beech stand on acid soil.

Species	Mean density (n ha ⁻¹)	Coefficient of variation (%)	Minimum - Maximum (n ha ⁻¹)	Proportion of species (%)
Beech seedlings	28,040	121.6	0 - 305,730	87.1
Non-beech seedlings	4,170			12.9
Sum	32,210			100.0

Note: Mean height of beech seedlings: 105 cm. Non-beech seedlings: 9 species, mainly *Salix caprea* and *Acer pseudoplatanus*. Statistic parameters refer to 120 sample plots of 3.14 m².

A density of 28,000 seedlings can be regarded as sufficient given the mean seedling height of 105 cm. The proportion of mixed-species clearly is not acceptable, particularly because they are on the average smaller than the competing beeches and will be exterminated with increasing height growth. The reason is the not sufficient light supply (Tab. 2).

Table 2: Light intensity above the regeneration layer of tab. 1, after the second entry of target diameter cutting.

Parameter	PAR (% of above canopy PAR)
Mean	15.1
Minimum	1.6
Maximum	31.7
Coefficient of variation (%)	50.6

2. *Natural regeneration underneath a beech single tree selection forest on a limestone soil in northern Thuringia ("Bleicherode"):* the stand originated 150 years ago from coppice with standards and is uneven-aged. More than any other type of forest, a single tree selection forest relies on spontaneous regeneration. Regeneration has to proceed permanently everywhere in the stand, thus making any of the above mentioned silvicultural measures impossible. Fig. 1 shows the seedling density and the species composition. As in the foregoing example, seedling density and spatially distribution are fully sufficient, but with increasing height the proportion of mixed species like maple and ash is approaching zero. Light intensity on the forest floor reached on the average only 7.2 % of above canopy light, but heterogeneity was higher than in the first example (Tab. 2), indicated by a range of 0.1 to 41.7 % and a coefficient of variation of 104 %.

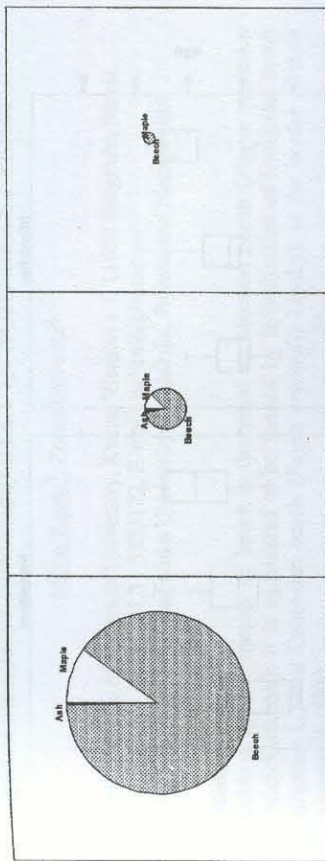


Figure 1: Density and species composition of regeneration in beech single tree selection forest "Bleicherode". From left to right: height < 0.2 m, n ha⁻¹ = 101,700; height 0.2-1.0 m, n ha⁻¹ = 21,100; height > 1.0 m, n ha⁻¹ = 1,240. The size of the circles corresponds approximately to the absolute seedling densities in the different height classes (after Tabaku 2000).

3. *Mixed beech-maple-ash spontaneous regeneration on a limestone site near göttingen, triggered by target diameter cutting and, for the last entry, group selection cutting (data from the investigation of A.M. Petrijan):* figure 2 shows the relative frequency of the germination years of the beech seedlings on two sites. The sample trees represent an area of approximately 2-3 hectares, thus the data describe fairly large stands. Leaving outliers apart (at "Hünstollen" ages of 8 and 29 years, at "Hengstberg" none), the regeneration is between 11 and 24 and 9 and 25 years old, respectively. Thus the time window of 14 and 17 years respectively for beech regeneration was rather narrow. It becomes even narrower if one looks at the dominant trees, i. E. The trees with favourable future prospects (Tree class 1 in Figure 3). Their age range amounts to 9 and 13 years respectively. The codominant and suppressed saplings are younger on average. After start of the regeneration, progenies of later seed years have clearly smaller chances to reach a later overstorey position. Besides it is remarkable that there was seed production almost every year within the total time period. This corresponds well to observations of Züge (1986) and Schmidt (2006) in the same region.

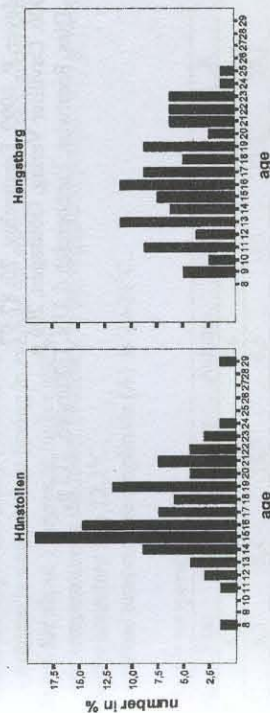


Figure 2: Age distribution of beech saplings in two thickets (data of A.M. Petrijan)

CLIMATIC CHARACTERISTICS OF THE BEECH FOREST (*Fagetum moesiacae montanum*) BELT IN NORTHEAST SERBIA

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Introduction

In Serbia a special species of beech is described as Moesian beech (*Fagus moesiaca* Domin, Maly/Czezozt): It is considered to be formed by hybridization of European beech (*Fagus sylvatica* L.) and Caucasian beech (*Fagus orientalis* Lipsky), at the border of their ranges (Jovanović 1985).

Forests of beech in Northeast Serbia occur as a special altitudinal belt. Based on the altitudinal classification of the Deli Jovan mountain vegetation (Kalinic et al. 1984), the lower boundary is about 600 m, and the upper boundary of the belt is about 1100.

This paper shows the climatic characteristics of the altitudinal belt of beech forests in this region in the zone between 600 and 1100 m a.s.l.

Materials and Methods

The climate of this altitudinal belt was described by the method of altitudinal gradients of basic data of meteorological elements, based on the data of multi-annual measurements (1961-2000) of a great number of lowland and upland weather stations in the study region. On this basis, the values of meteorological elements were calculated for a definite altitude (lower and upper limits of beech forest altitudinal zone). Annual and seasonal values were presented – for spring, summer autumn and winter and vegetation period of the most important climatic elements: air temperature and rainfall. Finally, the climatic type was assessed by Lang's and Thornthwaite's method.

Results and Discussion

Air temperature

The basic characteristics of the temperature regime for the mentioned heights above sea level in analyzed altitude belt, as per Table 2, are the following:

- in the lower boundary of analyzed belt (600 m), the mean annual air temperature is 8.3°C and in the upper boundary (1100 m) is 6.2°C;
- Autumn is warmer than Spring in average for about 0.5 degree Centigrade at lower altitude and for about 1 degree at higher altitude;
- air temperature at the lower boundary in the vegetation period (VP) is 14.8°C, while at the higher boundary it is 12.2°C;
- annual temperature amplitude (A) is 20-21°C.

Table 1: Air temperature (°C)

H (m)	Year	Spring	Summer	Autumn	Winter	VP	A
600	8,3	8,2	17,7	8,6	-1,4	14,8	20,7
1100	6,2	5,4	15,7	6,5	-3,1	12,2	20,1

Pluviometric regime

It is known that continental type of pluviometric regime occur in Serbia, having two maximum and two minimum precipitation amounts during a year. The primary maximum

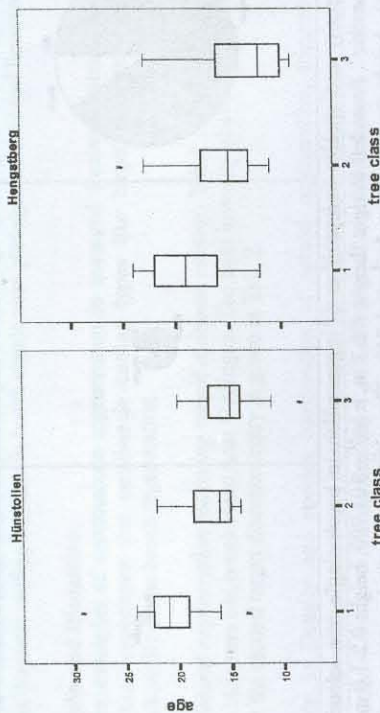


Figure 3: Age distribution of beech saplings in different tree classes. Class 1 = dominants; class 2 = codominants; class 3 = suppressed trees. Data are the same as in fig. 2.

Conclusions: there are many practical experiences and some scientific observations which demonstrate that spontaneous beech regeneration works well under a nature-based silvicultural regime. The reason might be a general suitability of small-scale cutting and regeneration methods for beech, as they mimic well the situation in natural beech forests. In addition the frequency of seed years has increased the last decades (Schmidt 2006), and the impact of game has gone down considerably. On the other hand, regeneration of mixed-species is greatly impeded by the superior competitiveness of beeches under these shady conditions. Thus, one important goal of nature-based silviculture is going to be missed as another one is to be perfectly reached.

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occurs most frequently at the beginning of summer period (in June) and somewhere at the end of springtime (in May), while the secondary maximum can most frequently be found in some regions in November. Primary minimum is at the end of winter (in February) or at the beginning of March, while the secondary one most frequently occurs at the beginning of autumn - in September.

The average annual precipitation amount ranges from 654 mm at the lower boundary to 701 mm at the upper boundary of the analyzed forest belts (Table 2).

The most frequent rains occur in summer with 29-31% of the annual precipitation amounts, while the driest season is in winter (about 20%).

The annual precipitation amounts increase with altitude for about 10 mm over 100 meters.

During the vegetation period, 58-60% of the annual amount of precipitation occurs.

Table 2: Average annual precipitation (mm)

H (m)	Year	Spring	Summer	Autumn	Winter	VP	VP/Y (%)
600	654	175	203	149	128	389	59,4
1100	701	192	204	167	138	408	58,1

Climate and geographic characteristics of the region

Climate and geographic characteristics of the region represent the influence of geographic position of a certain region to the climate features and vice versa (Kolic 1988).

The degree of continentality of the region was determined by Kerner's thermodynamic coefficient (DC) and shows that moderate continental climate occurs at the lower boundary of analyzed belt, mild continental (mountainous) climate up to 1100 m.

Table 3: Climate and geographic characteristics

H (m)	DC %	Continentality of the region		Drought index after De Martonne	Pluvial risk hazard
		Type of climate	DI		
600	2,1	Moderate continental	35,8	Permanent	9,9
1100	5,8	Mild continental	43,3	Abundant	8,9

The runoff type and irrigation demand determined by drought index (DI) after De Marton, is characterized by expressive exoreism, i.e. runoff is permanent and abundant, meaning that according to this parameter, we deal with wet regions namely, this is a typical forest region. Pluvial erosion hazard - risk of soil erosion caused by raindrop bombardment is expressed in accordance to the risk coefficient (C) after Fournier, indicating there is only a mild risk of pluvial erosion.

Climate classification

Climate classification after Lang and Thornthwaite is of utmost importance for the needs of forestry and especially for the choice of the methods for the forest growing (Kolic 1988).

Climate classification after Thornthwaite is performed based on values of calculated water balance. In the analyzed altitude forest belt, the climate varies from Subhumid moist to Mild humid (C₂ - B₁).

Table 4: Climate classification after Lang and Thornthwaite

H (m)	RF	After Lang		After Thornthwaite	
		Type of climate	Im	Type of climate	Type of climate
600	79	Climate of thin forests - not in optimum	11,8	C ₂	Sub humid moist
1100	113	Climate of high forests - they are in optimum	31,5	B ₁	Mild humid

Based on the climate classification after Lang, which is defined by the rain factor (RF), it can be seen that the humid climate occurs in the forest belt up to 700 m above sea level where the forests are not in their climate, physiological and biological optimum, and above mentioned height, they are.

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SPATIAL PATTERN OF TREES IN PURE STANDS OF NATURAL BEECH (*FAGUS ORIENTALIS*) FORESTS

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Introduction

The spatial pattern of a forest stand (in other words the organization of the trees in space) plays a main role in its dynamics. It indicates the establishing fortune for seedling and renewal capacity of the stand. Thus, the relative location of young and old trees of the same species can help us to understand the dynamics of regeneration (Pelissier, 1955).

Indeed, the spatial pattern observed results from the past dynamics of the stand: establishment of young trees, competition for the different resources and death due to senescence or competition (Pacala & Tilman, 1994; Batista & Maguire, 1998).

We can thus assume that some of the characteristics of the stand spatial pattern reflect the major trends in its dynamics. For example regular spatial structures are commonly supposed to indicate high competition in stands, whereas aggregate patterns indicate massive regeneration without subsequent strong self-thinning (Kenkel, 1988; Ward & Stephens, 1996; Pelissier, 1998). Therefore, the aim of this present study is describing the stand spatial pattern.

Materials and methods

The study site is located in the second district of Kelardasht forest in the west of Mazandaran province, north of Iran. The forest under study has the area of 30 ha, and is occurred in beech (*Fagus orientalis*) forest. It is a sample of pure stand of beech forest that is fortunately unmanaged and has not been harvested until now. The stand is located on a gentle (20-40) north-facing slope. The soils belong to entisole with bedrock of siltstone conglomerated. The climate is temperate, the annual mean temperature is 8°C and the annual mean precipitation is 1806mm, with maximum rain occurring in late summer and fall.

In the aforementioned pure beech stand, an area of 5.7 ha was determined and for all this area stem coordinates (exact to 0.1 m, using a compass and an ultrasonic distance-meter), 40 species and diameters at breast height ($d_{1.30}$) of all living trees about 7 cm in $d_{1.30}$ their position in stand were recorded.

Mathematical method

Stand spatial pattern is a complicated concept, including both horizontal and vertical use of space by trees. To simplify this approach, we focus on the horizontal location of trees in the stand and each tree is represented by a point, defined by its co-ordinates (x,y). In order to determine the spatial pattern of the distribution of trees in beech stand and with regards to an initial hypothesis for this research would be that in uneven-aged stands, a clustered or random distribution would be expected.

Therefore, specific tools are necessary to characterize the structure. Many methods have been developed to study structure (Ripley, 1981). Point pattern analysis, a branch of spatial statistics, can be used to analyze horizontal stem scattering and quantify the spatial pattern of plant community (Cressie, 1993). Spatial statistics based on point processes such as Ripley's function have often been used to describe the spatial distribution of trees and seems all the

more interesting as it gives a description of spatial structure at different scales at the same time (Cressie, 1993), and it could be applied on each species separately.

In this study, we used the Ripley's function and T-square to determine the spatial pattern of trees.

Ripley's function

The main characteristics of a point processes can be summarized by its intensity λ (the expected number of points per unit areas) and Ripley's $K(r)$ function, defined so that $\lambda^2 K(r)$ is the expected number of the neighbors in a circle of radius r centered on an arbitrary point of the process (Ripley, 1977). We can calculate estimators of λ and $K(r)$: $\hat{\lambda} = N/S$; where N is the number of point in the pattern and S is the area of the study region.

$$\hat{K}(r) = \frac{1}{N} * \frac{1}{N} * \sum_{i=1}^n \sum_{j \neq i}^n K_{ij}$$

Where $K_{ij} = 1$ if the distance between i and j is less than r , and 0 otherwise.

To simplify the interpretation, a linearized function $L(r)$ proposed by Besag (1977) was used:

$$\hat{L}(r) = \sqrt{\frac{\hat{K}(r)}{\pi}} - r$$

Then for a poison pattern, $L(r) = 0$ at every distance r ; for clustered patterns at distance r , $L(r) > 0$; and in the case of regularity at distance r , $L(r) < 0$. In order to test this « complete spatial randomness » (csr) hypothesis, we build confidence intervals using the Hopkins test.

T-Square Function

T-Square method is simpler to implement in the field than the Ripley procedure. Random points are located in the study region and at each random point two distances are measured: The distance (x_i) from the random point to the nearest organism, and the distance (z_i) from the organism to its nearest neighbor. The density estimator that utilizes T-square distances (z_i) has a different formula:

$$\hat{N}_t = \frac{2n}{\pi \sum (z_i^2)}$$

where \hat{N}_t = T-square estimate of population density, n = number of samples and z_i = T-square distance associated with random point i . This estimator should not be used unless it is known that the organisms being sampled have a random pattern. The most robust estimator of population density for use with T-square sampling was the following:

$$\hat{N}_t = \frac{n^2}{2 \sum (x_i) \left[\sqrt{2} \sum (z_i^2) \right]}$$

In order to test this « complete spatial randomness » (csr) hypothesis, we build confidence intervals using the Hopkins test.

Results and Discussion

Based on Ripley's $L(r)$ function, the spatial distribution of beech trees in natural stands indicated an aggregate pattern, because the index of pattern $L(r)$ was more than zero ($L(r) = 0.75$). In order to test the null hypothesis of spatial randomness, we computed a 95% confidence interval of (r) indicated that clumped pattern was acceptable ($H = 2.92$, the critical lower limit of Hopkins test for aggregated pattern = 1.37).

Also, based on T-Square method, results showed that the spatial pattern is clumped (Table 1). Hopkins test result with a confidence 95% indicated that the null hypothesis was unacceptable ($H = 2.70$, the critical lower limit of Hopkins test for aggregated pattern = 1.29).

A STUDY CONCERNING THE DEADWOOD IN "RUNCU-GROSI" NATURAL RESERVE (WESTERN ROMANIA)

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Introduction

More than one third of the European species living in forests depend on the old trees and the dead wood for survival. Dead wood creates habitats, shelter and food sources for birds, bats and other mammals, being also an important component for sheltering other species as insects (especially beetles), fungi and lichens. Dead wood has also an important role in sustaining biodiversity, forest production, offering environmental services as the carbon sequestration. The volume of dead wood depends on the productivity of the forest, the natural disturbances, the successional phases, the history of the forest and human intervention. The type of dead wood and decaying phases are influenced by the way the trees die(thunders, storms, drought, disease, etc.). In European broadleaved forests which are not included in economic circuit, the quantity of dead wood increases from 5% to 30% of the total woody biomass, volumes reaching from 40 to 200 m³/ha(e.g. in old-growth beech forests, the average dead wood volume reaches 136 m³/ha). The quantity of dead wood could increase dramatically after catastrophic events, such as windstorms (Dudley, N., Vallauri, D., 2004).

Materials and Methodology

"Runcu-Grosi" Natural Reserve is part of the Production Unit IV "Grosi" from Barzava Forest District, Arad County Forestry Direction, being situated in the eastern part of the county. The Reserve is located in the inferior part of the Mures river's basin, on the right slope, in the small basin of Grosi Valley. The limits of "Runcu-Grosi" Natural Reserve are natural. Its surface is 262.6 ha and the geographical coordinates are 46°11' north latitude and 22°07' east longitude.

The researches were undertaken on 500 m² experimental plots, statistically placed in the Reserve. The total area investigated was over 1% of the Reserve's area. Both living trees and dead wood were measured. For the standing dead wood, the height and the d.b.h at 1.3 m were measured. In the case of fallen dead wood, the diameters at both ends and the length were measured; they were taken into account only the pieces with a diameter over 8 cm at the thick end and over 1 m in length. 6 classes of decaying were used, the appreciation of those being done using the description made by Van Hees et al.

Results

1. The quantity of dead wood

After investigating the 58 experimental plots, uniformly distributed, with a total area of 2.9 ha (which represents 1,1% of the reserve's area), the data collected were processed and it resulted an average quantity of dead wood of 100 m³/ha. This quantity is not uniformly distributed on the Reserve area it is larger in oak (*Quercus petraea*) stands and in stands where beech (*Fagus sylvatica*) tends to substitute oak, and smaller in beech stands.

Table 1: Values of parameters that were estimated in T-Square method.

T-Square Est.	Population Estimate	Standard error of the population estimate	95 %Confidence limits	
			Lower	Upper
N _d	0.000038	16.22	0.0000381	0.0000382
N _r	0.00021	2156	0.000111	0.00191
N _r (per ha)	2.1	0.216	1.1	19.1

Therefore, we can consider that the structure pattern in beech stands is heterogeneous (Figure1). It can be used as a criterion to determine the sampling method, sample size (e.g. in stands with clumped distribution pattern we have to use samples with areas larger than the regular pattern). In order to determine silvicultural method, this knowledge can be useful. With regards to spatial pattern of trees in the study area (clumped pattern), group selection system can be assumed as a suitable method to forest management.

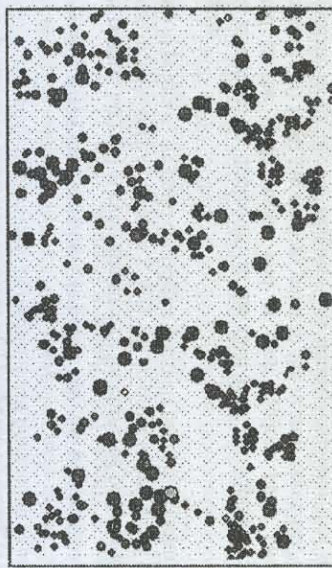


Figure1. Trees distribution map in beech stand

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The most significant quantities of dead wood represent two species: oak and beech. The quantity of standing dead wood (29% of the total quantity of dead wood) is smaller than the quantity of dead wood fallen to ground (71% of the total quantity). This situation is created by the fact that only a small number of dead trees on foot have large dimensions, the majority being formed by trees with small diameters (8-12 cm) dead by the competition.

Concerning the repartition of the dead wood volume on species, similarly with the total quantity of dead wood, oak (*Quercus petraea*) is preponderant (with 75%), almost all of the big trees dead on foot are from this species. The volume of the beech is only 24% of the quantity of dead wood on foot, because large trees dead on foot are quite rare from this species, which is dominating by the number of small trees.

2. The distribution of dead wood on diameter classes

Over 50% of the dead wood volume is represented by pieces (dead trees on foot, uprooted trees, portions of stems) with a diameter between 41-70 cm. this high quantity of dead wood with large dimensions is due to the exceptional dimensions reached in this Reserve by oak and even beech trees, these stands having a very high productivity.

Similarly with the distribution of living trees on diameter classes in the virgin forests, in the distribution of dead wood pieces on diameter classes it can be seen a decreasing of the number of pieces with the increment of diameters.

3. The distribution of dead wood on decaying classes

The distribution of dead wood volume on decaying classes is unequal and the quantities are small in the final phases of decay (especially the sixth class). This fact indicates a break in the continuity of the "supplying" with dead wood, normally because of the combined action of two factors: the forest harvesting in the recent past and the removal of the dead wood (the Natural Reserve "Runcu-Grosi" was established recently).

4. Microhabitats

In the decreasing order of their presence in the Natural Reserve "Runcu-Grosi", it can be observed that the litter and small woody material (small branches) were met in all the experimental plots. Dead branches fallen to ground appear in 93% of the experimental plots, this large number being associated with the action of wind and/or snowfalls which broke living branches, and also with the intra- and inter-specific competition for light between the trees, generating the dying of some branches which will fall to ground. Dead trees fallen to ground (trunks) with 83% and large dead trees, fallen (or broken) by windstorms or by falling of another tree with 74% are represented in majority by trees from the oak species - *Quercus petraea*. Trees dead on foot because of the competition during the initial phases of stand development (50%) are represented mainly by beech trees and a few exemplars of hornbeam (*Carpinus betulus*). The other types of microhabitats encountered have a low frequency (less than 50%).

Conclusions

The quantity of dead wood is a result of a multiple action of the following factors: the management of the forest, the stage of development of the stands, the species in the composition of these stands and the natural disturbances. In the "Runcu-Grosi" Natural Reserve, the average volume of dead wood is 100 m³/ha. This quantity is not uniformly distributed in space the distribution depends on the factors mentioned before.

EUROPEAN BEECH FORESTS AND THEIR MANAGEMENT

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Use of beech forests by Man in the past

In times before Man's strong impact on Holocene landscapes and forests (sub-Boreal/sub-Atlantic period), beech (*Fagus sylvatica*) was the most widespread forest tree species throughout Europe making up more than 60% of forest composition (Ellenberg, 1996; Pott, 2000). Within its wide and variable distribution area, beech developed various forest communities (Ribel, 1932; Horvat, Glavač & Ellenberg, 1963; Diekman et al., 1998; Neuhauslová et al., 1998; Dierschke, 2000; Bohm & Neuhausl, 1999/2000). It formed both mono-species forests as well as mixtures with all the main European tree species – from oaks in lowlands to shade-tolerant conifers in the mountains.

The pre-historic use of beech forests, namely gathering fuel-wood, grazing livestock and pannage, had various effects on beech forests. On the one hand, beech forests in the surroundings of settlements were converted in open grasslands; on the other, after abandoning the area, beech rather quickly colonized the abandoned land and sometimes formed islands of beech on sites originally covered by mixed broad-leaves (Birks et al., 1975; Godwin, 1975; Küster, 1998).

Consolidation of land ownership and land use in the Middle Ages created favourable conditions for an extensive exploitation of beech forests. Its forms were very variable, reaching from deforestation (acquisition of new land for agriculture), pannage, grazing and fuel-wood supply for domestic use to charcoal production for metal processing, salt works and glass manufacturing, etc. Long before organized forestry was established, the area of beech forests in many parts of Europe was strongly reduced and beech in remaining forests replaced by other species. The result of this process was nearly complete elimination of beech in European lowlands, fragmentation of beech forests in sub-montane and lower montane areas, and a considerable reduction of beech in forest composition. Large beech forests remained only in remote and inaccessible mountain areas.

Beech forests and their management in the industrial period

Due to low financial return, beech was not a very interesting species for the commercially oriented forestry of the industrial period. Fuel-wood supply for domestic and industrial use prevailed. Later, when hard-coal was introduced, beech was systematically replaced by commercially more interesting conifers. Only remote upland and mountain areas and areas with specific site conditions remained spared from this development.

For the management of beech forests in Hesse, Germany, a specific silvicultural system – the *Schirmschlagheirtrieb*/uniform shelter-wood system – was designed by Moser (1757). It combined two important aspects: low regeneration costs (due to abundant natural regeneration) and concentrated fellings (enabling spatial and temporal organization). In the original conception, the co-ordination of felling and regeneration took place in three steps: seeding -, release - and final felling. This silvicultural system has been widely applied in beech dominated forests throughout Europe. It has led to large-scale and uniform beech stands with a very low age and spatial diversity. Weeds growth and lack of natural regeneration has often given impetus to planting other species and thus conversion from beech. To evade this disadvantage, various forms of small-scale shelter-wood system (*Femelschlag*) had been designed and applied.

Despite these efforts, the proportion of beech in forests and the total area of beech forests decreased further significantly during the industrial period in the West, North-West and Central Europe. Remnants of natural beech forests exist in Central Europe as protected nature reserves (Průška, 1985). In the mountains of the sub-Mediterranean regions, the area of beech forests had been reduced by continuous grazing and/or conversion into coniferous (*Pinus* spp.) plantations. Management of beech stands as coppice led mostly to their strong degradation. Hardly any natural beech forests survived in these areas.

In the South-East European highlands, accessible beech forests were mostly cleared and then left to regenerate naturally. These forests survived with a more or less natural composition but with a changed structure. Inaccessible areas of the Carpathians and the Balkan mountain ranges bear today the largest remnants of natural beech forests with their full biological diversity (Fröhlich, 1941; Korpeľ, 1995; Smejkal et al., 1995; Biriş et al., 2001). These natural forests must be seen as a European natural heritage. They represent an inexhaustible source of scientific information (see e.g. Paucă-Comănescu, 1989; Korpeľ, 1995; Vrška et al., 2001).

Towards the end of the industrial period, ecological shortcomings of forestry based explicitly on commercial considerations became obvious. Already in the first half of the 20th century principles of a new forestry concept (mixed forests, continuous-cover forestry, close-to-nature forestry) had been worked out and applied locally. General destabilization of forests in the second half of the 20th century (forest die-back due to environmental deterioration) strengthened further the trend towards nature-base forestry to restore the ecological and physical stability of European forests. In this new forestry concept, beech, as one of the most important indigenous species, has an important place.

Modern approaches to beech forests and their management

Re-introduction of beech and restoration of its at least partial admixture is of essential importance in man-made forests on original beech sites (Fanta, 1997; Mosandl & Küssner, 1999; Tesar & Truhář, 2002). Design of a beech rehabilitation programme must be imbedded into an integrated silvicultural management system.

Ongoing climate change is expected to cause changes in distribution of beech and especially in its competitive ability to other species (Holten, 1990; Roloff, 1992; Felbermeier, 1994; Brugman, 1994). Also extreme fluctuations in climatic factors must be taken into consideration, as well as the combined threat of chemically changed soils, photochemical smog and increasing levels of Nitrogen deposition. Near-natural forests of mid altitudes are likely to be well buffered against the anticipated changes. Beech forests on extreme sites, however, will undergo considerable risks. It also can be expected that the upper limit of beech in mountains will shift to higher altitudes.

The assumption is justified that, under the continuously changing economic, societal and environmental conditions in contemporary Europe, adaptive forest management will be the best approach to integrate principles of sustainability, multifunctionality and biodiversity into a well-considered management system. A system, which will not set sturdy final goals using prescriptive planning, but will outline well-considered trends, avoid risks and will create room to react flexibly on changing situations by applying alternative solutions (Thomasius, 1991; Fanta, 1992; Lindner, 1999; Puhe & Ulrich, 2001).

A silvicultural system (or systems) intended to rehabilitate beech in European forests should be nature-based, derived from a sound knowledge of the life strategy and ecological properties of the species, related to site conditions and be highly flexible to serve various demands and purposes. With regard to the present situation in Europe, the following four main tasks for beech forest management can be defined:

- Application of nature-based principles in management of existing beech forests

DIRECT SEEDING OF BEECH – OPTIONS AND PROBLEMS

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Introduction

On large areas in Europe the conversion of pure conifer stands into mixed stands and the afforestation of former farmland with broadleaved tree species are major silvicultural objectives (Ammer et al. 2002, Willoughby et al. 2004, Madsen and Løf 2005). For both of these challenges European beech (*Fagus sylvatica* L.) is considered to be a promising option. However, planting beech into conifer stands and its establishment in open field conditions by planting is costly. For this reason direct seeding, which had been the usual measure of artificial regeneration up to the middle of the 19th century, was reconsidered to be a useful and cheap possibility to establish beech stands (Gommel 1994, Leder and Wagner 1996, Baumhauer 1996). Nevertheless, in one third of all cases where direct seeding of beech was carried out in silvicultural practice, it was not very successful and another third resulted in a disaster (Nörr 2004). This discouraging results were the starting point for recent research about the factors influencing the success of direct seeding and about the silvicultural options to control them. The following brief review tries to summarize the main results of the regarding investigations.

Factors influencing the success of direct seeding

The factors which have been identified to affect the success of direct seeding are numerous (Table 1). However, not in every case the same factors are of same importance. In general it can be distinguished between technical and natural variables affecting the success of direct seeding. It is evident from table 1 that the natural factors influencing seed germination and seedling growth are more complex and much more difficult to control than the technical attributes.

The time span during which seedlings are sensitive to the impact of mice, snails, insects, fungi, resource competition by ground vegetation or mature trees and abiotic stress is much longer for seedlings originating from direct seeding than for planted seedlings. Thus silvicultural measures should try to minimize the different hazards. Heavy thinnings for example can reduce root competition by overstorey trees and thus drought stress for seeds sown below the canopy (Ammer et al. 2002, Leder et al. 2003). Weed management which maintains bare soil has proven to be a very effective measure resulting in low mortality and enhanced growth in open field conditions (Coll et al. 2003). More difficult to control than competing vegetation are animal predators. Recent trials with tubes which was designed to protect the seeds showed no overall significant effects on the amount of established seedlings (Madsen and Løf 2005).

One of the technical factors influencing the success of direct seeding seems to be of particular importance. Thus the time span between the completion of seed preparation and their placement in the field should be as short as possible (Leder et al. 2003, Nörr 2004). Other technical measures like fertilization did not generally result in satisfactory number of seedlings (Ammer et al. 2002, Leder et al. 2003, Løf and Weiland 2004). Only Küßner and Wickel (1998) reported a positive effect of liming on seedling density and growth.

Overall direct seeding requires a thorough planning and carrying out. The many advantages of successful direct seedings e. g. undisturbed root development, high number of individuals and

- Conversion of coniferous monocultures on beech sites to mixed beech forests
- Design of silvicultural methods enabling production of high quality beech timber
- Application of planning methods in support of nature-based forest management.

Conclusion

Over wide areas of Europe, beech is the key-stone species for restoration of biological diversity, and both ecological and physical stability of forests. Its rehabilitation is one of the most important tasks of the contemporary European forestry. Introduction of adaptive, nature-based management system for beech rehabilitation must be derived from natural beech forests, especially their spatial structure and development dynamics. Its inherent part must be a proper, flexible planning. Under the present conditions, the planning method based on forest development types (Anonymus, 1996; Von Teuffel & Krebs, 1999; Perpeet, 2000) has the capacity to balance the ecological, economic and social functions of forests into a viable beech forest management system.

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therefore the option for future high quality timber (Willoughby et al. 2004) and low costs, suggests to apply this method more frequently (Ammer et al. 2001). It is however not recommendable in every situation, and some failures presumably had to be complained because of manmade elementary faults.

Table 1: Summing up of factors influencing the success of direct seeding

Factor	Importance	Author
Germinative capacity of the seeds	Predetermines possible seedling number	Leder (1998), Nörr (2004)
Professional preparation of the seeds	Seed dormancy has to be broken, growth of radicle should be imminent	Leder (1998), Nörr (2004)
Rapid delivery and placement	Germination in the field is negatively correlated with the time needed for seed delivery and placement	Ammer et al. (2002), Leder et al. (2003), Nörr (2004)
Access to the mineral soil, sowing depth	Facilitate to survive drought periods and is thought to hamper locating seeds by mice and birds, sowing depth should be between 2 and 5 cm	Gommel (1994), Städler and Melles (1999), Ammer et al. (2002), Leder et al. (2003), Nörr (2004), Madsen and Löff (2005)
Soil temperature	Should be below 15° otherwise secondary seed dormancy could occur	Leder (1998), Leder et al. (2003)
Timing	Most studies reported more successful direct seedings in late spring (May)	Gommel (1994), Leder et al. (2003) Nörr (2004), Madsen and Löff (2005)
Predators and diseases	Predation by animals or diseases can reduce or defeat the amount of germinated seeds and seedlings	Nörr (2004), Willoughby et al. (2004), Löff et al. (2004), Madsen and Löff (2005)
Resource competition	Germination and early growth is affected by competition for water caused by weeds or canopy trees	Ammer et al. (2002), Coll et al. (2003), Coll et al. 2004, Löff et al. (2004), Löff and Welander (2004), Willoughby et al. (2004), Löff et al. (2005)

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GROWTH AND MORTALITY OF NATURALLY REGENERATED BEECH SEEDLINGS IN RELATIONSHIPS WITH CANOPY CLOSURE AND SEEDLING DENSITY

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Introduction

During the initial phase of naturally regenerated forest stands, great spatial heterogeneity in growth conditions occurs, which affects the growth and survival of tree seedlings. Among the factors showing important spatial variation, light availability and seedling density are two factors that strongly influence seedling growth. Since light availability and seedling density are the factors that may be the most easily regulated through silvicultural actions, they constitute the main tools to control the development of natural regeneration. In order to identify the most appropriate silvicultural action to perform in a given stand to optimize regeneration development, it is therefore necessary to have a good knowledge of the combined effects of light availability and local seedling density on seedling development.

A series of experiments were performed in naturally regenerated beech (*Fagus sylvatica* L.) stands of northeastern France to quantify the effects of canopy opening and local competition on seedling development.

Effects of light availability and local competition on seedling growth

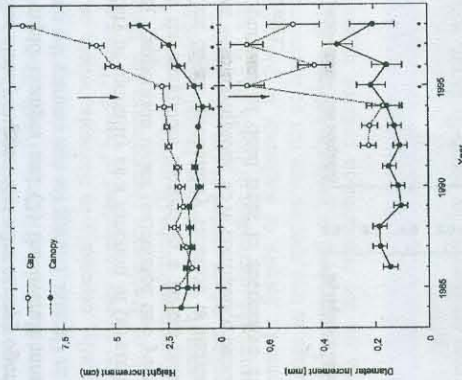
In order to analyze the growth dynamics of beech seedlings growing under changing canopy conditions, a beech stand in which two types of canopy opening (canopy release or gap creation) had been applied in 1995 was selected in 1997 in the Forest of Haye near Nancy. Three and four years after the canopy had been opened, 155 naturally regenerated seedlings were sampled in gaps or under the canopy. Seedling height ranged between 5 and 50 cm, and seedling age between 2 and 19 years. No relationship was found between seedling age and seedling size (height or diameter).

The effects of canopy closure and seedling age on height and diameter growth were analyzed on 113 seedlings using mixed models. Under closed canopy, average annual seedling height and diameter increments were 1.2 cm and 0.18 mm, respectively (Fig.1). Diameter growth increased in the first year after the canopy had been opened, and exhibited considerable inter-annual variation related to climatic conditions. Conversely, height growth did not increase immediately after canopy opening, but increased regularly in the following years. Four years after the gap had been created, annual seedling height and diameter growth were 9.5 cm and 0.49 mm respectively in the gaps, and 3.8 cm and 0.21 mm respectively under released canopy. Age did not affect the dynamics of seedling growth.

A second experiment was conducted in the same stand (Forest of Haye) in order to analyze the combined effects of canopy opening and local competition on seedling growth. In 1997, five regeneration patches located under different canopy closure degrees were selected. Percent of above canopy light (PACL) ranged between 5 and 45%. Two years later (in 1999), the canopy was felled by a storm, and the five patches were under full light (PACL=100%). The effects of local density were examined using neighborhood analysis. Different

competition indices (CI) and neighborhood radii ranging from 10 to 200 cm were tested. Models including PACL and CI accounted for between 0.56 and 0.64% of the variation in individual seedling annual diameter or height growth. Local density had a strong negative influence on diameter growth, and a much smaller influence on height growth. PACL was positively correlated with diameter and height growth before canopy opening. Differed effects of PACL (measured before the storm) on height growth were observed immediately after canopy opening, but disappeared after two years. No differed effects of PACL on diameter growth after canopy opening were observed.

Figure 1: Annual height and diameter increments for seedlings sampled under canopy or in gaps (least-squares mean \pm SEM) in the Forest of Haye. The arrow indicates the year in which the canopy was released (seedlings sampled under canopy) or the gaps created (seedlings sampled in gaps). The difference in annual height or diameter increment between the seedlings sampled under canopy and the seedlings sampled in gaps was tested for each year between 1994 and 1998 (*: significant F-ratio at the $p < 0.05$ level of probability).



Mortality in relationship with seedling growth and local competition

The data from the second experiment in the Forest of Haye were used to establish growth-mortality relationships. Logistic models were used to predict the probability of mortality from different combinations of size (height or diameter), growth (height or diameter increment) and competition index (CI). The best models were obtained using (1) diameter increment over the last two years, and (2) CI one year before and initial height (Fig.2).

Effects of canopy opening on seedling morphology

In many mature beech stands, a bank of seedlings exists. We have shown that this advance regeneration is able to recover rapid growth after canopy opening. However, questions remain about the morphological quality of the advance regeneration. Most seedlings that grew under closed canopy developed a typical shade morphology, with plagiotropic axes, large branches and forks, and it is not known if these branching defects will persist or disappear when the mature stand is opened.

COMPARING REGENERATION PATTERNS IN TWO BEECH-FIR OLD-GROWTH FORESTS IN SE EUROPE

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Introduction

Dinaric beech-fir forests are the most well preserved, continuous forest ecosystem in south-central Europe, stretching over the north and central part of the Balkan Peninsula. The natural structure and tree species composition of this beech-fir ecosystem has been well studied, as there are many remnant old-growth stands in these forests (Puncer 1980, Boncina 2000, Prpić et al. 2001). They are an important wood source and also serve as key habitat for several important and endangered animal species (Hartman 1999). They cover an area of 163.500 ha in Slovenia and 140.000 ha in Croatia. During the last century the tree species composition of this forest changed dramatically, especially in Slovenia, where once silver fir (*Abies alba* Mill.) dominated forest is now mostly comprised of beech (*Fagus sylvatica* L.) (Boncina and Ficko 2006). This alternation of dominance phenomenon has been noticed and intensively studied over central and south-eastern Europe (Bončina et al. 2003, Krammer 1992, Prpić et al. 2001). There are several reasons for the alternation, including reintroduction of red deer in the late 19th century and fir decline, which started in the 50's (Brinar 1974, Minšek 1964). To see the future trends concerning the alternation of beech and fir we analyzed regeneration in the old-growth Dinaric beech-fir forests of Rajhenav in Slovenia and Čorkova uvala in Croatia, in the latter this change in tree species was not so intensive. The aim of our research was to examine differences in regeneration patterns between the sites and to analyze the influence of light conditions on the regeneration patterns in canopy gaps and under the canopy.

Materials and Methods

Both old-growth forest reserves are covered by beech-fir forest, which is typically located on altitudes between 700-1200 meters in the Dinaric mountain range. Beech and fir are the dominant tree species in this forest type, but other species, such as maple (*Acer pseudoplatanus* L.), wych elm (*Ulmus glabra* Huds.), spruce (*Picea abies* (L.) Karsten), common ash (*Fraxinus excelsior* L.), and large-leaved lime (*Tilia platyphyllos* Scop.) occur infrequently. Limestone is the prevalent parent material, the average yearly temperature is 7°C, and precipitation ranges between 1600-2500 mm. In total, 4 large (0.07-0.2 ha) and 7 small (~0.02 ha) gaps were sampled in both old-growth forests. Inside gaps and under the canopy in the area surrounding the gaps, we used a 5x5m grid for defining the plot locations. In this way, we set up 773, 2,25 m² square plots, which we used to examine the density and species composition of regeneration and light conditions using fish-eye photography. To test the differences between the sites and plot types we used the standard t-test and Kruskal-Wallis ANOVA.

Results and Discussion

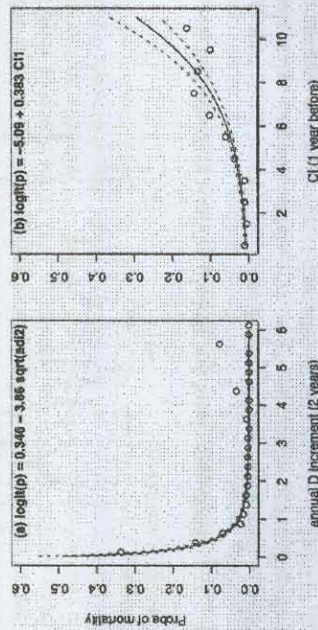
The density of regeneration in total was almost five times higher (62.066 per ha) in Rajhenav compared to the Čorkova uvala (13.083 per ha) forest reserve (t = 19,4586, p = 0,0000), which is mostly due to an almost ten-fold increase (54.699 versus 5588 per ha) in the density

A first survey was performed in 2003, in a beech stand that was partly felled by a storm in 1999 (Forest of Saint-Amond). Four years after the storm, 100 beech seedlings were selected in a plot located in a gap, and 100 seedlings in a plot located under closed canopy. It was shown that the seedlings in the gap were able to resume active growth and had less branching defects, compared to the seedlings that remained under closed canopy.

A second experiment was set up in the Graouilly Forest, where fifteen 0.75 to 2.4 m-high seedlings growing under closed canopy (PACL=5%) were selected in November 2004. In January 2005, canopy trees were felled around the seedlings and PACL (measured in summer 2005) ranged between 30% and 50%. The elongation and the inclination of the dominant axis and the main branches were measured in January 2005 and in November 2006. One year after canopy opening, the main axis became more vertical for 9 seedlings, less vertical for 5 seedlings and remained unchanged for 1 seedling.

The results from both studies clearly suggest that after canopy opening (1) the morphology of beech seedlings undergo rapid changes and (2) the overall morphological quality of the seedlings improves.

Figure 2: Annual probability of mortality as a function of (a) annual diameter increment (2-year average, adi_2) and (b) competition index (calculated one year earlier as the sum of the squared basal diameter of the neighbors located in a 80-cm-radius disc around the target seedling, CI_1). The equation of the probability function is indicated for each model. The broken lines draw the point wise asymptotic 95% confidence band for the predictor, and the dots are the observed proportions of dead trees in successive classes of annual diameter increment or competition index.

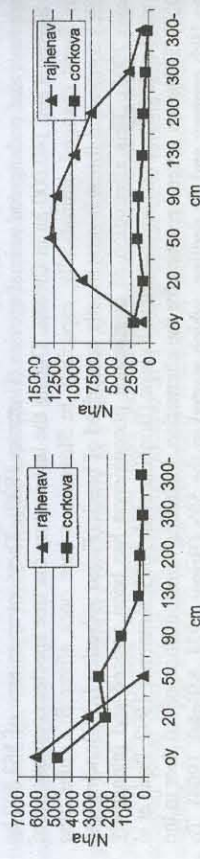


Conclusion

The results gained in this series of experiments may be used in regeneration simulators where the development of beech seedlings is predicted as a function of local intra-specific competition and canopy closure. More data are still needed on the effects of competition and canopy closure on seedling morphology, in order to evaluate the changes in seedling morphological quality, and to predict the ability of the seedlings to produced high quality trees.

of beech at Rajhenav (Figure 1 right). However, the total density of silver fir was more than twice as high (6312 versus 3187 per ha) in Corkova uvala ($t = -5.7711$, $p = 0.0000$). In spite of the fact that there was much less silver fir in the upperstory, the density of one year old and up to 20 cm tall silver fir seedlings in Rajhenav was higher than in Corkova uvala. However, the density of silver fir seedlings taller than 20 cm was higher in Corkova uvala, as there were no seedlings taller than 50 cm in the Rajhenav old-growth forest reserve (Figure 1 left). Lower densities of beech seedlings in Corkova uvala could be explained by lower radiation levels and smaller gaps compared to Rajhenav, and also by much more intensive competition from the herb layer in Corkova uvala (Table 1). The main reason for the dramatically low density of fir seedlings above 20 cm tall in Rajhenav is the heavy browsing pressure, due to a high population density of red and roe deer in the Dinaric mountains in Slovenia. This also explains the much denser coverage of ground vegetation in Corkova uvala, especially *Rubus* species, which is highly desired by deer.

Figure 1: Density ($n\ ha^{-1}$) of fir (left) and beech (right) one year old (oy) and older seedlings in different height classes (cm) in Rajhenav and Corkova uvala.



To analyze the variation of direct and diffuse relative radiation within gaps, the plots were classified, separately for the Rajhenav and Corkova uvala forest reserves, into four types (A, B, C, D) according to the prevailing combinations of both radiation components (Diaci 2002). The median values were used as thresholds for the types (Figure 2 left).

Figure 2: Four types of plots according to diffuse (FDIF) and direct (FDIR) radiation values. Lines represent median values for both radiation components (left). The right drawing shows the location of plot types in a gap, where the bold line represents the edge of a gap (e.g. crowns of surrounding trees).

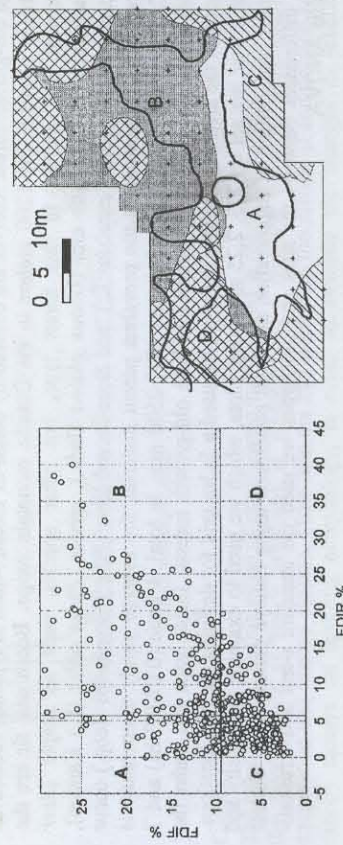


Figure 2 (right) shows the spatial pattern of the four types of plots. The locations of the groups indicate that there is, at least to some extent, a connection between groups defined by radiation and other ecological factors, such as precipitation, temperature, humus decomposition rate, and soil moisture, as they all follow in some way the geometry of the gap

(Diaci 2002, Diaci et al. 2003). We tested the differences among four types of plots separately for both forest reserves.

Table 1: Mean and p values from the Kruskal-Wallis test according to the received radiation (plot types A, B, C, D) separately for the Rajhenav and Corkova uvala old-growth forest reserves. The factors tested were woody regeneration coverage, ground vegetation coverage, density of one year old beech (beechoy) and fir (firoy) seedlings per ha, and density of older beech and fir seedlings per ha.

	A (N = 71)	B (N = 147)	C (N = 147)	D (N = 70)	P
Rajhenav					
regeneration %	63	72	43	48	0,0000
ground vegetation %	17	10	15	13	0,0000
beechoy N/ha	6385	3447	1935	889	0,0001
firoy N/ha	3693	3326	7317	5968	0,0000
beech N/ha	43631	61285	59834	64698	0,0620
fir N/ha	2128	2147	3296	5206	0,0001
Corkova uvala					
regeneration %	21	24	16	17	0,8012
ground vegetation %	46	40	37	31	0,0067
beechoy N/ha	1481	1162	4138	1355	0,5813
firoy N/ha	4444	4394	4342	5908	0,7835
beech N/ha	6584	5707	6079	3957	0,0867
fir N/ha	5322	7677	5977	6179	0,7260

The differences among plot types were significant for all the tested parameters except beech seedling density in Rajhenav. The highest values of regeneration coverage and smallest values of ground vegetation coverage were found in plots receiving the highest values of direct and diffuse radiation (type B), while fir density was the highest in plots with low levels of diffuse and high levels of direct radiation. In Corkova uvala, only ground vegetation coverage was significantly different among the plot types, showing the highest coverage in the plots with high levels of diffuse and low levels of direct radiation. The results of this study show significant differences in abundance of beech and silver fir regeneration between the reserves in the two countries, yet they only partly reveal general patterns of gap regeneration under different light conditions. Therefore, our future research will also focus on other factors influencing natural regeneration development in old-growth Dinaric beech-fir forest, such as browsing impacts and differences in climate and site conditions.

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ARTIFICIAL BEECH REGENERATION IN DENMARK – DEVELOPMENT OF DIRECT SEEDING AND PLANTING METHODS

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Introduction

There is a great need for artificial regeneration of beech (*Fagus sylvatica*) in Denmark. Beech is one of the favourite species in afforestation and in forest restoration in order to rehabilitate more natural forests with higher proportions of natural and more stable species. Most commercial conifer species are exotics in Denmark and they cover about 65% of the Danish forest area. The conifers are generally much more susceptible to windfall than broadleaves.

Presently, timber prices are low and the wood production contributes only little to economic returns in Danish forestry. Particularly beech timber has reached a low level these years. However, timber prices are likely to continuously fluctuate in the future, and periods with high prices are likely to occur. Therefore, many Danish forest owners and forest managers still want to establish and manage beech for high quality timber production.

Common artificial regeneration technique is expensive and usually includes 4-6.000 planted bare-root seedlings per ha. The costs are typically 3-4,500 Euro per ha and additionally a deer fence is needed at some sites (800-1,200 Euro per ha). Such high regeneration costs are difficult to justify, as the future timber value is uncertain. Government subsidies are to some extent supporting present regeneration practises, but such subsidy-programmes may be cancelled and leave forestry in a difficult situation.

Additionally, deer browse is a common challenge in forest regeneration – particularly when broadleaves are planted in conifer plantations. Then even beech is a popular food source for the deer and expensive deer fences are often needed. The deer is very popular among many forest owners, forest visitors, and hunters, and therefore a reduction of deer populations in general is not an attractive option in forest and wildlife management.

Our research aims at developing new and considerably cheaper (700 – 2.000 Euro per ha) artificial regeneration methods without reducing stock densities. We investigate both direct seeding and small containerized stock types for planting.

Successful direct seeding offers potentially higher stock densities at lower costs compared to planting. Direct seeding also includes a higher risk for regeneration failures, and previous research in Denmark and Sweden indicated the need for careful match of species and site when sowing (Løf et al. 2004, Madsen and Løf, 2005). Direct seeding is also viewed as an approach to develop "deer-browse-tolerant" regeneration methods, which involves direct seeding of species mixtures including beech. The densely sown regenerations include fast growing pioneer species, which are attractive to deer. Our hypothesis is that the nurse species improve the establishment of main species by protection against deer browse and late spring frost.

Planting small containerized seedlings in the summer (mid-June to late August) just two-four month after sowing in the nursery is another promising regeneration method to obtain well-stocked regenerations at lower costs. Such small seedlings are produced in nurseries in few

months, and they are easy to handle and plant. Additionally, the so-called 3. generation container types, which are characterized by an overall air-pruning of the roots, support a better root system development than former container-generations and bare-root seedlings (Bentzen, 2003).

Materials and Methods

Since 2002 a number of both planting and direct seeding experiments is established at several sites including both different site types (clear-cuts, shelterwoods, farmland) and soil types.

Planting: 21 planting experiments is established in 2002-05. The experimental approach for the planting experiments has typically been rather simple including only few treatments per species (typically 3-6 species per experiment) and site, e.g. bare-root seedlings versus containerized seedlings or containerized seedling of different container sizes.

The containerized seedlings are all transplanted from the nursery in the first growing season – often in late August – September, whereas the bare-root seedlings are planted according to the best local experience at our host districts, which in most cases was in the spring. By these experiments we mainly carry out a screening of the various seedling types for the most common forest tree species to obtain data and documentation for establishment success of these new plant types in Denmark. Additionally, this work has brought us practical knowledge about the handling and establishment of these plant types, as well as valuable experience and inspiration for the continued development of the whole regeneration approach linked to the small containerized seedlings.

Some experiments are more specialized and focus e.g. on additional aspects like the use of nurse trees (Black alder (*Alnus glutinosa*), Japanese larch (*Larix kaempferi*) or poplar (*Populus sp.*) to rapidly create a protective forest climate for the small seedlings.

Direct seeding: In the period 2002-2006 we have established 32 regenerations by mixed species direct seeding at Store Hjøllund Plantage in the central part of Jutland. This forest estate is almost completely dominated by coniferous species with Norway spruce (*Picea abies*) as the main. Each experimental area ranges from 0,5 ha to 2 ha, and the total experimental area is about 32 ha.

Beech is one of the main species we include at all experimental sites. The other main tree species are sessile oak (*Quercus petraea*), Japanese larch, Douglas fir (*Pseudotsuga menziesii*), sycamore maple (*Acer pseudoplatanus*) and Norway maple (*Acer platanoides*). At half of the sites the nurse species are mixed with the main species. The nurse species are mountain ash (*Sorbus aucuparia*), silver birch (*Betula pendula*) and Scotch broom (*Cytisus scoparius*). Fodder-fields are established and feeding the deer (roe deer – *Capreolus capreolus* - and red deer – *Cervus elaphus*) with sugar beets is carried out to reduce the browsing pressure at the regenerations. Additionally, deer are marked with GSM-GPS-collars to study their preferences for e.g. the regenerations and the fodder fields.

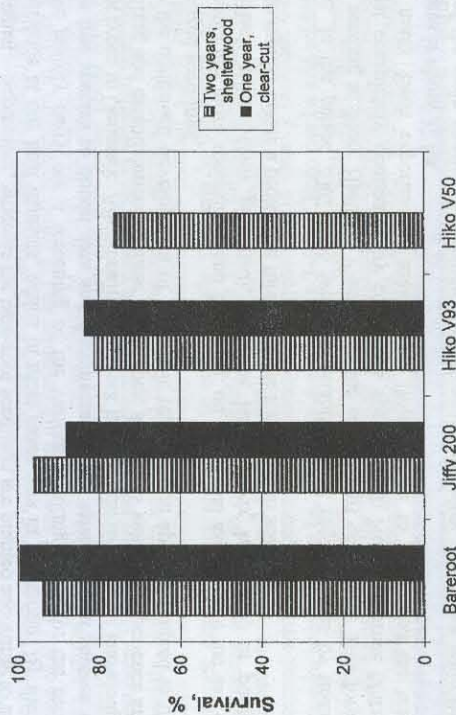
Results and Discussion

Preliminary results and experiences will be presented and discussed.

Planting: Figure 1 presents some of our preliminary results from our first plantings in 2002. The results show decreased survival with decreased container size and that the bare-roots as well as the largest containerized seedlings are performing well. However, we learnt much more than this – e.g. that the planting in September-October probably was too late and caused many problems that can be avoided by earlier summer planting of small seedlings. Experiences will be described and in conclusion the experiments for 2005, 2006 and the years

to come strongly focus on the effects of planting time and relations to e.g. critical weather and soil moisture conditions. So far we have experienced good establishment after summer planting even at dry and warm conditions.

Figure 1. Preliminary results of two beech planting experiments established in autumn 2002 – our first experimental year. Seedling survival after one growing season at a clear-cut site (Lindet Forest District) and after two growing seasons under a Norway spruce shelterwood at Birkebæk Plantation. The containerized seedlings were planted late September till middle of October 2002 and the bare-root seedlings were planted in March–April 2003.
 Jiffy 200: A 200 cm³ Jiffy7® 3. generation overall air pruned container type.
 Hiko V93: A 93 cm³ 2. generation tray system with drainage whole in the bottom.
 Hiko V50: A 50 cm³ 2. generation tray system with drainage whole in the bottom.



Direct seeding: Focus will be on the deer-browse-tolerant regenerations. So far we have seen average stock densities higher than 5,000 seedlings of the main species after two growing seasons. The proportion of beech is 20–70% with the lowest proportion after the 2002 sowing, which was not done completely correct – the beechnuts went too deep into the ground. Regenerations with nurse species hold additionally 36–37,000 seedlings in average of those species. The oldest regeneration from 2002 and 2003 are now in their third and fourth growing season, and the beech seems to be protected well by the nurse species, yet not exposed to too much competition.

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PATTERNS OF GAP DISTURBANCE IN NATURAL BEECH (*FAGUS ORIENTALIS*) FORESTS IN THE NORTH OF IRAN

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Introduction

Canopy openings were defined as canopy gaps considering the area directly under them (Runkle, 1982). In the absence of cutting, gap dynamics is a very important, in fact dominant, form of natural disturbance in some forest types. Several silvicultural systems also mimic natural gap dynamics (for example single-tree selection and small group selection system).

Canopy gaps are important in driving forest dynamics; often they are sites where tree regeneration is occurring (Watt, 1925; Oliver, 1981; Peterken, 1996). In natural forest, gap may be created by obvious discrete events, such as severe wind and heavy snow (Mountford, 2001). However, often gap creation is a more gradual process and arises due to a combination of natural senescence and deterioration induced by aging, competition between trees, more subtle climatic stresses such as drought episodes, and specific pests including insect infestation, fungal disease (Peterken, 1996).

The aim of the present study is to find the patterns of gap disturbance in natural beech forests in the North of Iran.

Materials and Methods

The study performed in Kheyroudkenar forest (36° 40' N, 51° 43' E), in the North of Iran. It has an annual mean temperature and precipitation of 15.8 °C and 1150 mm respectively with 350–1350 in elevation. The soils belong to *Inceptisols* and *Alfisolis*.

Using stratification method in different slopes and aspects, 96 separated gaps in all over the field were selected and survived. These gaps were drawn with Auto Cad software.

In order to determine the gap's shapes, at first the longest and shortest distance within the gaps were measured. Then, by means of these diameters, the area of three regular shapes (diamond, oval, and rectangle) was calculated considering their formula for each gap. Next, the shape coefficient was determined by calculation the real gap's size related to the calculated area for each shape. Finally, the gap is similar to that which its shape coefficient is nearer to one. The direction of the longest axis was considered as the orientation of that gap an eccentricity (the ratio between length and width) up to 1.6 (Diaci, 2002). So the orientation was defined in four classes: W-E, N-S, NE-SW, NW-SE.

The relationship between the orientation and aspect (setting manner) was divided into three phases: parallel, diagonal, and vertical. The gap size was calculated by Cad software. The obtained Data were analyzed by descriptive statistics. Gap frequency distribution was composed considering size of 100 m². The orientation in different aspects and setting manner in slope classes was assessed. Pearson's chi-square goodness of fit test was used for assessing the significant deviations with 95% confidence interval.

Results and Discussion

In this study area, 98 gaps were recorded. Gap size frequency can be explained by log-normal distribution (figure 4). Gap size ranges from 16 to 667 m² with an average of 217 m² and a median of 172 m². The maximum of gap frequency is reached within the 100 m² size. Gaps up to 300 m² are about 81% of gaps recorded.

Shape frequency distribution is shown in figure 1. Diamond and oval are dominant shapes and rectangle shape represents the minority. Diamond and oval deviate significantly from rectangle.

The orientation-aspect graph (figure 3) illustrates in northern-facing slopes, NE-SW and N-S were majority. In other directions, there is no significant difference between the orientations. Diagonal and parallel manner represent the majority while the vertical manner are underrepresented. Statistical test confirms this difference.

Setting manner frequency in slope classes (figure 2) reveals that in 0-20% class, the most frequency belongs to the diagonal manner. In 20-40% class, there is no significant difference. In 40-60% class, we have no vertical manner at all.

More than 60% of gaps were formed by uprooting (as a main cause) and stem breakage (by fungus and wind). Gap size frequency confirms that most of gaps had small area. It indicates that regeneration is always established on small gaps. Based on this result, gap size should be large enough for light-demanding trees to regenerate. The average area of gaps and their distribution pattern in stands can be used to stand structure management.

The average area of gaps and their distribution pattern in stands can be used to stand structure management. The elements of the forest management system are knowledge in related to gap formation and operating with in natural gap size ranges. Therefore, harvest gap should be similar size distributions to frequent natural size distributions and according to the patterns of gaps disturbance in this study, gaps up to 300 m² can be created by harvesting for establishing of natural regeneration.

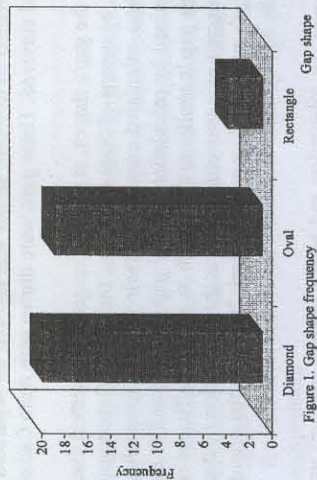


Figure 1. Gap shape frequency

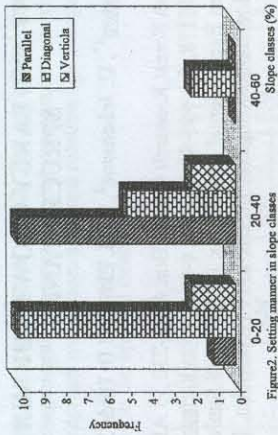


Figure 2. Setting manner in slope classes

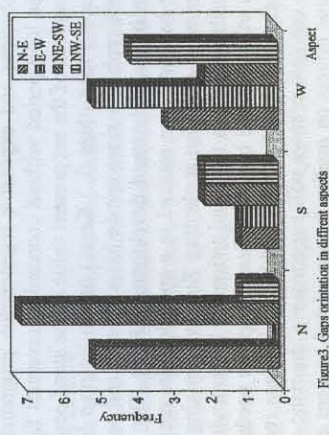


Figure 3. Gaps orientation in different aspects

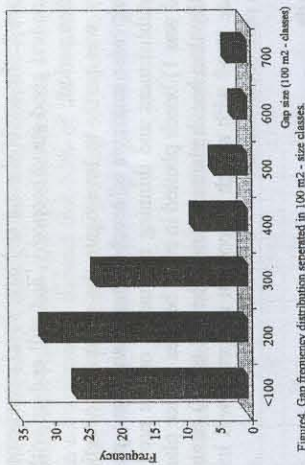


Figure 4. Gap frequency distribution separated in 100 m² - size classes.

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ESTABLISHMENT AND EARLY GROWTH OF MIXED BEECH AND SPRUCE STANDS

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Introduction

When establishing new beech (*Fagus sylvatica* L.) stands after clear-felling, forest managers are often faced with laborious and expensive regeneration programs and slow early stand growth. Furthermore, the long period without economical revenues from commercial cuts is disadvantageous in estimations of the net present value of the stand economy. Mixed stands of beech and Norway spruce (*Picea abies* (L.) Karst.) has in Sweden been put forward as an alternative to reduce these problems since spruce has a cheaper and easier regeneration and a better economical return in the early stand development (REF). The demand for rationality from the forestry sector has moreover resulted in a specified alternative with systematically mixing the tree species row- or stripwise at planting. Row-wise mixing means simple planting instructions and the possibility to thin the stand rationally by removing complete rows. The different growth rhythm of spruce and beech implies that spruce needs to be thinned in order to not out-compete the closest beech trees. Since this will be done row-wise, the beeches in the rows closest to the cut spruce rows will experience a dramatic change of competition which may cause negative effects on quality factors related to stem straightness, branching, forking, etc. Another question related to mixed beech-spruce stands is how balance the proportion of the species in the establishment and later stand management in order to achieve a high wood production and good stand economy, and still end up with a beech stand at the later phase of the rotation period.

The aim of this study was partly to investigate the volume production and wood quality effects on beech of strip-wise mixtures of beech-spruce plantations, partly to investigate the effects of different establishment and thinning treatments on the production economy. The hypothesis to be tested was 1) beech planted in rows besides spruce planted in rows develops into poorer wood quality than beech planted besides beech, and 2) establishing and managing the mixed beech-spruce stand with a high proportion of spruce will improve the production economy compared to pure beech stands.

Materials and Methods

The experiment was established on four sites in Sweden and four in Denmark. The sites were planted in 1981 and XXX, respectively. The treatments were applied on plots according to table 1. The distances between the planting rows were 1,7 m as the spacing within the spruce rows whereas the spacing within the beech rows were 0,9 m. The planting of beech was done under a shelter-wood of larch which was finally removed 1993. All spruce rows bordering to the beech rows were thinned in 2000/2001.

In 2000 (and 2006), the following variables was assessed through inventories on subsample plots; diameter, occurrence of quality defects and wood quality estimations on all trees, and height on sample trees. The wood quality was assigned tree-wise to any of the four classes; A-desirable future crop tree (FCT), B-possible FCT, C-not possible as FCT or W-wolf tree. The data was used in the growth simulator ProdMod (Ekö, 1985) to forecast the stand growth. The two mixed stand treatments differing mostly in the amount of beech and spruce were chosen

for simulation of growth, i.e. treatment 6 and 7. The growth of these two treatments was simulated with two management programs; one where spruce was removed from the stand early (1) and one where spruce was grown a normal rotation age for spruce stands (2).

Table 1 The tree species in the applied treatments

Treatment	1	2	3 ¹	4 ¹	5 ¹	6 ¹	7 ¹
Tree species mixture	pure beech	Pure spruce	3 r.b.+ 3 r.s.+ 3 r.b.etc.	3 r.b.+ 4 r.s.+ 3 r.b.etc.	3 r.b.+ 5 r.s.+ 3 r.b.etc.	4 r.b.+ 3 r.s.+ 4 r.b.etc.	5 r.b.+ 3 r.s.+ 5 r.b.etc.
Prop. of b.r.	1	-	0,50	0,43	0,38	0,57	0,63
Prop of b.r. next to s.r.	-	-	0,67	0,67	0,67	0,50	0,40

r, denotes rows, b denotes beech and s, denotes spruce

Results and Discussion

Growth and quality development

The stand growth of the different treatment was similar up to the year of 2000 (Table 2). Exceptions are lower survival of beech in some treatments, particular in treatment 3. This was mainly caused by vole damages. No effects of the treatments on the growth, as reflected in diameter or height, on either beech or spruce could be seen. However, basal area and volume differed due to different stem densities. In all treatments the spruces were larger than the beeches (27-50 dm higher and 6,4-7,4 cm larger in diameter) but no clear tendency related to treatments could be observed.

The quality of beech was similar in the treatments and the percentage of stems which could be used as FCT (class A and B) varied between 49% and 57%. Since the treatments differed in the proportion of beech which grows next to spruces (Table 1), the expectation was that treatments with a high proportion of beech rows next to spruce rows should have an inferior quality due to a less effective quality training from competition of spruce. This was however not visible in the treatment effects. However, a specific analysis of the quality of beech rows next to spruce rows, in all treatments, showed that 52% of the beeches belonged to class A and B. The corresponding figure for beech rows growing only next to other beech rows was 56%. It was a small effect which was not statistically significant and gave no support for the first hypothesis.

Table 2 Stand characteristics in the mixed stand treatments in year 2000.

Variable	Tree sp.	3	4	5	6	7
Stem dens. (n ha ⁻¹)	Beech	1578	2543	2308	3039	2842
	Spruce	1614	1786	1916	1321	1147
Survival (%)	Beech	48	91	94	81	70
	Spruce	99	96	94	94	94
Diameter (cm)	Beech	4,6	4,9	5,6	5,4	5,6
	Spruce	11,5	11,2	13,0	11,8	12,0
Height (dm)	Beech	68	61	73	87	82
	Spruce	95	111	112	116	117
Basal area (m ² ha ⁻¹)	Beech	2,6	4,9	4,5	7,1	6,9
	Spruce	16,8	17,7	19,8	14,4	12,9
Volume (m ³ ha ⁻¹)	Beech	10,0	16,3	16,0	27,8	26,4
	Spruce	76,7	91,4	105,6	78,6	71,0
Quality of beech (%)	A	11	24	18	23	22
	B	38	33	39	29	33
	C	50	42	40	47	43
	W	1	1	3	1	2

EFFECTS OF CANOPY OPENING ON CARBON BALANCE AND HYDRAULIC CONSTRAINTS IN NATURALLY REGENERATED FAGUS SYLVATICA AND ACER PSEUDOPLATANUS SEEDLINGS

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Introduction

Beech (*Fagus sylvatica* L) and sycamore (*Acer pseudoplatanus* L) are often found in mixture in the forests of western and central Europe. Natural regeneration is the usual regeneration scheme for these mixed beech-sycamore stands. During the first stages of the regeneration process, seedlings grow under the canopy of adult trees which are progressively removed.

Low light intensities under the forest canopy limit severely growth and survival of tree seedlings. The current consensus is that shade tolerance results from a complex interplay between several traits involving seedling architecture, growth dynamics, carbon gain capacity and carbon balance at individual level, all contributing to seedling survival under low irradiance (Givnish 1988, Messier et al. 1999, Walters and Reich 1999). One of the components of shade tolerance resides in the ability of individuals to optimise carbon gain under low light environments, by maximising light interception and use of the intercepted light, while minimising carbon loss by respiration (Walters and Reich 1999, 2000). Plants in shade have higher light interception efficiency (Sterck, 1999). The photosynthetic capacity of leaves is known to display a large plasticity in response to different levels of irradiance, characterised by a large variety of structural and physiological changes including increased carbon assimilation and respiration, and greater reserve content (Kobakowski et al. 2003, Gansert and Sprick 1998). In addition, seedlings grown in shade show low hydraulic conductance and high xylem vulnerability to cavitation (Shumway et al. 1993, Cochard et al. 1999). Shade-exposed seedlings express a series of morphogenetic, hydraulic and trophic constraints.

Following canopy opening, changes in microclimatic conditions induce morphogenetic, hydraulic and trophic alterations that might affect seedling carbon balance. The objective of the present study is to assess the responses of naturally regenerated seedlings of beech and sycamore during two years following canopy opening, in terms of growth dynamics and ecophysiological traits. The following hypotheses were tested: (1) canopy opening induces higher height and diameter growth, as shown by Collet et al. (2002); (2) this higher growth is associated with higher assimilation and transpiration of seedlings and with changes in hydraulic traits; (3) the acclimation to high irradiance levels takes several growing seasons.

The results of growth and quality performance up to year 2000 gave no support that it should be important to choose one of the different row mixtures. Keeping the number of aggregated beech rows at a minimum of three rows, it should be possible to have many spruce rows in between. The limit of the number of spruce rows is probably rather set by the minimum distance between beeches in different row aggregations when the last spruces are cut, and the stand should be transformed to a pure beech stand. In treatment 5, which have five spruce rows between the beech row aggregations, this distance is 10,5 meters. This may probably be the maximum distance which could be allowed if a relative symmetrical competition on the crop trees is needed.

Production economy

The growth simulations showed that alternatives with five spruce rows (treatment 5) instead of three (treatment 7), almost doubled the average growth of spruce (Table 3). Keeping the spruce to the age of a normal rotation period (alt.:2) almost tripled the standing volume of spruce at the final cut compared to a cutting 25 years earlier (alt.:1). The implication of this on the Net Present Value is that the alternative 5:2 produces the highest value, and are furthermore the only alternative with generates an income with used interest rate. This results hence supports the second hypothesis. It should however be highlighted that possible effects on the wood quality of beech in the later stand development could not be included. Keeping a higher proportion of spruce in the mixture also imply more complicated management.

Conclusions

The results from this study show that row-wise mixture of beech and spruce can be a commercially interesting option for establishing beech stand on areas previously occupied by e.g. conifers.

Table 3 Growth simulations and economical calculations of treatments 5 and 7 with two stand management options with an early final cut (1) and a later (normal) final cut of spruce (2).

	5:1	5:2	7:1	7:2
Total age (year)	Beech 119	119	119	119
	Spruce 44	69	44	69
Dominant height¹ (meters)	Beech 29,8	29,8	29,8	29,8
	Spruce 21,2	28,9	21,2	28,9
Volume¹ (m3 ha-1)	Beech 322	339	367	344
	Spruce 114	274	142	319
Average growth (m3 ha-1 year-1)	Beech 6,3	5,9	6,7	6,4
	Spruce 9,9	8,0	5,4	5,9
Net Present Value² (SEK)	-127	7478	-16843	-9403

¹ Calculated at time for the total age given above for beech and spruce, respectively.

² The interest rate in the calculations of the Net Present Value was 2%.

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Materials and Methods

In a deciduous stand of North-eastern France (Graouilly forest, Moselle), two mixed regeneration patches containing beech and sycamore seedlings and located under closed canopy were selected. Seedling height ranged between 10 cm and 1 m. In January 2005, each of these plots was split in two subplots, one remaining under shade, while the canopy over the other one was removed. A third plot was further selected in a several-year-old gap.

In each species, ten seedlings under canopy (shade seedlings, S), ten in recent gaps (shade to light seedlings, S->L) and three in the old gap (sun seedlings, L) were sampled for ecophysiological measurements.

Relative light intensity reaching the plants was estimated by analysing hemispherical photographs, and seedling 3D architecture was reconstructed after digitizing the seedlings. This enabled to estimate interception of photosynthetically active radiation (PAR) and to simulate seedling photosynthesis and carbon balance. Light-saturated assimilation and stomatal conductance were recorded monthly using an open gas exchange system (LiCor Li6400).

Hydraulic properties were assessed by leaf specific conductance (measured with a high-pressure flow meter, HPFM) and xylem vulnerability to cavitation (measured with a centrifugation technique developed by Cochard et al. (2005)).

Height and diameter of beech and sycamore seedlings growing in gap or under closed canopy were measured on a total of 3415 seedlings in March and December 2005.

Linear mixed effect models with plot as random effect were fitted to test for canopy opening and species effects.

Results and Discussion

Beech and sycamore exhibited an immediate reaction to canopy opening. For sycamore seedlings, mean annual seedling height and diameter increments were 2.42 cm and 0.95 mm respectively one year after canopy opening and 1.45 cm and 0.50 mm respectively under canopy. For beech, height and diameter increments were 5.53 cm and 1.83 mm respectively in gap versus 3.37 cm and 0.54 mm respectively in shade.

During the first year after canopy opening, PAR interception efficiency did not change significantly in both species. But seedlings of beech exhibited a slight increase of light-saturated CO₂ assimilation (Asat reached 7.10 $\mu\text{mole m}^{-2} \text{s}^{-1}$) and stomatal conductance (gsat reached 0.14 $\text{mole m}^{-2} \text{s}^{-1}$), compared to seedlings that remained under close canopy (S plants, Asat and gsat were 5.52 $\mu\text{mole m}^{-2} \text{s}^{-1}$ and 0.10 $\text{mole m}^{-2} \text{s}^{-1}$ respectively). However, for both species, the rates remained much lower than those of sun-acclimated seedlings (L plants, Asat and gsat were 13.59 $\mu\text{mole m}^{-2} \text{s}^{-1}$ and 0.37 $\text{mole m}^{-2} \text{s}^{-1}$ respectively for beech). In addition S->L beech seedlings, contrary to sycamore, show higher stem hydraulic conductance (7.10⁻⁴ versus 2.10⁻⁴ $\text{kg s}^{-1} \text{m}^{-2} \text{Mpa}^{-1}$ in average) and higher xylem vulnerability to cavitation than S seedlings. The xylem water potential level producing 50% loss of hydraulic conductivity (PLC50) is higher in S->L plants than in S plants (-3 Mpa versus -4.07 Mpa in average). This results suggested that hydraulic constraints remained high in S->L seedlings. Indeed in the newly created gaps, air evaporative demand was higher leading to higher transpiration rate, compared to the shaded seedlings (S seedlings). However, we show that assimilation and stomatal conductance remained weak compared to seedlings in old gaps (L seedlings). The maintenance of xylem integrity, through stomatal aperture control, might impose a limitation to maximum plant transpiration rates (Cochard et al. 1996, Jones and Sutherland 1991).

Asat and gsat of seedlings from the opened plots (S->L plants) decreased from July to September in both species. This variation was amplified in seedlings from the opened area plots. At the same time, the rate Asat/gsat decreased, suggesting a biochemical limitation of photosynthesis (Grassi and Magnani 2005).

In a next step we will estimate interception of PAR from hemispherical photographs and 3D architecture of seedlings and then simulate saplings photosynthesis and their carbon balance. These simulations will be further compared to measured whole plant gas exchange.

In conclusion, the first year after canopy opening, seedling height and diameter growth were enhanced. However net CO₂ assimilation and transpiration increased slightly compared to S plants. This might be linked to persistence of hydraulic constraints. Then, light acclimatisation would take more one growing season.

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GROWTH AND SURVIVAL IN TRANSPLANTED BROADLEAVED SEEDLINGS IN RELATION TO LIGHT UNDER NORWAY SPRUCE STANDS

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Introduction

European temperate broadleaved forests used to cover much larger areas than today and restoration of these forests has been emphasized to obtain sustainable forestry (Hannah et al., 1995; Stanturf and Madsen 2002). One type of restoration activity is conversion from Norway spruce to broadleaves, and there is a discussion whether how much of the widespread homogenous Norway spruce forests should be converted back to more natural broadleaved forests. Such conversion has also been put into practice over large areas.

In achieving conversion, underplanting of especially European beech (*Fagus sylvatica* L.) beneath Norway spruce shelterwoods or in small gaps is regarded as an alternative to management systems based on clear-cutting. Underplanting is an old silvicultural method that lately has attracted new attention (Otto 1986; Zerbe 2002). However, little research have been done, which address the constraints for forest conversion through planting of beech under Norway spruce shelterwoods or in small gaps. Moreover, little is known concerning alternative tree species to beech. For adjusting the density of shelterwoods to the various tree species, more information is needed concerning survival and growth in various tree species in relation to different light regimes.

Materials and Methods

The experiment was established in 2001 at a site dominated by Norway spruce in southern Sweden and the spruce forest was 40-years-old when the experiment started. The experimental design was randomized blocks with sub-plots (split-split plots). Four blocks were laid out with four shelterwood treatments in each block. The treatments were: Untouched control shelterwood, dense shelterwood, sparse shelterwood and a clear-cut area or gap. Stand data in each treatment is presented in Table 1.

Table 1. Stand data in each of the four shelterwood treatments. Mean ± SE. For percent light above canopy level (PACL), minimum and maximum relative light levels are shown.

Shelterwood treatment	Number of stems, hectare ⁻¹	Tree height, m	Relative light, % of PACL
Control	494 ± 47	19.0 ± 0.7	1.5 - 14.1
Dense	538 ± 24	20.4 ± 0.1	3.8 - 19.1
Sparse	294 ± 33	19.0 ± 0.5	9.4 - 30.4
Clear-cut	0	-	41.5 - 76.9

Each of the four shelterwood treatments was 20 x 20 m with a 10-m buffer zone in each direction. Each shelterwood treatment and block consisted of two insecticide treatments (sub-plots), each sub-plot including seven rows of different tree species. The insecticide treatments were: No insecticide treatment and insecticide treatment (permethrin). The seven tree species

were planted in species-separated rows of 20 seedlings in each row (sub sub-plots). Thus, each shelterwood treatment consisted of 14 rows of seedlings. The tree species were ash (*Fraxinus excelsior* L.), beech, lime (*Tilia cordata* Mill.), maple (*Acer platanoides* L.), Norway spruce (*Picea abies* L. (Karst.)), oak (*Quercus robur* L.) and wild cherry (*Prunus avium* L.). All blocks were fenced against large herbivores.

The seedling height (stretched length) was measured in all living seedlings in the beginning of October in 2001, 2002, 2003 and 2004. Soil water content (TDR-technique), air temperature and humidity, precipitation, photosynthetic photon flux density (PPFD) were measured continuously during the four growing seasons. Light availability under the canopy was also estimated using hemispherical photographs. In order to account for size-related variations, the mean relative growth rate in length (R_L , year⁻¹) was calculated for the 2004 growing season. R_L was calculated using the formula:

$$[1] \quad R_L = (\ln(L_2) - \ln(L_1)) / (t_2 - t_1)$$

where L_1 and L_2 denote seedling height at the end of the previous growing season and at the beginning of October in 2004 and $t_2 - t_1$ is one year.

Results and Discussion

Average relative light levels in the various shelterwood treatments were 4%, 11%, 19% and 68% for control, dense, sparse and gap respectively. However, there was a large variation in relative light within each treatment (Table 1).

Only beech and lime obtained a positive relative growth rate in the control treatment (Figure 1). The same tree species also had the best survival in this treatment (data not shown). Something that corresponds to earlier findings on shade tolerance during conversion (Lüpkke et al. 2004). However, both tree species grew better in the dense shelterwood why approx. 11-19% relative light would be appropriate for the species.

Especially oak showed a negative relative height growth in the control treatment. A positive relative growth rate was only obtained in the gap. The other three species showed a tendency for better growth with increased light (Figure 1).

Light is probably the most limiting factor for underplanted seedlings, but with changes in light changes in soil recourses also follow. In the present study we have found that soil water content decrease with increasing number of shelterwood trees during dry periods (data not shown). Thus, the underplanted seedlings experience not only limitation in light but also limitation in available soil water and nutrient supply.

Another factor that seldom is taken into account during studies on the adaptance of various tree species to light is the influence from mammalian and insect herbivores (Löf et al. 2005). In the present study mammalian herbivores were excluded due to the fence and the influence on growth was little from insect herbivores (Figure 1). However, there was a tendency for better growth when seedlings were treated with insecticide in the control treatment, especially for oak.

BEECH UNDERPLANTING UNDER NORWAY SPRUCE SHELTER – SOME RESULTS FROM SUSTMAN-PROJECT

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Introduction

Teuffel et al. (2004) have estimated that pure Norway spruce (*Picea abies* L. Karst.) stands occur in Europe at least on 6 to 7 million hectare outside of the natural spruce range. 4 to 5 million hectare of it are located on sites that would naturally be dominated either by broadleaved or mixed broadleaved-conifer forests. In many cases these Norway spruce forests have proven to be unstable and have suffered from forest decline, windthrow, pest outbreaks, drought and soil deterioration. Together with a decreased public acceptance of spruce monocultures and the probability of increasing climate extremes, especially such as storms, as a consequence of the climate change, these are reasons for conversion of such stands back to the naturally occurring, in central Europe beech (*Fagus sylvatica* L.) dominated forests. (Oleskog and Löf 2005)

Especially converting pure Norway spruce stands by underplanting with beech have been a major silvicultural challenge in Europe during the last decades. The EU-project SUSTMAN ("Introduction of broadleaved species for Sustainable forest Management"; within the 5th framework) has carried out research in this issue over three years till 2005.

Materials and Methods

The design of the experimental site (8,5 ha) in the Harz Mts. was established in 1991. The spruces have had an age of 71 at that time. The stocking degree on half of the area was lowered to 60%. Beech was planted after preparation and liming with a spacing of 1,5 x 1 m and 3 x 2 m.

To enlarge the degree in shading, five different thinning variants (oriented on the basal area) were practiced:

- 1) No thinning since planting (100 % of basal area)
- 2) Thinning 1991 (80%)
- 3) Thinning 1999 (80%)
- 4) Thinning 1991 + 1999 (65%)
- 5) Thinning 1991 + 1999 (55%)

At one edge of the site a gap occurred, so that there were even almost open field conditions for some of the young beeches.

Most measurements were done in the years 2003 / 2004. At this time the spruces were 84 and the underplanted beeches 16 years old. 50 beeches – all of them were dominant trees – were chosen for the investigation, which comprised different growth and quality parameters like height, diameter, crown volume, branch diameter and branch angle, inclination of tree top, leaf area, weight of dry biomass and many more. Most of these measurements were separately done in five different tree layers of same relative length (tree height divided by five). To complete and enlarge the gradient in light conditions another 20 beeches were selected and measured in spring 2006.

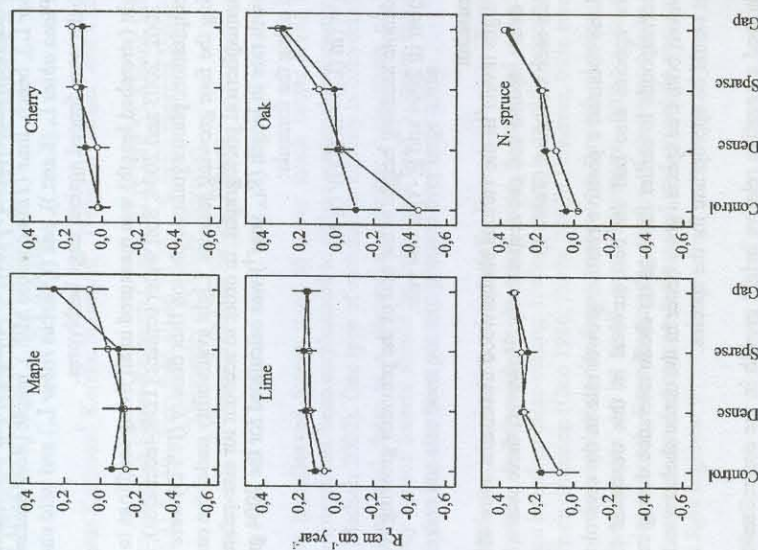


Figure 1: Relative growth rate in length 2003 to 2004 in maple, cherry, lime, oak, beech and Norway spruce, four blocks and four shelterwood treatments. Filled symbols denote permethrin treated seedlings and open symbols not treated seedlings. Ash is excluded in the figure. Mean \pm SE.

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Hemispherical photography was used to quantify the canopy closure above each investigated beech and these images were analysed with WinScanopy-software. Distances to neighbouring beeches and their heights were measured to quantify the competitive situation.

Results and Discussion

The light conditions for the growth of the investigated beeches were measured as a gradient from around 15 up to over 70 % ISF (Indirect Site Factor). This value quantifies the amount of incident indirect (= diffuse) radiation that penetrates below canopy in relation to open field or above canopy conditions.

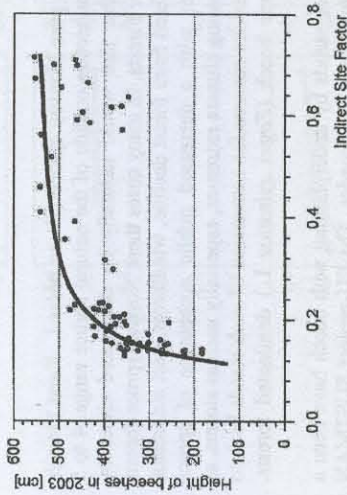


Figure 1: Relation between height growth of the investigated beeches and their light conditions

The non-linear relation between height growth of young trees and the incident radiation is described in literature very often (Mossandl 1984, Brunner 1993, Sagheb-Talebi 1996).

Lüpke and Hauskeller-Bullerjahn (2004) used for their investigation the photosynthetic active radiation (PAR), but found a similar correlation. They compared the shape of the curve with the shape of a light compensation curve. "The PAR-value, which showed no height growth at all, could be calculated by extrapolating the model functions, and was regarded as the compensation point of height growth. It amounted ... with beech to 5,3 % of open field radiation." This value was determined for eight year old beeches under beech canopy.

The own results (Fig. 1) also remind of the shape of a compensation curve, just above 50 % ISF the spreading is getting too large to give a clear picture of the curve.

The main focus of the further analysis will be the quality aspect. First attempts to combine the results from the measurements of branch diameter, branch angle, inclination of the tree top and the stem form to a kind of "quality index" led to figure 2. It's still not a satisfying result and the index will still be modified, but it might give a first idea of the probable relation between quality and light in this experiment.

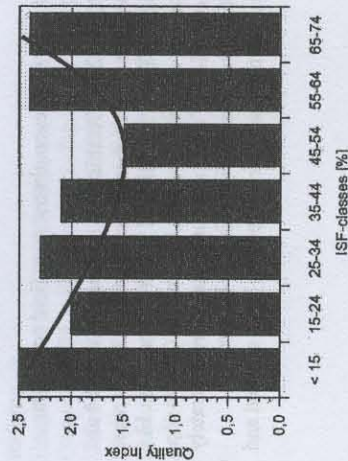


Figure 2: Quality (branchiness, stemform, inclination of tree top) of the investigated beeches in relation to their light conditions. A high value for quality index is equal with poor quality.

The further aim of analysing work will be the connection between the information from figure 1 and 2 to find a compromise between fast height growth and good quality. The influence of the competitive situation for the beeches will be still analysed as well.

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QUALITY ASPECTS OF ADVANCED-PLANTED BEECH IN SPRUCE STANDS UNDER A VARYING COMPETITION REGIME

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Introduction

In Germany, during the past 20 years mature pure spruce stands have been often converted with beech in order to maintain or improve economic and ecological sustainability of forests (Oleskog and Löf 2005, Fürst et al. 2004). The resulting shift in the supply of wood for future markets requires amongst others timber of high quality. To reach this goal, such stands need a special management of the spruce shelter and of the beeches themselves.

By now, there is a lack of knowledge how the combination of the inter- and intraspecific competition regime affects special quality parameters of advance-planted beeches (v. Lüpke 2005).

Hence, the objective of the present study is to quantify the combined competition effects of the Spruce shelter *Picea abies* (L.) Karst. and beech neighbours *Fagus sylvatica* (L.) on the quality of target beech trees with the help of different competition indices.

Materials and Methods

The study sites are located in North-Rhine Westphalia, Germany, 350-550 m a.s.l. on sites with a moderate nutrient supply and a subatlantic climate (mean annual precipitation 1000 mm, mean annual temperature 6°C). Within 9 stands of varying density of the spruce shelter (aged 66-104 years) and beech regeneration (aged 8-20 years), the research areas were established. At these areas, the positions of the shelter trees were mapped and crown and tree parameters were measured. The beech trees were classified according to quality classes based on crown and stem shape. This population of understorey trees provided the basis for a stratified sample of 154 randomly selected target beech trees from the upper sociological classes. The sample covers a height range of 1,68m till 11,70m and 4 quality classes. By measurement, the subsequent quality parameters have been derived from the target trees: (i) the height from bottom to the first living branch *h/b* [m] which corresponds to the length of the branch free bole, (ii) the ratio between the dbh and the diameter of the thickest living branch *asix* and (iii) the forking height *hf* [m] of the stem axis. The interspecific competition regime has been quantified through the indices of Nagel (1999) *CE_C66* and Hegyi (1974) *CE_H*. The modified index of Pretzsch (1995) *CI_P* and the one of Biging and Dobbertin (1992) *CI_BD* include the intraspecific neighbour influence.

Model

The competition indices were linked to the quality parameters by fitting linear and nonlinear regression equations to the data. Additionally, the single effect of each index contributed to the prediction of the quality variables by the method of potential curves. Therefore, the *CI*'s and *CE*'s were divided in equidistant classes, respectively. Because most indices showed L-shaped distributions, the lower classes were subdivided once or twice (Spelchna et al. 2005). Within these classes, the upper 20, 10 or 5 percent were selected to calculate the median of the quality variable and the competition index, respectively.

Results and Discussion

Regression Analysis with single competition effects

The single competition effects on the quality variables *qv* were evaluated for each *CI* and *CE* after the subsequent linear and nonlinear regression types in equation 1 till 4.

$$[1] \quad qv = a_0 + a_1 * CI$$

$$[2] \quad qv = a_0 * \text{EXP}(a_1 * CI)$$

$$[3] \quad qv = a_0 * \text{EXP}(-a_1 * CI)$$

$$[4] \quad qv = a_0 * (1 - \text{EXP}(-a_1 * CI))$$

Table 1 shows the results of the best fitted linear and nonlinear functions for each quality variable. The models were checked carefully for high correlations of parameters in order to reduce their amount within a model.

Table 1: Results of the linear and exponential fitting of each quality variable and competition index, separated after the potential-curve (p) method and the original data.

Quality Variable	Competition Index	Parameter estimates				Model	
		a ₀	a ₁	a ₂	Type	r ²	
<i>h/b</i> n=154	<i>CI_P</i>	0,470	4,580		1p	0,88	
	<i>CI_P</i>	0,085	4,260		1	0,79	
	<i>CI_BD</i>	2,953	2,690	1,720	4p	0,51	
	<i>CI_BD</i>	1,143	4,927		4	0,23	
	<i>CE_H</i>	5,171	12,879		3p	0,93	
	<i>CE_H</i>	2,735	37,647	0,320	3	0,34	
	<i>CE_C66</i>	5,615	2,563		3p	0,68	
	<i>CE_C66</i>	2,655	2,422		3	0,21	
	<i>CI_P</i>	161,280	17,142	54,958	3p	0,89	
	<i>CI_P</i>	100,532	2,699		3	0,44	
<i>asix</i> n=154	<i>CI_P</i>	96,172	39,850	61,050	3p	0,89	
	<i>CI_BD</i>	44,331	368,348	50,689	3	0,38	
	<i>CE_H</i>	58,890	216,590		1p	0,80	
	<i>CE_H</i>	46,780	171,500		1	0,74	
	<i>CE_C66</i>	61,282	0,920		2p	0,60	
	<i>CE_C66</i>	25,100	87,580		1	0,30	
	<i>CI_P</i>	4,212	3,518	2,528	4p	0,86	
	<i>CI_P</i>	2,770	6,930	1,465	4	0,49	
	<i>CI_BD</i>	3,226	8,777		4p	0,42	
	<i>CI_BD</i>	2,478	-0,743		3	0,12	
<i>hf</i> n=92	<i>CE_H</i>	4,706	9,313	1,745	3p	0,90	
	<i>CE_H</i>	3,577	2,143		3	0,35	
	<i>CE_C66</i>	2133,000	0,001	-2127,000	4p	0,32	
	<i>CE_C66</i>	4,151	0,798		3	0,15	

Regression Analysis with the combined competition effects

The residuals of the best suited nonlinear regression equations (Table 1) have been checked for relationships with the *CI* or *CE* for each quality variable. The following models show the combined competition effect between shelter density and competition within the understorey:

SOME CRITERIA OF REGENERATION DENSITY IN YOUNG BEECH POPULATIONS

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Introduction

The competition between trees, in particular in seedling and sapling stages, is an important issue from silvicultural point of view. The competition in multistoried mixed stands is interspecific, whereas in pure stands is intraspecific and it strongly depends on age of trees and structure of the stands (Nyland 1996, Otto 1994). Competition for light, water and nutrients depends largely on the stem number per unit area and the crown form of the trees. Crown classes illustrate the results of intense competition in the stands. One result of competition among plant species of the forest is the development of vertical structure of the vegetation (Barnes et al. 1998).

A suitable density of saplings could improve the quality of the young populations, which would produce a valuable stand later. Distribution of saplings over the regeneration area and its homogeneity is a factor that should be considered by foresters during tending and thinning operations for density regulation. Although there is usually no special spatial distribution pattern of regeneration, but in most cases it could be considered a quadratic or triangular pattern existing among the saplings (Schütz 1990). Various measures of stand density or competition criteria have been developed; among them the crown competition factor (CCF) is introduced as a very applicable factor. (Schütz 1984) showed a clear relationship between stand density and crown reaction of Douglas-fir trees, which varied between 1.0 and 1.8. He added that this criterion could offer different thinning opportunities, which is correlated with crown diameter and stem number in the stand. Allgaier (1991) found a CCF of 1.4 in her studied mixed natural regeneration in Fennel-gap. For beech saplings, she found a rate of 0.3 and clarified a significant relationship between CCF and exposition within maple and ash regeneration.

The objective of the present investigation is to study the competition of beech saplings within the regeneration area, which could be applicable in further silvicultural operations for arrangement of density in young beech stands.

Materials and Methods

Beech saplings was studied in various forest associations (mainly *Gailito odorati-Fagetum typicum*) growing in the submontane region near Zurich (Swiss Central Plateau). The sample plots were established in regeneration gaps resulting from Swiss irregular shelter wood system (Femelschlag). Number of saplings and Crown Diameter (CD = distance between the tip of the longest branches) of each beech sapling were assessed within 2*2m sample plots, that were laid out from the center to the edge of the gap and under the old growth stand as well.

Three collective criteria (a, b and c) and one individual criterion (d) was investigated within the sample plots as following:

- a) Number of saplings per square meter (N)
- b) Mean Distance of Saplings (MDS), calculated in ha by using of equation [1] (Schütz 1990) as following:

$$MDS^2 = (10'000 \cdot 2\sqrt{3}^{-1}) N^{-1} \Rightarrow MDS = 107.5 (\sqrt{N})^{-1} \quad [1]$$

[5] $hib = a_0 * EXP(-a_1 * CE_H) * CI_P$
 [6] $asix = (b_0 + b_1 * CE_H) * a_0 * EXP(-a_1 * CI_P)$
 [7] $hf = EXP(-b_1 * CE_H) * (a_0 * (1 - EXP(-a_1 * CI_P)) + a_2)$

Table 2 gives an overview of the parameters and the goodness of fit.

Table 2. Parameter estimates of the combined competition effect on quality variables of the target trees

Quality Variable	n	Model r ²	Parameter estimates			
			a ₀	a ₁	a ₂	b ₀ b ₁
hib	154	0,78	4,505	0,393		
asix	154	0,78	2,870	0,915	20,427	51,479
hf	92	0,51	2,338	6,336	1,996	0,809

The results from Table 1 clearly show that the method of potential curves is superior to the fit of the original data in all cases and suited to clarify trends when variation in the data is high. For the majority of relations, exponential functions could be applied.

Except of the *asix* variable, the index of Pretzsch (1995) *CI_P* is more appropriate for prediction than the one of Biging and Dobbertin (1992) *CI_BD*. The same is true for the index of Hegyi (1974) *CE_H* which is a better predictor than the one of Nagel (1999) *CE_C66*. One important fact is, that the intraspecific indices include a different collective of competitors because of a more restricting modus of neighbour-identification in the case of the index of Biging and Dobbertin (1992).

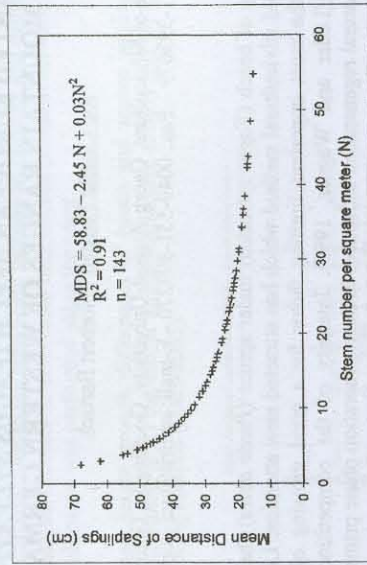
Obviously, the length of the branch free bole and the forking height increases with greater intraspecific competition whereas the relation of branch diameter to dbh decreases (see model types in table 1). For each quality variable, a successively more dense shelter implicates the opposite response of the target trees.

The combination of the competition reveals a different strength of the effects (see table 2). In the case of the branch free length of the bole, the linear component *CI_P* has a greater impact as the *CE_H* has. For the *asix* value, the interspecific component *CE_H* is of more influence. The forking height is mainly determined by the intraspecific index of Pretzsch (1995). For further investigation, other functions can be fitted to the data. Another aspect could be the modification of the L-shaped distribution of the competition indices into uniformly distributed ones by an extended sample.

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Figure 1: Relationship between stem number (N) and mean distance of saplings (MDS) within the sample plots.



Offering enough growth space for developing the crown and root is very essential for young trees. It should be taken into account that establishing too dense stands will be as much unsuitable as establishing stands with low density, which the later will make trees become branchy with wide growth rings and knotty wood. Therefore a balance must be reached for given species on a given site through appropriate density control. The silviculturists could use different competition criteria and crown classes as a basis for judging the vigor of the stand and for conducting thinning and other cultural operations. Comparison of the above mentioned four criteria, presented in this paper, indicates that growth space doesn't show an exact result; even sometimes it could cause mistakes. In the contrary the crown competition factor could be more useful to illustrate the density and competition of the stand.

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c) Crown Competition Factor (CCF) calculated by using of equation [2] (Schütz, 1984 and 1990) as following:

$$[2] \quad CCF = (MCD \sqrt{N}) 107.5^{-1}$$

where MCD is the Mean Crown Diameter

d) Growth Space (GS) which is independent to surface and deals with crown competition of individual sapling in relation to its neighbors. It is calculated by equation [3] as following:

$$[3] \quad GS = CD (SBD)^{-1}$$

where CD is crown diameter and SBD is stem base diameter.

A sum of 4805 beech saplings was studied within 143 sample plots. In order to eliminate the age effect, only 9 years old saplings (median) were selected and data were analyzed statistically by using of SAS software.

Results and Discussion

Results showed that the density of beech saplings was not homogenous and a various competition condition was obvious over the regeneration area. The number of saplings (N) had wide amplitude which varied between 2.5 and 54.8 per square meter. The mean number of saplings accounted to 13.4 ± 1.8 per square meter (Table 1).

The mean distance of saplings (MDS) varied between 14.5 and 68.0 cm whereas the average accounted to 36.3 ± 2.1 cm (Table 1). The relationship between number (N) and mean distance of saplings (MDS) within the 143 sample plots showed a significant negative correlation ($p < 0.001$) (Fig. 1).

The crown competition factor (CCF) of the young beeches varied between 1 and 4.8. The mean CCF accounted to 2.7 ± 0.1 (Table 1). This indicates that in some parts of the regeneration area the density is in balanced condition (100%) but the saplings will start to compete soon. In some other parts the density is too high (480%) and a strong competition exists already among the saplings. With other words there is almost 5 times of overlapping in crown space of saplings. Such close stands could result in producing slim stems with short and narrow crowns that will increase the mortality risk and storm damages.

The growth space (GS) of beech saplings varied between 1.2 and 12.0 with an average of 5.0 ± 0.1 (Table 1). The growth space under the old growth stand was higher than in the gap center. This is because of plagiotropic crown and small stem base diameter among saplings grown under the mature trees and crown closure of the old growth stand (Sagheb-Talebi 1995).

Table 1: Summary of competition criteria of the studied beech saplings.

Criteria	min.	max.	mean	median
Stem Number (N)	2.5	54.8	$13.4 \pm 1.8^*$	8.3
Mean Distance of Saplings (MDS)	14.5	68.0	36.3 ± 2.1	37.3
Crown Competition Factor (CCF)	1.0	4.8	2.7 ± 0.1	2.7
Growth Space (GS)	1.2	12.0	5.0 ± 0.1	4.9

* Confidence limit (95%)

INFLUENCE OF SHELTERWOOD AND NATURAL REGENERATION OF NORWAY SPRUCE (*PICEA ABIES* (L.) KARST) ON UNDERPLANTED EUROPEAN BEECH (*FAGUS SYLVATICA* L.) IN LOW MOUNTAIN RANGES OF WESTERN GERMANY

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Introduction

Advanced planting of beech (*Fagus sylvatica*) under spruce (*Picea abies*) shelterwood or in small gaps is an old silvicultural method which has attracted more attention. Light conditions are likely to be the most important limiting factor for a good growing of underplanted European beech (Leder and Wagner, 1996). Intensity of the competition with spruce shelterwood and natural regeneration influences in the regeneration phase primarily the height growth (Mayer, 1992). The main objective of the present study is to analyze the effects of different light conditions on the annual height growth of beech and spruce, two species differing in shade tolerance.

Material and Methods

The research was carried out in five Norway spruce stands (80-100 years old) with underplanted European beech (15-16 years old), located in the Sauterland (at an elevation of 485-570 m a.s.l.) and closed to Paderborn (350-385 m a.s.l.) in Western Germany. The annual average temperature is approximately 7 °C and the annual average precipitation is around 850-1,200 mm (400-500 mm in the growing season). Tree growth and light data were recorded within circular plots (10 m² size) that were distributed at 10 m distance along the sampled line transects. These were chosen to be representative for the gap or part of the stand where beech was planted. Understorey tree measurements included: height and annual height increment for the recent three growing seasons of the central pairs of one beech and the most competitive spruce, distance between these two competitors, height of other beech trees, counting of other spruce trees by height classes and determination of the spruce age. The light growth that penetrates the overstorey canopy is very often the most important limiting factor for the growth. Alternatively stand basal area is often used to assess stand density and competition (Stancioiu and O'Hara, 2005). Both light and overstorey basal area were determined for the assessment of growing space. Light conditions were measured in the centre of each plot above each investigated sapling using the hemispherical fish-eye photos technique. Data analysis was performed using WinScanopy software package. The obtained index, *Indirect Site Factor* (ISF), is equal to the percentage of above canopy light that reaches a sapling.

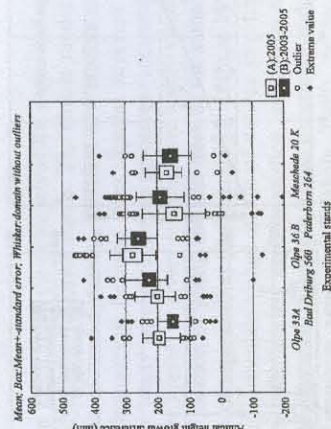
Results and Discussion

The underplanting beech density varied on average from 0.2 saplings m⁻² at Bad Driburg (ISF: 18-28%) to 0.47 saplings m⁻² at Olpe 33 (ISF: 15-25%), while natural spruce regeneration density varied between 1.87 at Paderborn (ISF: 5-35%) and 8.9 saplings m⁻² Olpe 33 (ISF: 15-30%).

Apart from several spruces at Paderborn, the spruce saplings were smaller than the beech saplings. Annual beech height increment was in 2005 on average 2.8 (Bad Driburg) to 5 (Olpe 33) times greater than the spruce. However, height increment was lower for beech than for spruce (Fig 1). Annual height growth differences in 2005 and average annual height growth differences in 2003-2005 between beech and spruce showed that the requested initial

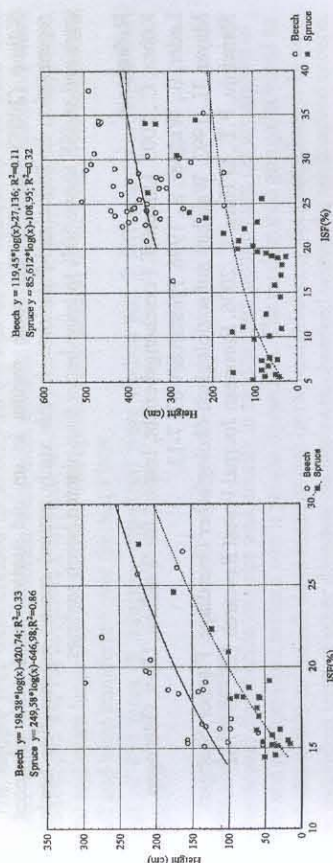
advantage of beech saplings compared with the spruce regeneration increases further in the case of Olpe 33 stand (significantly, $p < 0.05$). Olpe 36 and Meschede (not significantly, $p > 0.05$) and decreased in Bad Driburg (not significantly, $p < 0.05$) and in Paderborn (significantly, $p > 0.05$). Due to the significant increase in Olpe 33 and decrease in Paderborn the following analysis includes in most cases only the comparison between these two stands. Analyses of significance was performed using the t-test.

Figure 1: Annual height growth differences of beech and spruce saplings. The depicted annual height increment is A) the recent annual increment (2005) and B) the average of the recent three growing seasons (2003-2005).



Beech saplings that were investigated in Paderborn (Fig 2, right) and Bad Driburg are about twice as high as those from Sauterland (Olpe, Meschede) (Fig. 2, left), at an elevation difference of 200 m.

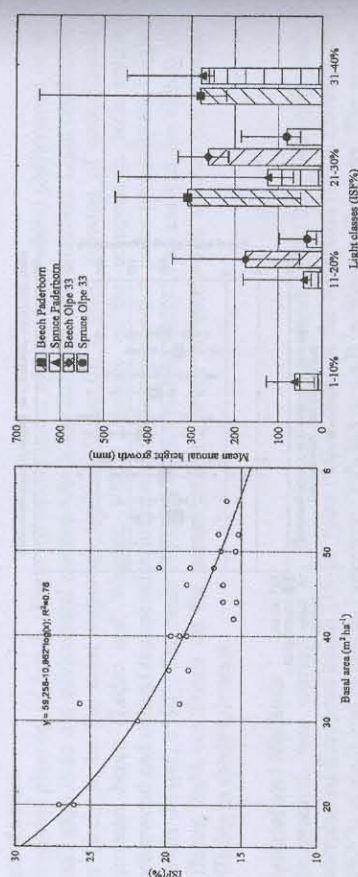
Figure 2: Scatter plots and logarithmical regression models for height (Olpe 33: left, Paderborn: right) as a function of light (ISF).



The recorded average age differences between underplanting beech and young spruce varied from -1 to 4 years, beech being 15-16 years old and spruce 7-20. The light quantity available for beech and the basal area of the spruce old stand was strongly correlated in the case of the stands Olpe 33 ($R^2 = 0.77$) (ISF: 15-25% = BA: 55-20 m² ha⁻¹) (Fig. 3, left) and Olpe 36 ($R^2 = 0.56$) (ISF: 17-28% = BA: 52-24m² ha⁻¹), moderately correlated for Meschede ($R^2 = 0.36$)

(ISF: 13-27% = BA: 48-22 m² ha⁻¹) and Paderborn (R² = 0.24) (ISF: 15-38% = BA: 36-15 m² ha⁻¹) and weakly correlated in the Bad Driburg stand (R² = 0.05) (ISF: 18-28% = BA: 46-20 m² ha⁻¹). Under stand conditions with levels of available light from 15 to 25% ISF (BA: 55-20 m² ha⁻¹) in Olpe 33, growth of shade tolerant species (beech) was favoured compared to the mid-tolerant spruce (Fig. 3, right), while in the Paderborn stand spruce growth caught up with beech growth with ISF >20% (Fig. 3, right).

Figure 3: Scatter plots and nonlinear regression model for light (ISF) as a function of basal area (BA) of old spruce stand in Olpe 33 (left). Box-plot for mean annual height increment (right) with light classes as the grouping variable.



The light conditions are good enough in the investigated stand to establish beech as advanced regeneration. The results of this study confirm the existence of an initial advantage in height growth of beech saplings in the lower light classes compared with the spruce regeneration. New openings in the spruce stands to favour the beech saplings are not necessary at the moment.

Kühne (2005) came to the same results in an old spruce stand with advanced beech regeneration in Rhineland-Palatinate. In this study natural spruce regeneration needed large gaps and an ISF above 50% to grow better than planted beech saplings.

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SPATIAL STRUCTURE OF TREES IN OLD-GROWTH ORIENTAL BEECH STANDS OF NORTH IRAN

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Introduction

The spatial structure of a forest stand (in other words the organization of the trees in space) plays a key role in the dynamics of forest stands. The classic models are not sufficient for recognition and prediction of stand dynamics, therefore new models are required to study the dynamic of stands and interactions between trees. Spatial structure of real stands is well known to be non poisson. Many natural or human processes (competition, growth, mortality, thinning, regeneration, etc.) result in a very complex and highly variable structure. (Goreaud et al. 1997). The relative location of young and old trees of the same species can help us to understand the dynamics of regeneration (Pelissier 1995, Collinet 1997). The point process formulation can be used to simulate virtual stands of various structures. As far as trees are concerned, where slow growth hinders experimentation, simulation on virtual stands seems particularly interesting, for instance, in order to test an experimental design before creating it, to compare various silviculture scenarios (Pukkala 1989), or to predict the effect of environmental changes (Pretzsch and Kahn 1995).

Materials and Methods

This study is carried out in a pure oriental beech (*Fagus orientalis* Lipsky) which is located in an altitude of 1200 to 1300 m.a.s.l. in "Eshkete – chal" of Ramsar region in the Caspian Forests of northern Iran.

The experimental design was completely randomized design with 20 sample plot each one ha area. The sample plot were divided in to 0.25 ha (= sum of 80 sub-plots). All trees were assessed within the sub-plots, which were them divided in to four diameter classes of, small size timber (ST 10, 15, 20, 25cm), medium size (MT 30, 35, 40, 45 cm), large (LT 50, 55, 60, 65 cm) and extra large (XL.T >65 cm). The spatial coordination of all trees were determined as well and were transferred over the maps later.

A total of 454 trees (8 selective sub-plots) were studied and 7 different forest types were recognized.

Results and Discussion

The horizontal distribution of trees was usually in randomized groupe form (in the middle of cluster and random) and seldom was it poison or random. The randomized groupe covered an area of 400 to 800 m² which were made of one or two neighbouring diameter classes. In same cases, individual trees of other diameter classes were observed within the randomized groupe. This study within the 80 sub-plots results in classification of 7 different structural types as following: 1) Initial uneven-aged or young stands in regeneration stage, 2) Typical uneven-aged stand, 3) uneven-aged stands tending to even-aged from and homogeneity, 4) even-aged like (= regular) stand in ST/MT classes, 5) even-aged stand in MT classes, 6) even-aged in LT/XLT classes, 7) temporary decay stage.

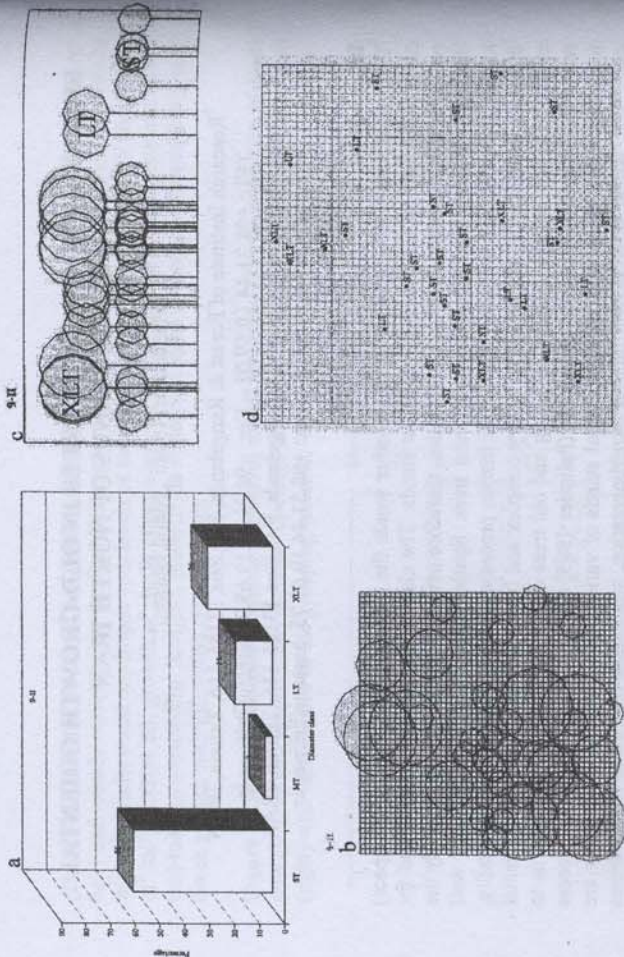


Figure 1 shows the a. Mathematical structure (histogram), b. horizontal profile, c. vertical profile and d. point pattern map of the type 7, for example.

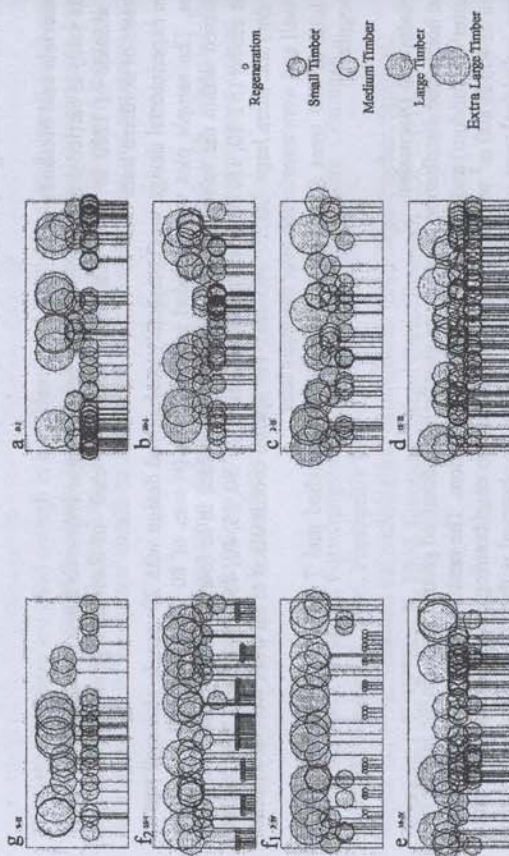


Figure 2 shows the vertical profile a) Initial uneven-aged or young stands in regeneration stage, b) Typical uneven-aged stand, c) uneven-aged stands tending to even-aged from and homogeneity, d) even-aged like (regular) stand in ST/MT classes, e) even-aged stand in MT classes, f) even-aged in LT/XLT classes with extreme XLT class, g) even-aged in LT/XLT classes with extreme LT class, h) temporary decay stage.

Studying of relation between over - storey and under - storey (regeneration) showed different patterns and structures. For example, no regeneration were observed in type 4 (even - aged in Studying of relation between overstorey and understorey (regeneration) showed different patterns and structures. For example, no regeneration were observed in type 4 (even-aged in ST/MT classes) as a young stand, while groups of thickets were observed in type 6 (even-aged in LT/XLT classes) as an old stand. This depends on the age of the stand and receiving of light in the understorey.

Distance between trees were measured by triangular method and the results are given in Table 1: Distance between trees in the diameter classes

Diameter class	Structural type	Distance between trees(m)		
		Max.	Min	Mean
Small timber (ST)	Initial uneven-aged or young stands in regeneration stage	5.50	0.75	2.70
Medium timber (MT)	even-aged stand in MT classes	7.50	1.00	4.20
Large timber (LT)	even-aged in LT/XLT classes with extreme LT class	12.75	4.00	8.35
Extra large timber (XLT)	even-aged in LT/XLT classes with extreme XLT class	16.25	5.00	11.20

By using of frequency distribution of trees in diameter classes and using of French and Belgium references (Collet et al. 1998, Bary-Lenger et al 1993) we could define the typology better. Spatial structure considering European (Goreaud 2000) and Canadian studies (Boucher et al. 2002) illustrates the horizontal and vertical structure of the stand and demonstrates the situation of a tree beside it neighbours. We could also study and understand the competition, growth and development of the individual trees, as well as development of the stands and the succession of different types (Wijdeven 2003, Cemagref 2001).

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REESTABLISHMENT OF NATURAL REGENERATION IN DEGRADED ORIENTAL BEECH (*FAGUS ORIENTALIS* LIPSKY.) AREA IN THE CASPIAN FOREST REGION OF IRAN

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Introduction

Hyrcanian broadleaved forests of Iran have an area about 1.85 million hectares. It is estimated that mixed and pure Oriental Beech (*Fagus orientalis* Lipsky.) stands have an area of 355000 ha, 30% of the standing volume and 23.6% of the stem number. Over the past decades, Shelterwood silvicultural system in mixed and uneven-aged Beech stands have not been successful and made dispersed bare patches with dense covering with Fern, Berry and etc. Recently, rehabilitation of these degraded areas (5-25% of regeneration areas) are deeply taking into consideration.

Based on Sagheb Talebi et al. (2003) Beech trees growing in 200 m² to 500 m² area gaps are better for reproduction. Shahnavazi (2000) showed that regeneration gaps area vary from 80m² to 1230m² in the virgin and natural Beech stands. Those gaps for European Beech (*Fagus sylvatica*) with 384m² to 1467m² areas (Emborg et al. 1990) are nearly similar. Considering that, degraded gaps have an areas nearly 1500 m² and often more than 0.5 ha, how can we reestablish Beech natural regeneration in degraded areas?

On this basis, 5400m² of a mixed Beech zone in the central mountainous Hyrcanian region fenced, cleaned and different artificial and natural regeneration methods were experimented to find suitable procedure.

Materials and Methods

The study site is located in the central Hyrcanian mixed Beech degraded forest, which typically includes Beech (57.9%), Hornbeam (27.3%), Caucasian Alder (5.5%) and Caucasian Oak (2.7%) and the other species. It was at 1400m above sea level (36° 29' N and 51° 32' E) on the north slope with Acid Brown soil covering *Matheuccia struthiopteris*, *Driopteris filix-mas*, *Driopteris filix-femina*, *Rubus spp.*

The different treatments consist of Alder and Maple nurse plantation, soil scarification, direct seeding and control. The statistical design is given as a randomized block experiment with four replicates. Each plot has an area of 144m² (12x12m) including a border of 2m around the plot and totally 5400m² which protected from game and livestock grazing. Within each plot, 25m² (5x5m) were selected for data collection based on numeration and height measurement of seedling species composition during two years (2004-2005) after site preparation.

Results and Discussion

List of reestablished tree species seedlings other than artificial regeneration for the first two years are as follows: *Acer velutinum* Boiss./*Carpinus betulus* L./*Alnus subcordata*

C.A.M./*Fagus orientalis* Lipsky./*Ulmus glabra* Huds./*Quercus castaneifolia* C.A.M./*Acer cappaducicum* Gled./*Tilia platyphyllos* Stev./and *Sorbus torminalis* (L.) Crants. Full results are available for the first five years (2007), because the effect of treatments can be assessed later. Species composition of natural regeneration are shown in table 1.

Table 1: Natural regeneration species number ha⁻¹ in Shoorab experimental area

year	maple	horn-beam	alder	beech	elm	oak	maple	linden	service tree	total
2004	10671	3328	1571	514	171	57	28	14	0	16357
2005	14742	4900	1428	714	128	114	28	14	14	22085

Total number of seedlings shows an increase of 35% during one year. Maple, Hornbeam, Alder and Beech comprise over 98% of the whole numbers. Mean height growth of four main natural regenerated species is presented in figure 1.

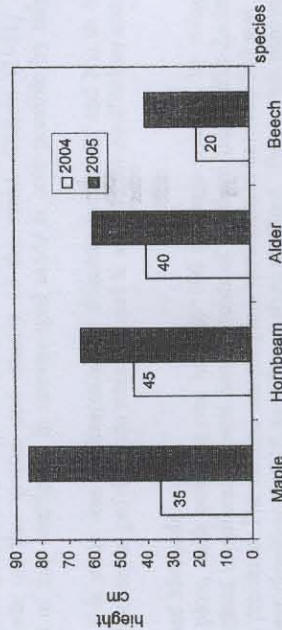


Figure 1. Mean height growth of natural regenerated species in Shoorab experimental area

The primarily results clearly show that reestablishment of natural regeneration do not appear without site preparation in degraded areas. Observations in the Shoorab regeneration area are confirmed this opinion. Nevertheless the presence of seed trees around degraded patches are necessary. Shade tolerant species such as Maple and Alder which are abundant in the Caspian forests play an important role in Beech reestablishment. In such areas, by using weed control and soil scarification treatments Beech seedlings are supported under light demanding species. There were no seedlings in Shoorab degraded study area for the twenty five years before. Now, by using site preparation measures in a protected area, the number of reestablished seedlings exceed of 22000 per hectare.

INVESTIGATION ON DIAMETER INCREMENT IN UNEVEN-AGED ORIENTAL BEECH FORESTS OF NORTHERN IRAN

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Introduction

Mixed and pure beech stands (*Fagus orientalis* Lipsky) of the Caspian region covers 17.5 percent of surface and 30 percent of volume in northern forests of Iran. Group selection system has been introduced for application in these uneven-aged high forests (Sagheb-Talebi and Schuetz, 2002, Marvie Mohadjer, 2005). For application of this system, the frequency and distribution (stem number and basal area) in diameter classes, annual diameter increment and stem number in the first diameter class (N_{10}) are the most important elements for achievement of equilibrium state in uneven-aged stands. It is also important to have information about ingrowth, outgrowth and removal rate (Schuetz, 1975 and 1997). According to the studies of De Licourt (1898) there is a decreasing coefficient for the stem number in diameter classes which depends on the species and density of the stand. Collete (1951) believes that achievement of this coefficient in uneven-aged stands is only possible by using of control method.

The aim of this study was to determine the diameter increment and N_{10} in oriental beech stands as a first step to provide data which is used to achieve the equilibrium state.

Materials and Methods

Six sample plots, each covering one ha (100*100 m) were selected by using of selective sampling method in natural oriental beech stands of northern Iran, Neka-Zalemroud region, Mazandaran province. The studied sample plots were located between 640 and 1540 m.a.s.l., with northwest direction and 15 to 20% of slope gradient. The crown canopy of the plots varied between 75 and 80%, stem number between 136 and 258 N_{ha}^{-1} , basal area between 26 and 42.7 m^2ha^{-1} and volume between 388 and 509 m^3ha^{-1} . All standing trees with a diameter at breast height (dbh) more than 7.5 cm have been assessed in each plot. Moreover, marked and felling trees were recorded. Determining of diameter increment in the last ten years was done by using of increment borer in different diameter classes (at least three trees per diameter class). Data analysis was carried out by using of SPSS and Excel soft wares.

Results and discussion

Basal area and volume distribution of the plots in four timber sizes, namely small (dbh<30cm), medium 35<dbh<50cm), large (55<dbh<70cm) and extra large (dbh>70cm), showed that the highest proportion of basal area and volume were concentrated in large and extra large timber sizes. This shows that the studied stands were old.

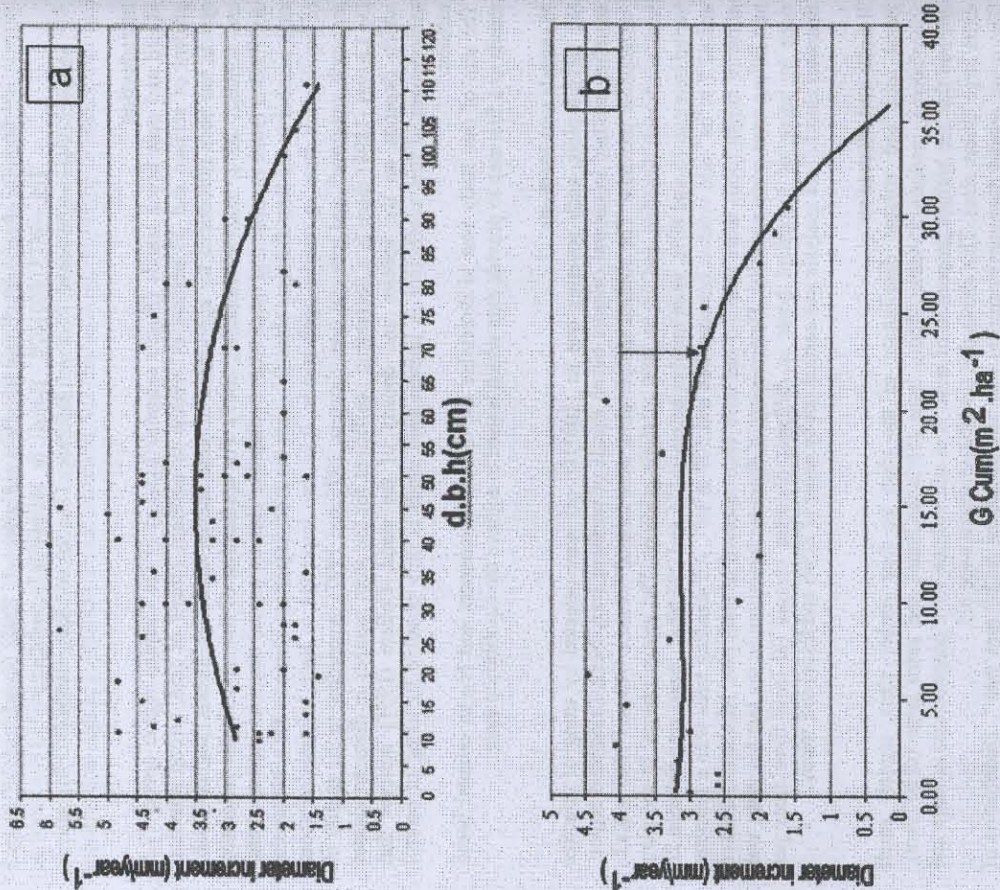
The mean annual diameter increment (id) was calculated to 2.7 mm year⁻¹. Distribution of annual diameter increment in diameter classes (Fig. 1-a) showed that the highest rate of annual diameter increment (id=3.5 mm year⁻¹) could be observed between 40 and 55cm dbh classes.

Distribution of annual diameter increment in basal area classes (Fig. 1-b) showed that it starts with slightly more than 3 mm year⁻¹ in basal area of less than 5 m^2ha^{-1} and decreases to less than 0.5 mm year⁻¹ in basal area class of 35 m^2ha^{-1} . The mean annual diameter increment (2.7 mm year⁻¹) has been observed in 23 m^2ha^{-1} .

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Figure 1: Distribution of annual diameter increment (id) in a) diameter classes and b) cumulative basal area.



Considering the growth rate and appearance of red rot and decay in wood, target diameter could be introduced between 80 and 85 cm in stands with 350 and 400 m³ ha⁻¹ and a cumulative basal area between 20 and 25 m² ha⁻¹. For improvement of the stand structure and becoming closer to equilibrium state, a stem number of 120 Nha⁻¹ in the first diameter class (N₁₀) could be expected. However, at least two or three period of method control is suggested.

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MORPHOGENETIC RISK FACTORS OF FORKING ON YOUNG COMMON BEECH

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Fork on common Beech is a frequent flaw at the young stages of development which adversely affects the formation of a trunk. The morphogenetic determinism of forking remains still largely hypothetical. For instance, fork emergence is assumed to depend: (i) on the arrangement and dimensions of the buds at the end of the growth unit when the terminal bud is present (Bovlanski, Schädelin, Champagnat, Schütz, Sagheb-Talebi, Galoux, Kurth), and (ii) on the absence of this latter, generally due to late or early frost and browsing (Nicolini, Caraglio).

These two hypothesis were tested on young beeches (age < 20 years) in controlled conditions.

When the apical bud is present, we identified the length of the uppermost lateral buds relative to the length of the terminal one as the most explicative variable of fork incidence. In the case of apical bud death we analysed its consequences in relationship either with polycyclism or with late frost. We highlighted the influence of the polycyclism on the fate of the forks. Thanks to logistic regression we provided actual quantification of the effect of the identified variables and factors.

BEECH RECRUITMENT IN FOREST GAPS AFTER THE 1999 WINDSTORMS IN THE NORTH VOSGES. FROM DISPERSAL TO EARLY SURVIVAL

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Introduction

Natural disturbances have been shown to be crucial in forest dynamics. Tree recruitment for instance is highly dependent on the size of the gaps created by natural disturbance. Different processes such as seed production, seed dispersal, germination and seedling survival may be critical (Clark et al. 1998) may be of importance in tree recruitment as well. However, in forest regeneration, few studies have focused on seed supply and early stages of seedling recruitment (Jones and Sharitz 1998, Clark et al. 1999).

Therefore, the objective of the present study is to analyze the effect of different environmental factors on beech recruitment in gaps of various sizes ranging from 2.5 ares to 5 ha. We focused on three main processes: seed production and seed dispersal, seedling setting and seedling survival.

Materials and Methods

The experiment started in 2002 and was set up in the forest of La Petite-Pierre, North Vosges, France. In this forest, numerous gaps were created after the 1999 windstorm. 70 study plots were set up in 43 gaps, ranging from 2.5 ares to 5 ha, and 10 study plots under closed canopy. In each of those study plots, seed dispersal was studied in 2002 and 2003 by means of three seed traps (0.5 m²) and seedling recruitment by means of 12 permanent quadrats (of 8 m²). In 2003, beech seeds were classified in seeds with a fully developed embryo, in seeds predated before dispersion and in empty seeds. In each quadrat, beech seedlings were counted and their ages were determined for three consecutive years (2002, 2003 and 2004). In each study plot, soil characteristics (pH, C/N ratio and humus), topography and light environments were studied. Light environment was estimated by hemispherical photographs and by use of a calculated angle (called alpha). The measured topography was used to calculate the heat index (Geiger 1966). It corresponds to the average of the angles between the horizontal line and the top of the gap border trees in the east, south-east, south, south-west and west directions. Seed dispersal and seedling recruitment were analysed thanks to the inverse modelling method (Ribbens et al. 1994). The number of seeds in each seed traps can be estimated by

$$[1] \quad \hat{N}_i = \sum_{j=1}^{n_{traps}} P(\text{diam}_j) \cdot f(x_{ij}),$$

where \hat{N}_i is the estimated number of seeds in the seed trap i , $P(\text{diam}_j)$ is the seed production of the tree with diameter diam_j ($j=1, \dots, n_{trees}$), x_{ij} , the distance between tree j and seed trap i and $f(x)$ a dispersal function. Three different functions were tested: the lognormal, the generalized exponential and the 2DT function. The best suited function was the generalized exponential function. The fitted parameters were determined using the maximisation of the likelihood function for a Poisson distribution.

Seedling number (at the plot level and at the permanent quadrat level) was estimated by:

$$[2] \quad N_{seedlings} = T_{germination} \cdot \prod_{i=1}^{n_{quadrats}} (1 - a_i \cdot F_i) \cdot N_{seeds}$$

where $N_{seedlings}$ is the estimated number of seedlings growing during the year of measure, $T_{germination}$ is the estimated germination rate, F_i the i environmental factors, N_{seeds} the estimated number of seeds. The fitted parameters ($T_{germination}$ and a_i) were determined by the Likelihood Ratio Test (LRT). This method takes into account both the quality of the fit and the complexity of the model (Johnson and Omland 2004).

Seedling survival was analysed by means of logistic regression and the best regression model was determined by means of the Akaike's Information criterion (AIC) (Johnson and Omland 2004).

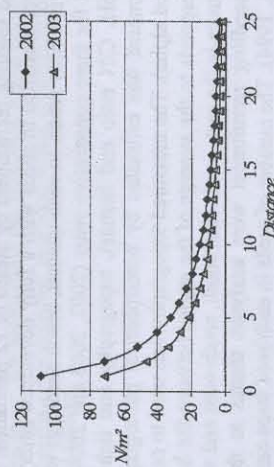
Results and Discussion

Seed production and seed dispersal

Estimated seed production differed both between years and with topography. Indeed estimated seed production was higher in 2002 than in 2003 and in 2003, compare to 2002, estimated seed production was larger for trees on slope facing north than those on slope facing south. As it is well known that seed production depends on the climate of a region, therefore, it seems that the topography may modify the general influence of the climate at the stand scale.

The best model (maximum likelihood) was obtained by taking into account only trees within 25 m of each seed trap (Figure 1). Therefore, beech primary dispersal occurs at short distances but still at further distances than the tree crown size. Therefore, beech recruitment is compromised in the centre of gaps with a radius of more than 30 m due to a lack of seeds. This is particularly true when only the seeds with a fully developed embryo are taken into account as the estimated proportion of those seeds decrease from 65 % near the tree to 40.7 % at 25 m.

Figure 1: Number of seeds (N/m^2) estimated by the generalized exponential function for a tree of 50 cm diameter, for years 2002 and 2003.



Seedling recruitment

Mean seedling recruitment rate was very low for the three years, corresponding to 0.29 % of the total number of seeds and 1.11 % of the full seeds. No significant difference was observed between plots in forest and plots in gaps.

Within gaps, the main factors affecting seedling recruitment were at the plot level: vegetation cover, heat index, soil disturbance and soil obstruction by branches, distance to the nearest beech tree, litter thickness and alpha angle. The seedling recruitment model ($R^2=0.546$, $p<0.0001$) can be expressed by:

$$N_{seedlings} = 0.0020 \cdot (1 - 0.58 \cdot veget) \cdot (1 + 0.82 \cdot Pert) \cdot (1 - 0.25 \cdot Enc) \cdot (1 - 0.38 \cdot HT) \cdot (1 + 0.59 \cdot D \cdot min) \cdot (1 + 2.73 \cdot OI - 2.45 \cdot OI^2) \cdot (1 + 1.09 \cdot Alpha - 1.18 \cdot Alpha^2) \cdot N_{seeds}$$

The same factors were significant at the permanent quadrat level, except litter thickness and soil disturbance. The model ($R^2=0.294$, $p<0.0001$) can be expressed by:

$$N_{seedlings} = 0.0012 \cdot (1 - 0.74 \cdot veget) \cdot (1 - 0.85 \cdot Enc) \cdot (1 - 0.33 \cdot HT) \cdot (1 + 3.98 \cdot D \cdot min) \cdot (1 + 1.29 \cdot Alpha - 0.69 \cdot Alpha^2) \cdot N_{seeds}$$

Where $N_{seedlings}$ is the estimate number of seedling and N_{seeds} the estimate number of seeds.

In our study, inverse modelling showed good results to apprehend seedling recruitment in a varied environment such as canopy gaps and enable to determine the predominant factors playing a role in seedling setting. Except for the soil obstruction by branches that physically prevent seedling recruitment, it appeared that the factors affecting seedling recruitment were those affecting the soil water balance. Recruitment limitation occurs with a decrease of water resources due to competition by herbaceous vegetation or by trees nearby. Topography influenced beech recruitment through its effect on direct sunshine that increased evapotranspiration and soil surface water content. Beech regeneration was difficult in gaps on slope facing south. Finally, it appeared that beech recruitment was better for alpha angles between 56 and 75°, corresponding to gaps of a few ares on a flat surface. As beech recruitment depends more on soil water content than on light level, there was a negative effect of direct sunshine on seedling recruitment.

Our study showed that in natural conditions and without vegetation, the control of beech recruitment is possible only the first 4 years after gap creation. After this period, the vegetation cover will prevent further seedling recruitment. This effect is very important in forests where *Rubus fruticosus* dominates the herbaceous layer.

Seedling survival

Seedling survival was greater in gaps than under forest canopy, especially for seedlings younger than two years old. The difference in seedling survival was highly significant ($p<0.0001$) for the seedlings of the year with 31.0 % survival under forest canopy and 71.0 % in gaps. Seedling survival increased with seedlings age. Survival was greater than 90 % for seedling older than two years and was similar between forest and gaps.

Seedling survival was affected by the different factors studied. However, the results obtained through logistic regression showed that other factors, such as biological factors, may be more important than abiotic factors. Our results showed that the effects of environmental factors affecting seedling survival were different between years: the general climate probably modify their effects.

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BEECH SILVICULTURE AND SILVICULTURAL TRENDS IN LORRAINE (NORTHEASTERN FRANCE).

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In Lorraine, European beech (*Fagus sylvatica*) trees grow in most forest areas from the limestone plateaus to the Vosges mountains. One-third of the production area (220,000 hectares) is covered by stands where beech is the main species. Beech constitutes an essential component in forest ecosystems in Lorraine.

A high production potential, but unknown risk ...

Lorraine belongs to the continental biogeographical region, the batisc-rhenan sub-region. Plains, hills and plateaus (generally under 400 m a.s.l.) are mainly made of limestone, marl, clay, except the south part which stands on Trias sandstone formation. This is the beech-oak domain. The Lorraine side of the Vosges mountains (400 to 1300 m a.s.l.), which mainly consists of sandstone (lower Vosges) or crystalline (high Vosges) substrate, is the mixed conifer-beech domain.

Lorraine climate is semi-continental with oceanic influence. Its main features are :

- a high number of frost days (up to 90 days per year) ;
- a relatively short growing season : 7 months at most with an average yearly temperature of 9-10°C in plains ;
- high precipitation : from 700 to 2100 mm per year all along the year. According to the Gausson's climate synthesis, there is no dry season. Yet, depending on the soil and water reserves, water may be deficient in spring.

These environmental and bioclimatic conditions are very favourable to beech and allow production of high value trees.

The trends presently observed in environmental factors must also be taken into account. Global change might be partly responsible for the increasing production of beech forests in Lorraine observed in the 20th century (Badeau *et al.* 1995, Bontemps *et al.* 2005), and for the higher frequency of windstorms and extreme droughts. The climatic conditions during the next century predicted by Météo-France models (Badeau *et al.*, 2005) suggest a reduction of the distribution area of beech in France.

A high diversity in structure and species ...

Historical and silvicultural considerations mainly account for the high diversity in structure and species observed in Lorraine beech stands.

- Old coppice with standards characterized by a low density of good quality stems. The coppice cut was stopped in the middle of 20th century. As a consequence, coppice has grown now inside standard crowns which induces mortality of low branches and a decreasing quality (mainly related wood colouring). Today, the aims in these mature stands are to manage threat to quality and to optimize the use of young stems for perpetuating forest cover. Now, the silvicultural regime consists mainly in uneven-aged management.

- Red-zone stands with many scrap metal woods due to both world wars. Extracting scrap metal wood by clear cutting was the aim in the last fifty years. That's generated many even-aged stand.

- Mountain beech stands, as many deciduous were cut for firewood, the number of coniferous tree increased in stands. Due to their strong natural dynamics beeches have remained in stands and are now forming mixed stands with coniferous trees. The silvicultural regime tends to preserve this mixing due to ecological and economical interests.

- beech stands totally (or partially) destroyed by windstorm in December 1999, where vigorous and very diversified seedlings are growing. Now, the aim is to manage these great surface of young stands more rationally by using the natural dynamic of vegetation.

- Even-aged stands, the main part of beech areas. Until 1990, this stands were manage with a long and high competitive period in young stands, followed by light thinnings from below. It resulted in pure pure and dense stands producing, in 120 or 140 years, very straight long timber. But sanitary problems often appeared with age (red heart, defoliations, bark beetles ...) and stringy wood (thin rings, thick wood) was produced, which did not sell well. That the reason why more dynamic silviculture has been developed, since 1990 in order to produce commercial stems in less than 120 years. This silvicultural regime consists on (expensive) precommercial thinnings in young stands, which produces more vigorous stems, but also many branches and a high forking risk. As a consequence, new itineraries, with some lightest (less expensive) interventions targeting at particular stem, have been proposed (see below).

Economical trends in the beech market

In the last decades, the following economic trends were noticed in many European countries (Wilhelm G.J., 2003 ; Gerken and Gérard, 2004):

- low competitiveness of beech wood in the industrial wood market;
- downward trend in sawn beech prices and highly fluctuating market, especially for low quality wood;
- increasing labour cost.

In spite of uncertain economic prospects, with similar investments, high quality beech woods production allows higher and more stable economic value, compared to industrial wood production.

Silvicultural regimes traditionally applied on beech were based on a rotation of 120 to 140 years. In the last decade, research on the wood quality of beech trees have shown that a rapid growth associated with a short rotation produces the highest quality, characterized by large and homogeneous rings, a straight and cylindrical stem, and the absence of red-heart. Long rotations are also associated with many sanitary problems that affect old stands (more than 100-year-old) and strongly depreciate the stand value because of defoliation, bark beetles, general growth decline, and a much higher sensibility to windstorms (Boeck *et al.*, 2003).

Foresters can also rely on progress in forestry research, better knowledge of ecosystems and species behaviour (autecology and synecology). Today, they know that investments are no longer necessary to sustain beech stands because of a favourable natural dynamic growth. But their high competitiveness must be controlled to preserve diversity.

Considering these ecological and economical uncertainties, forest managers wonder how beech trees will react and which place should be kept for beech in tomorrow's forests.

Beech silvicultural trends in Lorraine

Foresters don't know exactly how ecological and economical prospects will evolve in the next century and promoting highly diverse stands ensures a higher capability to adapt to these uncertainties. Mixed-species stands are known to have a higher resilience to extreme weather

events or biotic threats, to have a higher stability of their economic value, and to fulfill many coming up social expectations such as landscape or environment management standards. Therefore, foresters are presently advised to :

- grow beech only on adequate sites,
 - apply dynamic silviculture that allows rapid stem growth and short stand rotation,
 - favour species mixture.
- These general recommendations should induce vigorous stands able to withstand future stresses without growth reduction or other risks.

In this general context, beech silviculture in the public forests of Lorraine follows three main technical recommendations:

- Mix species at all stand stages;
- Reduce the investment by
 - focusing silvicultural treatments on a small number of high quality stems (beech or other high-value species);
 - using natural dynamics which are very favourable to qualify beech stems;
- Apply dynamic silvicultural methods and aim at short rotation period.

The general objective is to apply a dynamic and careful silviculture aiming at producing high quality white wood in clear and mixed stand. A series of silvicultural scenarios meeting this general objective were built, that allow to obtain various types of end-products and to adapt to different ecological and silvicultural conditions. These scenarios are based on the natural dynamic of the trees and the stands, and can be parted into four successive phases: installation, qualification, active growth and maturation. Only the first two phases concerning early stand treatments will be presented here.

The installation phase covers the period from seed germination up to the first physical contact among the trees. The objective of this phase is to obtain a mixed-species regeneration which will allow a valuable output. The point is to further natural and diversified regeneration in a forest climate while controlling competing vegetation, at the lowest

Two itineraries are suggested:

- a rapid regeneration period, less than 15 years, to obtain vigorous seedlings and promote the survival and growth of light-demanding species;
- a long regeneration period, lasting approximately 30 years. This option is particularly interesting when the present mature stand is over capitalized, and allows to optimize the value of stand and to reduce economic loss.

The qualification phase covers the period from first physical contact among trees up to the acquisition of a trunk naturally pruned on a 5- to 8-m-height. The aim is to ensure that a potential for high quality stems is achieved in a short period of time. Three itineraries are suggested :

- a 'single tree itinerary' which gives priority to natural pruning and natural differentiation of 'super-vital' trees with some slight interventions (breaking or girdling of a few competing stems : it requires no more than 200 interventions per hectare during all the young stage ;
- a 'stand itinerary' with some 'traditional' interventions (extracting competing stem) but only targeted at precious wood species (approximately 50 to 100 stems per hectare), which offers more security for biodiversity ;
- a 'stand itinerary' with precommercial thinnings which stimulate diameter growth of 400 stems per hectare (especially precious wood species, but also beech stems).

The choice among the different itineraries is based on a technical stand analysis characterizing the site conditions and the potential of the present stand, and depends on the possible investment and the general management strategy of the owner. Presently, no management decision tool is available to forest practitioners to analyze technical and economical pertinence of the different possible silvicultural itineraries (especially 'single tree itinerary' or interventions targeting at particular stem).

Looking forward to hearing from the research community.

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NATURAL REGENERATION OF BEECH (*FAGUS SYLVATICA*) WITHOUT SOIL PREPARATION

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Introduction

In Sweden, as in most European countries, the common way to regenerate beech is to wait for a mast year, scarify, and cut a shelter after the seed-fall. Removal of the shelter-wood will be made in steps over a 20 year period (Bjerregård and Carbonnier, 1979). The method is considered to produce good results, but there are some drawbacks:

- All sites are not suitable for scarification, for example sites with frequent boulders, steep slopes or wet soil. Furthermore sites with high biodiversity values, with historical remnants, and recreation areas should be treated with care.
- Much of the valuable timber is harvested during mast years which has an adverse impact on the market.
- If the regeneration attempt ends with a failure, a second attempt will be difficult due to that sites often is invaded by grass and herbs.
- The uneven interval between mast years makes long-term planning difficult.
- The shelter-wood trees are often damaged by the sun or a rising water table.
- The possibilities to maximize the value of the old stand are limited since all trees do not reach their target diameters.

A more extensive regeneration method is practiced with good results at some estates in southern Sweden. Under a longer period seeds from several rich mast years, and also small amounts of seeds from less rich years, will contribute to form the next generation. No scarification is made, but the site conditions are controlled by several light cuttings, regulating the light conditions so the beech seedlings will be favoured in the competition against weeds. Similar methods are used in Denmark (Bornebuch, 1947) and northern France (Evans, 1982).

This extensive regeneration method has not the drawbacks as listed above. However the quality of the resulting regeneration has not yet been scientifically assessed. The main objectives of this study are to map the regeneration method and to study the regeneration dynamics. The objective is also to study the growth and yield of the shelter stand.

Materials and Methods

The study was started 1992 surveying seven beech stands on a bigger estate in south Sweden. Site index varies from F 22 up to F 30, corresponding to from 4,3 up to 7,1 m³ ha⁻¹ and year (Table 1). At start the early regeneration-phase stands were in the beginning of, or just before, the regeneration phase, in the middle regeneration-phase stands about half of the regeneration time had passed, and in the late regeneration-phase about 75 % of the time had passed. In the two last stands the last shelter trees were cut in 2002 and 2000 respectively. In every stand four plots were randomly selected. At every plot the seed-fall was measured every year by three seed-traps. On each of the four plots, nine permanent subplots of 1 m² were established. On these plots both advanced and new seedlings and mortality among older generations were annually observed. Height was measured on a sample of marked seedlings of all cohorts. At every plot a sample of vegetation was gathered every third year. Diameter and height of

shelter trees was measured on a circle with a radius of 25 m connected to each of the four plots. Silvicultural treatments have been decided and carried out by the local forester.

Table 1. Description of the seven stands of the regeneration study

Regeneration phase	Better site index, easy to regenerate	Medium site index, moderately difficult to regenerate	Poor site index, difficult to regenerate
Early	Stand 1	Stand 2	Stand 3
Middle	Stand 4		Stand 5
Late	Stand 6		Stand 7

Results and Discussion

For each of the seven stands the amount of seed were averaged over the mast years from 1992 up to the present (Table 2). In the period between the mast years only few seeds were collected in the seed-traps (500 seeds ha⁻¹ in 1999, 1400 in 2001, 3300 in 2003 and 4800 in 2005). Interestingly there were mast years both in 1992 and 1993. It is also notable that during the 14 years observation period there has been 7 mast years, which is more frequent than is stated in most textbooks.

Table 2. Mast years and millions of seed ha⁻¹ as an average for the seven stands in the experiment.

Year	Seed	Year	Seed	Year	Seed	Year	Seed	Year	Seed
1992	5,3	1993	1,5	1995	7,8	1998	0,9	2000	2,7
								2002	5,7
								2004	0,9

The total number of seedling show a big variation in the early regeneration-phase (Fig. 1), lower in the middle phase, and is almost none in the late regeneration-phase. Only the numbers of advanced seedlings (established before the observation period) are stable. In the beginning of the regeneration period and after cuttings in the shelter stands, the competition from other plants and shelter trees is small, and a greater number of plants are established after the mast years. This is most obvious when cuttings in the shelter-woods are carried out in connection to the mast years, e.g. in the second stand a cutting in the shelter-wood was made after the seed-fall 1998, resulting in almost 43 000 new seedlings ha⁻¹ in autumn 1999. This mast year gave none, or relatively small, contribution to the number of seedlings in the other observed stands. After shelter-wood cuttings the amount of vegetation increase, more in the early regeneration-phase stands, where the competition from young beech is small. An abundant field vegetation will make it difficult for new seedlings to establish. A rapid decrease in the number of seedlings was observed the first years after the germination, especially in the early regeneration-phase stands. The advanced seedlings show however a low mortality during the whole generation phase. The reason is probably that they are well established and competitive. In the middle- and late regeneration-phase stands some of the advanced seedlings are cut in precommercial thinnings, since they owing to lack of competition has developed into wolf-trees.

In almost all stands the advanced seedlings are the highest (Fig. 2). Only in two stands, where the number of plants, and the competition, has been low, plants of other cohorts have reached at least the same height. In the early regeneration-phase stands the mean height has not changed in two of the stands. In the middle- and late regeneration-phase, when the establishment of new seedlings is less frequent, the mean height increase. In the late regeneration-phase stands few new seedlings establish and because of competition their height growth is very low.

ASPECTS ON EUROPEAN BEECH DECLINE IN SOME EXPERIMENTAL PLOTS IN ORIENTAL CARPATHIANS

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Introduction

The European beech have had some periods of weakness in Europe, noticed as: "beech bark disease" considered produced by *Cryptococcus fagisuga* and *Nectria coccinea*, but in many cases these biotic factors have been not recorded on high intensity and only the site and stand characteristics seem to be favouring the disease (Perrin, 1983; Lang, 1983; Lonsdale, 1983; Parker, 1983); "beech canker" produced by *Nectria ditissima* with high intensity in some special conditions (Perrin, 1981; Cael, N., 1999); and "beech decline" caused by a complex of biotic and abiotic factors (Nageleisen, 1993, 1994; Pilard-Landeau et al., 1994; Maresi et al., 1998) in which *Phytophthora* spp. may have a special role (Blaschke and Jung, 1998; Hartmann, 1998; Jung, 2004).

In Romania beech problems have been identified as "beech canker" (Mărcu, 1978; Petrescu, 1971; Chiriță, 1985 unpublished; Rang, 1992; Chira and Chira, 1998; Marcu et al., 2003), rarely as "beech bark disease" (Chira and Chira, 1998), and finally as "beech decline" (Chira, 2004). In all these cases the decline occurred after a combination of different factors: draught, frost, difficult site conditions, tree age, and several bark and wood fungi and insects (Chira, 2004).

The objective of this work has been to characterise the specific aspects of beech decline in some sites of Oriental Carpathians during the last period of time.

Materials and Methods

Beech decline has been studied in some experimental plots of the forest districts of Suceava (NE of Oriental Carpathians).

The evolution of beech decline and biotical factors (fungi, insects) has been surveyed in 11 experimental plots (min. 50 trees) between 2001 and 2005, but the decline symptoms, species resistance to decline, sanitary state of the trees etc. have been noticed on many other points. Soil influence has been recorded under declined and healthy points of the same parcel.

Results and Discussion

Decline symptoms. The following symptoms have been generally recorded: rare leafage, yellow leaf, and small leaf; shoot discoloration, branch dying (very frequent on thinner ones); infections with bark and wood fungi and insects; root discoloration; infestation with bark and wood insects; stem brown bleedings (generally linked by insects holes) and grey or blackish bark and red-brown wood discoloration; wet-hart on dying trees.

Climate conditions. Several dry seasons (with an extreme draught in 2000) seems to be the primary factor which starts beech the decline (Chira et al., 2004; Barbu, 2002-2004). Late frost of 1999 could also favour this process.

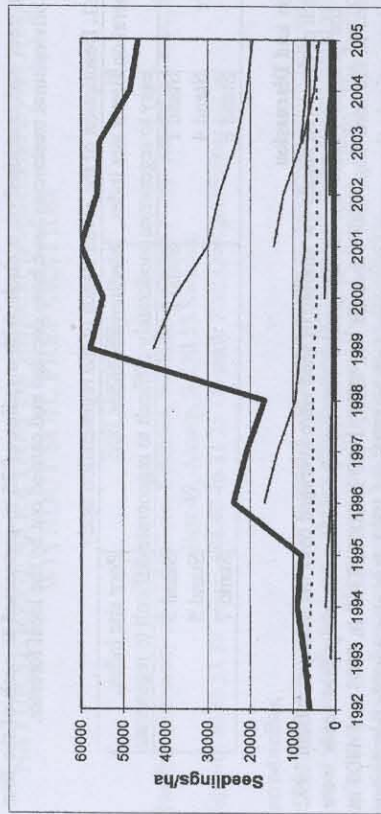


Figure 1. Change in number of seedlings in stand no 2, an early regeneration-phase stand of medium site index and moderately difficult to regenerate. Thick lines show the total number of seedlings, dotted line advanced seedlings, and thin lines the number of seedlings of every new cohort.

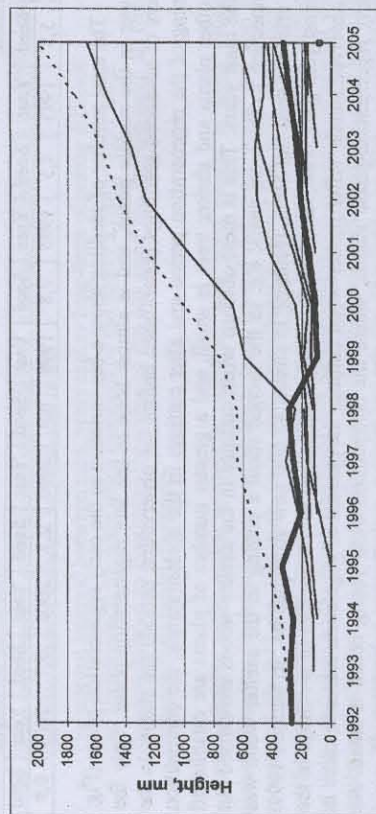


Figure 2. Height development in stand no 2, an early regeneration-phase stand of medium site index and moderately difficult to regenerate. Thick lines show the mean height, dotted line height of advanced seedlings, and thin lines the height development of every new cohort.

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Stand characteristics. Stand composition has been highly variable, from pure beech forests to different mixed beech stands with sessile oak, common oak, hornbeam, common ash, Norway maple, sycamore, etc. Beech has had high productivity, ± even-aged structure, and normal density (0.7-0.8). Stand age has been old (109 yr. on average), with rare exception (42-57 yr.).

Site characteristics. Beech decline have been dispersed or grouped in relative small areas, rarely in large bands (strips). Beech decline has especially occurred in hilly zones, on relatively flat sites (plateau, low and long slopes, foot slopes, and narrow steps on slope), with very low external drainage. Rarely, beech decline has occurred on a slope, but only on lower physiological available volume of soil (sandy deposit). In all cases the control profiles have showed better pedo-hydric situation.

Associated fungi. *Nectria coccinea* and beech cankers have been noticed in a large number of beech stands, but no important correlation with decline has been calculated. *Schizophyllum commune* has frequently occurred on standing trees in some stands. The type of decline with bark and wood degradation has been rarely found. *Coriolus hirsutus* has generally followed *S. commune* on standing trees. *Armillaria gallica* have been seldom noticed on dead trees roots. Black-coloured roots have also been observed in the clayey horizons of soil.

Associated insects. In several cases the intensity of beech bark scale (*Cryptococcus fagisuga*) has been correlated with crown defoliation and tree diameter. Other bark insects (*Agryllus viridis*, etc.) have been recorded on many dying trees. From xylophagous insects, *Xyleborus saxosus* and *Trypodendron domesticum* have been noticed, sometimes in relative high population.

Decline evolution. Both rapid and slow decline evolution have been noticed, but the second chronic phenomenon is more common (even it had a rapid start). In all the experimental plots the crown defoliation has decreased in time (2001-2005), even some moments of slow recovering followed some better seasons (2002, 2003 or 2005). In several years the mean defoliation increased from 29.8-42.2 % to 50.9-64.1 % (and rarely more).

In some points from the European Forest Survey (from Braşov county - SW of Oriental Carpathians) beech have shown a moment of weakness in 2000-2001, caused by late frost, summer draught and high infestation with *Phyllaphis fagi*, followed by a good recovery in 2-3 good years.

Other species resistance to decline. In some old plots (plateau on clayey soils) beech and silver fir have shown a similar high sensitive to decline; only some isolate trees of planted Norway spruce being moderate resistant. In some decline points, old (or even relative young) trees of sycamore maple and European hornbeam have shown a similar low resistance to decline. In the other cases, the (relative young) trees of European hornbeam have proved more resistant. In the majority of plots sessile and common oak have recorded a significant better resistance to stress than beech. In one case small-leaved linden has been more resistant to decline than beech, but in the past this species was disappearing on beech and sessile oak stands affected by canker / decline (Chira et al., 1998).

Management of beech decline. Sanitary cutting of the dying trees are indicated both to save the wood value and to prevent the infestation with fungi and insects. To re-evaluate the type of ecosystem in any decline forest, to understand if there is a concordance between the forest species requirements and the real ecological features of the forest site is considered fundamental. Therefore many of the studied forests have been reconsidered in this point of view.

Conclusion

European beech decline has been recorded between 2001 and 2005, especially in the hilly zone of north-eastern Romania. The phenomenon has start after a severe draught (and a late frost) and it has been favoured by other site (plateau or nearly flat slopes with soils excessively rich of clay or sandy slopes) and stand (old trees) factors. Associated bark and wood fungi and insects have been noticed. Sessile oak, common oak and sometimes hornbeam and small-leaved linden have been proved more resistant to the local conditions in the last decade climate stress conditions.

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BIOTIC FACTORS INVOLVED IN THE DECLINE OF BEECH IN ROMANIA

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Introduction

Beech had been considered for centuries a less valuable forest species of Romanian forests; due to this reason it has become a relevant species from the economic perspective relatively later compared to other forest species. As a consequence, natural beech forests have been maintained in many sites, often with high production potential and showing a special resistance to the action of biotic factors.

The beech is the most widespread forest species in Romania; it accounts for about 33% of the total forest area and it presently represents 50% of the total harvested wood volume. At the same time, it has an important silvicultural role in the beech-conifer mixtures, forming stable forests with Norway spruce. During the last three decades several species affecting the health of beech stands have been identified (phytopathogenic fungi, insects and even species of mites); this represents the beginning of the beech decline in Romania – less frequent and intensive than in other countries of Western Europe and North America.

Materials and methods

Observations and measurements in sample plots were performed. The analysis and measurement of the collected biological material (samples of branches with leaves) were consequently undertaken in the laboratory in order to establish the species which damage the beech.

Results and Discussions

The paper presents a summary of the results of the researches performed (and also published) in the last three decades on pests and diseases of beech leaf and bark; the most relevant species are presented in the table 1.

The data in the above table show that insect species (very different from the systematic point of view) prevail, complemented by „new” species - mites from *Aceria* genus.

Among the species identified on leaves, *Rhynchaenus fagi*, *Phyllaphis fagi*, *Dasychira pudibunda* and *Mikiola fagi* seem to be no longer under the natural biologic control; they produced for the first time gradations in our beech forests.

Moreover, after a natural cease of the gradation in the past, after a period of 7-10 years - the gradation periodicity, the species *Rhynchaenus fagi* appeared again in different forest areas of Romania; nowadays, it is recorded in almost all beech forests. Although a very small weevil, of only 2-3 mm length, it produces important damages, as it affects the leaves both in the adult and in the larva stage, and the attack cumulates during the growing season. *Typhlocyba douglasi*, *Apiognomonina errabunda*, *Aceria nervisequa* and *Aceria stenaspis* are species which have been identified for the first time on beech leaves in Romania.

Few species have been found on the bark of beech, only fungi from the *Nectria* genus and *Ascodichaena rugosa*.

Nectria ditissima – the beech cancer, is a species with a chronic evolution, which has lately extended to very large areas. The frequency of the attack is high in some forests, since the fungus can not be kept under control by removing the trees with cancer on the trunk during the tending operations.

Species which damage beech leaves and bark

No.	Species	Class	Order	Family	
On leaves					
1	<i>Rhynchaenus</i> (=Orchestes) <i>fagi</i> L.	INSECTA	Coleoptera	Curculionidae	
2	<i>Phyllaphis fagi</i> L.		Homoptera	Aphididae	
3	<i>Typhlocyba douglasi</i> (Edw.) (=T. cruenta)		Lepidoptera	Jassidae	
4	<i>Dasychira pudibunda</i> L.				
5	<i>Lithocolletis fagninella</i> Zll.		Diptera	Lithocolletidae	
6	<i>Mikiola fagi</i> Htg.				
7	<i>Apiognomonina errabunda</i> (Rob.) Höhn		Sphaerales	Diaporthaceae	
8	<i>Aceria nervisequa</i> Nal.		ARACHNIDA	Acar	Eriophyidae
9	<i>Aceria stenaspis</i> Nal.				
On bark					
10	<i>Nectria ditissima</i> Tul.	PYRENOMYCETES	Sphaerales	Hypocreaceae	
11	<i>Nectria cocinea</i> (Pers. et Fries) Fries.				
12	<i>Ascodichaena rugosa</i> Butin	DISCOMYCETES	Phacidiales	Rhytismataceae	
	<i>f.c. Polymorphum rugosum</i> Hawksw. et Punth.				

Table no. 1

Regarding the fungus *Nectria coccinea*, found in our microflora, it must be carefully kept under control in order to observe a possible association with the louse *Cryptococcus fagisuga*, when it produces very serious damages – a necrosis of the beech bark.

We have not included in our investigations the xylophages species (especially the fungi that produce wood rots) as they are relatively well-known. We only emphasise that the beech is the most susceptible forest species from this point of view, the wood rot develops very quickly both in old and young trees, especially when they are stressed or dry, and especially in logs. The most common species involved in this process are *Fomes fomentarius*, *Schizophyllum commune*, *Ganoderma applanatum*, *Stereum hirsutum*, *Cortiolus hirsutum*.

In this category we also mention a „new” species, identified in Romania – *Inonotus nidus* – which produces a heart wood rot. The fungus is a debility parasite infecting wounds produced by improper pruning and frost cracks. It produces asexual spores (a rarely found phenomenon in basidiomycetes) and the basidiocarp is annual, lacking trama, with the feature of a crust which covers the trunk hollows.

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CONTRIBUTIONS TO THE BEECH ECOCLIMATOLOGY AND PHENOLOGY (1962–2006)

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Introduction

The beech (*Fagus sylvatica*) stands not only for a representative European species due to its spreading area but also for the main species of the Romanian forests; yet, in the past the beech was not paid enough attention. Only after an action initiated by ASAS and carried out in the Forest District Măneciu–Prahova in 1978, having as subject „the extension of resinous species outside the area”, following the protests of some participants who were defending the beech, a real campaign was launched in favour of this species: scientific meetings, articles published in the Forests Magazine, etc. But they didn't last long either. That is why we are greeting the Conference organized by the International Union of Forestry Research Organizations (IUFRO) in Braşov, with the theme „Beech ecology and silviculture”.

Materials and methods

The researches into the beech eco-climatology were performed by the author of the paper in the Curvature Carpathians (Braşov Mountains) throughout 45 years (1962–2006). Most of the researches were performed in the mountainous massif Postăvarul (Braşov Mountains) at altitudes ranging from 534 to 1800 m. The meteorological and phenological stations were installed under specific conditions at altitudes of 535 m, 609 m, 1026 m, 1450 m and 1724 m, so as to supply the field data characteristic to both phytoclimatic layers and areal limits – altitudinally – of the main forestry species in our country, including the beech. The meteorological measurements and the phenological field observations, as well as data processing have been carried out by means of common methods in climatology and phenology.

Results and discussions

The researches bring several contributions to observing the influence of climatic factors upon the natural, ecologic regeneration, upon the increases and upon the phenology of this valuable species of the Carpathian forests.

As far as the **natural regeneration is concerned**, the novelty aspects are firstly related to the influence of light, extreme temperatures, snow layer, late or early frosts. It is well known that in our country the beech has the best climatic conditions in its habitat and it generally regenerates easily enough.

Yet, sometimes, during the seedling period, i.e. the „exchange of generations”, the beech loses ground in competition with other species.

At this very moment both the beech mast sprung from November – December – January and the young sprung plantlets are not protected by the **snow layer**. It is the case of sunny slopes, hill tops and large peaks situated at altitudes lower than 1000 – 1200 m which often remain uncovered by snow and, when the **night frosts** occurs again, the sprung beech mast is completely damaged. Since it can not form the second root, the beech is defeated by the common oak or by other species that are not disadvantaged by such a „handicap”, becoming „masters” on these types of grounds.

At mountainous altitudes, higher than 100 – 1200 m and even sub-mountainous (hilly), but on shadowed slopes, where the snow layer covers the ground until late in spring, the beech „fights” with the competitive species „on an equal footing”, managing to grow in mixed forests in proportions that assure its continuity and even the achievement of pure beech forests of great productivity.

Therefore, **eliminating the beech from the sunny slopes is not an effect of the competition on the „light front” and of the „heat front”, but a result of the temporary loss of the snow layer as an opportunity factor, with protective, decisive effect.**

In other words, **the relation snow layer – beech plantlets represents a key moment in the process of the beech natural regeneration, an important station-based factor of the prefiguration (accomplishment) of the natural bio geographic mosaic, of biodiversity.**

It is known that under other station and meteorology - based conditions as well as under brush conditions, the intense elimination of the beech plantlets and the significant diminution of the increases is caused by the **insufficiency of light, respectively by the shadows caused by the maternal brush**; this deficiency, specific to the vegetation period, is likely to equal and even to exceed the harmful effect of the above-mentioned meteorological factors. The comparative research into the dynamics of the amount of plantlets installed after the beech fructifications in 1968, 1973, 1978 followed by other researches developed in the experimental surfaces, „Crucea Albastră” – Poiana Braşov, „Warte”, „Măgurele” – Cristian etc., as well as the biometric determinations on seedlings under different microclimatic conditions, conditioned by the different illumination (shadowing) degree as a consequence of variations in brush consistency, demonstrate, in a convincing manner, that beech silviculture asks for the consolidation of the new orientations (principles) of ecologic optics and attitudes, with important economic implications.

Named by the silviculture classics „the shadow species”, the beech proved to be a species that, especially during the first years of vegetation, bears with difficulty shadowing the maternal brush; that is why the spring seedling may completely disappear until the end of the vegetation season or, through rare remained examples, to lead to very low increases and to disappear within the next years.

In the „in extenso” paper we are presenting multiple edifying data resulted from our researches as related to the influence of shadowing upon the beech seedlings. In this abstract we only mention the result of an experiment started in 1969: barely sprung plantlets in the spring of 1969, replanted on open ground reached, at 32 years old, 8 m height and 22 m diameter, while the seedlings that remained under the massif only reached 1,5 – 2 m height and around 1 cm diameter.

We also have other examples that prove that **only exceptionally the beech may be labelled as „shadow species” only if we wish to point out its exceptional capacity to bear the shadowing, its tolerance degree of the photic insufficiency. The beech’s high demands related to light are indisputable.**

Consequently, we support the idea that in beech forests and exploitable beech mixtures it is necessary to reduce the regeneration period and the number of trees fellings, gathering the whole wooden material only by 2 tree fellings well coordinated with the fructification years.

Under the conditions of the phyto-climatic layering in the Curvature Carpathians, the beech is presented in all the layers and sub-layers, beginning with the hilly one, 200 – 300 m until the lower mountainous one (inclusively), respectively until the bases of pure spruce forests.

Following the topo-climatic researches carried out in Braşov Mountains throughout 1964 – 1996, upon relief forms and phyto-climatic layers, those values of the climatic parameters that define the altitudinal (local) limits of the beech habitat and of its divisions were determined. In the paper herein we are presenting the climatic characteristics of the slope’s sectors which

offer optimal conditions for this species, so called „slope warm area”, situated at altitudes ranging from 650 up to 1250 m and the climatic conditions from the altitude of 1450 to 1500 m, which represent the real barrier in the beech altitudinal spreading, as well as those from the depression plain of Bârsa, also not favourable for the beech.

The phenological observations on the beech, done from 1961 until now in Braşov Mountains led to important conclusions.

Against the background of the species’ genetic program, the beech phenological rhythm is obviously conditioned by the evolution of meteorological conditions. For instance, as compared to the average date, April 17th, when the beech buds open (in Braşov at the altitude of 609 m), in different years, the same phenophase may register deviations of ± 20 days, i.e. 3 week accelerations or delays.

Altitudinally, the beech phenophases are late, on average, with 4 days/100 m level difference, which is confirmed by the fact that at the altitude of 1600 m, the leafing process begins only around June 1st, and the end of the vegetation period, imposed by the emergence of early snows and frosts, takes place in the first half of September.

In the paper herein there are presented all the beech phenophases: the medium and extreme data when they were produced, at the altitudes of 600 m, 1000 m, 1450 m și 1600 m, as well as the amount of adequate temperatures, the length of inter-phasic periods and the vegetation period.

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IS BEECH BY ANY MEANS AN INTERESTING SPECIES IN NORTH AMERICA AND HOW IS BEECH REGENERATED?

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Introduction

European beech (*Fagus sylvatica*) is a very important commercial species in Europe and the title of the conference highlights the fact that we are in Romania, the largest beech country. European beech is prized for its timber and many other uses, so it is easy to understand why European beech is interesting. However, European beech is only one of ten species of beech that are found worldwide.

American beech (*Fagus grandifolia*) is the only beech native to North America. This paper discusses two questions that are sometimes asked about this species: 1) is there any interest in American beech and 2) by what means does American beech regenerate?

Discussion

Description of American beech

American beech is a common tree species in the eastern forests of the United States. It is easily identified, even at a distance, because of its smooth, thin, light blue-gray bark, which can be seen on individuals of all ages. Other distinctive characteristics include long, narrow, sharp pointed, spindle shaped buds; deciduous simple leaves bearing parallel venation and short petioles; and a triangular edible nut contained in a bur that is 12-18 mm long. The leaves, buds, and bark of European beech are darker than its North American cousin. It is a slow growing but long-lived species that sometimes attains an age of 300 to 400 years. However, most trees of this age are usually affected by rot, particularly in the lower section of the stem. American beech trees reach heights of 37 m with a diameter of almost 1.2 m.

Range and Site

American beech is widespread in eastern North America extending from the maritime provinces of Canada south to the Gulf coast and west to east Texas. It occurs from sea level to 1,000 meters in the northern part of its range to 2,000 meters in the southern Appalachian Mountains. Typical sites within this area are moist, rich uplands, and lowlands.

Ecology

American beech is extremely tolerant of shade, prefers moist well-drained sites, produces root sprouts as well as stump sprouts, and is long lived. These characteristics place American beech as a long-term inhabitant in the forest types in which it occurs.

Beech is classed as very tolerant of shade and in some parts of its range it is the most tolerant species. Its principal competitors are sugar maple, eastern hemlock (*Tsuga canadensis* (L.) Carr.), and balsam fir (*Abies balsamea* (L.) Mill.). Beech prefers moist well-drained sites although it can survive on drier soils. It cannot endure prolonged flooding however. Beech sprouts well from the stumps of young trees but this trait diminishes as stump diameter increases. Beech trees may develop a large number of root sprouts or suckers. In some areas

this is the sole means of reproduction and there may be as many as 1700 to 2200 sprouts per hectare. This vigorous sprouting often interferes (moisture and shade) with the reproduction of other species. Beech is generally considered a slow grower and is long lived. Of 12 broad-leaved species rated according to their longevity, beech was exceeded only by white oak and sugar maple. Self pruning in beech is good in well-stocked stands but open-grown trees develop wide crowns with branches low to the ground. Epicormic branching is sometimes a problem in stands thinned too heavily.

Interest in Beech

American beech is a commercially valuable species because of a number of desirable properties of the wood. It ranks high in holding nails, but wood should be pre-bored prior to nailing because of the high density of the wood. The wood wears well and holds a polish, and it bends readily when steamed. Care is needed in gluing, but the wood finishes well with paint or transparent finishes. However, untreated wood is not durable and is subject to heartwood decay. Sapwood and heartwood are permeable when pressure-treated preservative compounds like creosote. But red heartwood is extremely resistant to penetration by preservatives by any means.

The wood of American beech has a number of uses: lumber, veneer, charcoal, railroad ties, pulpwood, cooperage, boxes, crates, baskets, pallets, furniture, flooring, sash, doors, trim, paneling, general millwork, woodenware, novelties, handles, brooms and brushes, food containers, turnery, and chemical extracts such as methanol, acetate and wood tar (creosote).

Thus there has been long-standing interest in American beech because of its commercial importance. But now there is interest in American beech of a different kind that has resulted in changes to the composition of the forests containing beech and changes to the form of beech trees. This change has been brought about by the beech bark disease, which threatens the commercial importance of American beech.

Beech bark disease is an insect-fungus complex involving the beech scale insect (*Cryptococcus fagisuga*), the exotic canker fungus *Nectria coccinea* var. *faginata* and the native *Nectria galligena* that kills or injures American beech. Beech scale was introduced to Nova Scotia around 1900 and the disease has subsequently slowly expanded its range through a large portion of the range of American beech (Morin et al. 2003)

Mortality of beech is high in areas that are initially invaded. However, the disease does not completely eliminate the beech. Although the stem is killed, the roots are not and beech is capable of producing numerous sprouts from roots, which are capable of re-colonizing the site. The presence of this disease has raised questions about how to manage beech (Houston 2004).

Regeneration

Information about American beech regeneration has recently been reviewed by Nyland and et al. 2006. Beech regenerates either by seeds or by root suckers. Seedling reproduction is more common in the northern part of the range while root sprouts are the dominant reproductive form in the south (Ward 1961). Although beech will sprout from stumps, coppice stands of beech are generally not common.

Regenerating beech and other hardwood species presents different challenges depending on whether beech bark disease has become part of the forest ecosystem or not. Mature beech

killed by the disease produces a dense understory of young beech from numerous root sprouts. The understory is so thick and casts such a dense shade that other hardwood species are prevented from being regenerated. Unfortunately deer do not browse beech but prefer other tree species thus compounding the difficulty of regenerating other hardwood species.

Many hardwood stands have become less productive as a consequence of the activities of the beech bark disease. This loss of productivity is the result of a combination of the loss of large, mature, beech and the development of dense thickets of beech from root sprouts that inhibit the regeneration of less shade tolerant hardwood species. However, Leak (2006) recently reported that uneven-aged stands managed using single-tree selection over a 50 year period has improved disease resistance and increased the merchantable potential of stands treated in this manner.

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BEECH FORESTS IN JAPAN - ECOLOGY AND SILVICULTURE -

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Introduction

There are 10 - 15 species in the genus *Fagus* in the world. Major distribution areas of *Fagus* species are temperate and humid regions in the mid-latitude of the northern hemisphere, which mostly overlap the populous areas of human being. Many of the beech species share common characteristics in ecology. At the same time, we may find a large variety of management systems among different areas of beech distribution, reflecting the differences in natural environment, human history, or social and economical situations of each region. In this paper, I provide an overview of ecology and managements of beech forests in Japan.

Distribution of *Fagus* in Japan

Two endemic species of *Fagus* are distributed in Japan, i.e. *Fagus crenata* Blume and *Fagus japonica* Maxim. Distribution and dominances are different between these two species. *Fagus crenata* is one of the most dominant species in cool temperate forests in Japan and ranges across almost all over the Japan archipelago, with the highest dominance in mountainous areas along the Japan Sea in the northern Japan (Fig.1). On the other hand, *Fagus japonica* is less dominant and its major distribution areas are restricted to the Pacific Ocean side of the main land Honshu (Fig.1).

In general, *Fagus crenata* has a single stem and tends to form pure stands, while *Fagus japonica* often forms multiple stems and grows in mixed stands with other broadleaved trees. In forest ecology and silviculture, much more studies have been conducted for *Fagus crenata* than *Fagus japonica*, because of the greater dominance and commercial value of the former species.

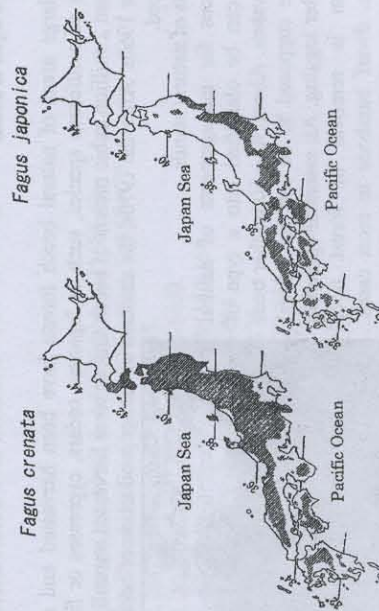


Fig.1: Distribution of two *Fagus* species in Japan

Association with dwarf bamboos

One of the distinguishable characteristics of *Fagus crenata* from European, Oriental and American beeches is association with dwarf bamboos (Fig.2). Most of the forest floors of *Fagus crenata* stands are densely covered with dwarf bamboos. Dwarf bamboos sometimes grow up to 3 m in height, and its above ground biomass reaches 8 kg m⁻².

Simultaneous deaths of dwarf bamboos, which occur once in several decades, is an important factor for natural regeneration of beech forests along with canopy gap formations (Nakashizuka et al. 1988).

Reproductive performances of *Fagus crenata*

Fagus crenata is a tree species showing the typical "masting" or "mast seeding" behavior, which is defined as an intermittent synchronous seed production within a population (Kelly 1994). In general, a good seed crop comes in every 5 - 7 years in a population of *Fagus crenata*.

Recent works have revealed that two annually-fluctuating factors are involved in the mast seeding of this species; 1) intensity of flower set, and 2) predation of immature seeds by insects (Yasaka et al. 2003). The most influential insects are three moth species of which larvae feed on immature fruits in early summer (Igarashi and Kamata 1997). Seeds damaged by insects are aborted, and the rates of predated seeds often exceed 90% of total seeds. As the predation rate can be lowered in a year with abundant flowers following the year with little flowers, the large annual fluctuation in the number of female flowers is considered to have an evolutionary advantage for reproductive success by escaping potential predations by insects (Kon et al. 2005a).

The proximate factors causing annual fluctuation in flowering intensity of *Fagus crenata* are internal resource dynamics and weather cues, i.e. minimum temperature from late April to mid-May in the year preceding flowering (Kon et al. 2005b).

Silviculture of *Fagus crenata*

1. Brief history

In Japan, the large areas of natural beech forests have been harvested and converted to artificial stands of coniferous species, such as Japanese cedars, cypresses or firs, since the 1950s. More than 2 million cubic meters of beech timber were harvested annually at the peak years of the late 1960s. After the 1970s, the amounts of timber production of beech have been gradually reduced.

2. Managements of natural stands

Current practices for managements of natural beech forests can be classified into a type of shelter wood system. About 30 - 50 mother trees per hectare are supposed to be left for natural regeneration after logging. An essential operation in this system is removal of forest floor vegetations, i.e. dwarf bamboos in most cases. Scarifications are carried out by a bulldozer to remove dwarf bamboos (Fig.3). Root systems of



Fig.2: *Fagus crenata* stand with dwarf bamboos in the forest floor.



Fig.3: Scarification by a bulldozer for natural regeneration.

bamboo vegetations should be removed together with their above ground parts to suppress the recovery of vegetations. Herbicides are not used for vegetation control from the environmental reasons.

3. Afforestations

Afforestations of beech trees have not been so popular in Japan. Recently, however, quite a few attempts of afforestation are carried out for restoration of beech forests. Major causes of seedling mortality are damages by various mammals, such as mice, hares and deer. Another problem involved in beech afforestations is potential risk of genetic contaminations in natural populations of beech. Seedlings for afforestations are often brought from distant regions, because of shortages of seedling supply from regional seed sources. Some recent studies have revealed that the genetic variation showed strong geographic structure in natural populations of *Fagus crenata* (Tomaru et al. 1998). Thus, long-distant transportations of seedlings can result in genetic disturbances among natural populations.

4. Seed storage

For stable supply of seedlings from regional seed sources, a simple method for long-term storage of beech nuts were established to cover its relatively long intervals between good seed years (Koyama et al. 1997). Beech nuts which are dried to moisture contents below 10% (dry weight basis) and stored at -20 °C can maintain their viabilities for at least 5 years.

Preservation of biodiversity in natural beech forests

One of the relevant topics related to beech forests in Japan is increasing public interests and expectations to conservations of biodiversity of beech forests. In 1993, the large area of pristine beech forests in the Shiragami Mountains in the northern most edge of the main land Honshu was designated as an UNESCO World Heritage site for its rich natural environment. Various large mammals inhabit in the region, such as black bears, Japanese serows, or snow monkeys which are the most northern-living non-human primate.

Impacts of climate changes

Some research projects on the potential impacts of global warming on the distribution and vulnerability of natural vegetations have initiated by a multidiscipline team incorporating the researchers from forestry and environmental sciences. Using the 1 km mesh data of climatic parameters derived from a climate change scenario, it was predicted that all beech forests in western Japan will be out of the suitable sites and that there will be more extensive areas suitable for beech forests over Hokkaido under warming climate in 2050 and 2090 (Matsui et al. 2004).

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PRE-COMMERCIAL THINNING OF BEECH: STRIKING THE BALANCE FOR TIMBER PRODUCTION, BIODIVERSITY AND FOREST RECREATION

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Abstract

Beech (*Fagus sylvatica* L.) is one of the economically most important tree species in Europe. It is often managed under silvicultural systems which include natural regeneration resulting in dense young stands. Many foresters consider pre-commercial thinning indispensable for the production of high quality timber and even for the maintenance of biodiversity and optimal opportunities for recreational activities.

This study comprises four contrasting management regimes for young beech, initiated at an age of 14 years: 1. no pre-commercial thinning, 2. stripwise thinning leaving alternate 1-1½ metre wide belts of beech, 2½. stripwise thinning followed by heavy selective thinning, and 3. perpendicular stripwise thinning leaving a 'chessboard' pattern of beech for subsequent selective thinning. In addition to these main treatments, the study includes effects of strip width, manual pruning, and stump height on tree and stand development.

Until an age of 21 years the height growth of potential crop trees was essentially unaffected by thinning practice, diameter growth was unaffected by treatment 2 but strongly promoted by treatment 2½ and 3, and natural pruning was hampered by increasing thinning grade. The exterior wood quality of potential crop trees (excluding natural pruning) improved with increasing thinning grade, except for the less optimal treatment 3. For ground flora, cover as well as species diversity increased with increasing thinning grade at this stage of stand development. Additionally, a vigorous understorey of beech and other tree species developed with increasing thinning grade due to stump regrowth and additional natural regeneration.

In conclusion, the study clearly indicates that the common practice of stripwise pre-commercial thinning is unjustified. The justification of heavy 'chessboard' thinning (with pruning) depends on whether the potential reduction in rotation length and the improvement in wood quality outweigh the discounted costs of pre-commercial thinning and selection and pruning of crop trees. Combined stripwise and early heavy thinning ranges between these extremes. However, biodiversity, forest recreation and other issues may override these conclusions.

EXPERIMENTS ON YOUNG BEECH STANDS SILVICULTURE AT THE FRENCH FOREST SERVICE (OFFICE NATIONAL DES FORÊTS)

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Introduction

In France, beech stands managed by the French Forest Service extend to large areas (745 000 ha). Due to low wood prices (since windstorms in 1999) and high cost of pre-commercial thinnings, silviculture of young beech stands appears now as a very important issue in high forests. The key question is: how to obtain stands of high quality at the end of the silviculture life cycle included a young stage (dominant height up to 14-17m) with minimum costs? High quality means 60 to 90 trees per hectare with sufficient natural pruning (6m to 9m of trunk without any living branch) and adequate vigor (dominant trees with large crown) guaranteeing high reactivity to dynamic thinnings at the adult stage. Nowadays, there is no consensus on the way to achieve such a goal. Clearly, pre-commercial thinnings trigger diameter growth but slow down natural pruning. This confusing trade-off lead to suggest two types of silvicultural scenarios: (i) one or two moderate pre-commercial thinning(s) (Ho = 4m, 8m) followed by a phase characterized by high density promoting natural pruning, (ii) no pre-commercial thinnings but extensive interventions favouring species mingling (see Bock, this meeting). This last scenario is rooted in the hypothesis of a natural social differentiation between trees during early development stages. Since 1987, the Research Department of the French Forest Service settled several experiments on young beech stands silviculture. Here, we quickly present these experiments and give some results on the trade-off between natural pruning and girth increment, focusing on plain forests.

Material and Methods

Two sets of experiments were used for this study.

The first one encompasses 8 experiments (34 plots) dating from late 80's characterized by different modalities and different initial heights (Ho ≈ 7m-13m). The experimental designs consist on a set of several square or rectangular plots with just one factor tested (silvicultural treatment). Only one experiment have 3 replicates and two experiments concern plantations. These experiments contain control plots where very limited interventions were applied. On each plot, a sample of usually 250 selected trees per hectare was measured every 2, 3 or 4 years depending on the variable of interest: girth at breast height, height, height of the first living branch (among others). The second one consists in current multi-site experiments (5 sites¹, 30 plots of about 50 ares) dealing with stands of comparable initial height (Ho ≈ 3-5m). Two factors are tested (silvicultural strategy: 8 modalities; fertility: 3 modalities) and all sites have a control plot. The sample consists in 250 tree/ha representative of 500 selected trees per

¹ In fact, this network contains now 11 sites and more than 50 plots but just a part of it was used for this study. . . This network will be extended in the next years.

hectare. Girth, height, height of the first living branch are also regularly measured in all plots.

We performed the same study than Duplat and Démarcq (2000, Oak-Key project). On each plot, we calculated the Reineke Density Index (RDI, see Reineke 1933: $RDI = N(d_p/a)^b$) based on the equation of LeGoff and Ottorini (1999) just after the first intervention (total number of trees and basal area are known on each plot through inventory). This allowed to calculate the relative Reineke Density Index, i.e. the ratio between the RDI in plots with interventions and the RDI in corresponding control plots:

$$[1] \quad RDI_r = RDI_p / RDI_c$$

We also calculated mean girth increment (δC_p), mean height increment (δH_p), mean height increment of the first living branch (δH_{b_p}) in each plot for 3 to 8 years after the first intervention, relative to the control:

$$[2] \quad \begin{aligned} \delta C_r &= \delta C_p / \delta C_c \\ \delta H_r &= \delta H_p / \delta H_c \\ \delta H_{b_r} &= \delta H_{b_p} / \delta H_{b_c} \end{aligned}$$

We plotted each of these variable as a function of RDI_r and fitted non-linear mathematical models constraints by [1,1] using STATISTICA 6.0 software. Each model is given with its coefficient of determination R^2 , proportion of the variation which is explained by the model.

In the analysis, we separated stands with initial height upper to 7m (first set of experiments: higher stands) from stands with initial height less than 7m (second set of experiments: lower stands). We also plotted curves obtained for sessile and pedunculata oaks (Duplat and Démarcq 2000).

Results and Discussion

Girth increment (fig. 1): for both lower and higher stands, the best model we found was an equilateral hyperbola (higher stands: $R^2=0,845$; lower stands: $R^2=0,766$). Higher stands appeared to have higher response to interventions. With heavy interventions ($RDI_r < 0,2$) a doubling or more of girth increment compared to control plot can be expected. Common oak species displayed the same qualitative response for lower stands. However, for higher stands Duplat and Démarcq found a linear response. As they didn't have stands with RDI_r lower than 0.2 we can not conclude on this difference.

Height increment (fig. 2): we found no significant relationship between δH_r and RDI_r for higher stands (Duplat and Démarcq found a significant one for oak species but with very low value of R^2). For lower stands ($R^2=0,516$), we can notice that only very heavy pre-commercial thinnings may significantly reduce height increment. There is no significant difference with common oak species.

Height increment of the first living branch (fig.3): the qualitative response of stands clearly depends on initial height. The best model we found was a logistic one for lower stands ($R^2=0,791$) and an equilateral hyperbola for higher stands ($R^2=0,824$). Such a qualitative response was also obtained for common oak species but in a different way. For lower stands, natural

pruning didn't slow down for weak interventions ($RDI_r > 0,6$). Contrary to oak species, heavy interventions ($RDI_r < 0,2$) in higher stands lead to a stop of the natural pruning process for common beech species.

These results confirm that interventions in young beech stands lead to an increase in girth increment and a decrease in height increment of the first living branch. There is no way to avoid such a trade-off for a single intervention on a period of 3 to 8 years. More studies must be conducted to conclude on a longer period. We hope this will be achieved soon with our current network of multi-site experiments on young beech stands silviculture.

Figure 1: relative girth increment δC_r , as a function of relative Reineke Density Index RDI_r , in higher stands (thick blue line) and lower stands (thick black line). Curves obtained by Duplat and Démarcq (2000) for common oak species are also drawn.

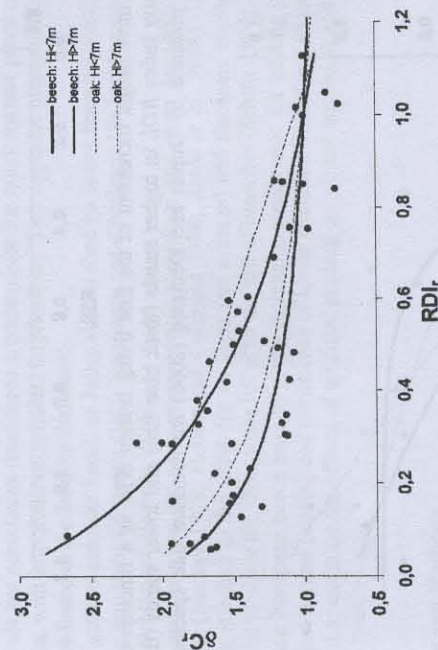


Figure 2: Relative height increment δH_t , as a function of relative Reineke Density Index RDI_t , in lower stands. The curve obtained by Duplat and Démarcq (2000) for common oak species is also drawn.

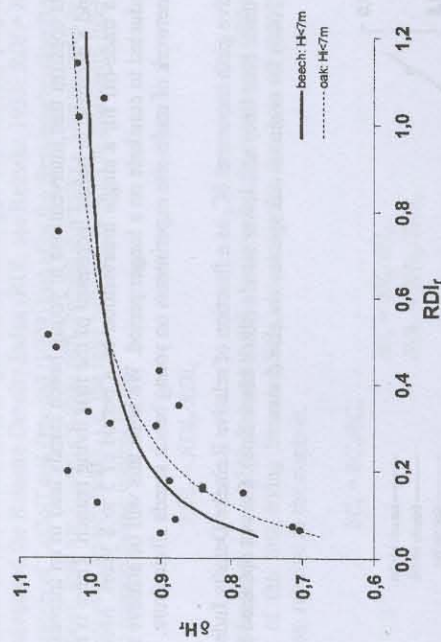
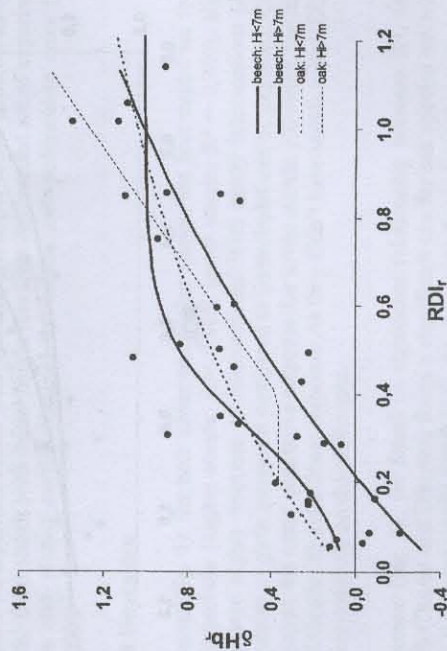


Figure 3: Relative height increment of the first living branch δH_b , as a function of relative Reineke Density Index RDI_t , in higher stands (thick blue line) and lower stands (thin black line). Curves obtained by Duplat and Démarcq (2000) for common oak species are also drawn.



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EFFECTS OF EUROPEAN BEECH ARTIFICIAL PRUNING ON WOUND OCCLUSION AND WOOD QUALITY

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Introduction

European beech (*Fagus sylvatica* L.) has long been regarded as a forest species that prefers to grow in dense and closed canopy (Bagneris 1876). In naturally regenerated stands only few trees present adequate stem and crown form and high levels of stocking are required to provide a reasonable choice of *final crop trees* when thinnings commence (Evans 1984). Dense stands are sometimes considered a prerequisite for quick natural pruning of European beech trees, with important economical implications. Two opposite viewpoints regarding this process are found in the forestry literature:

- many authors consider beech as being able to shed its lower branches *easily* and without leaving any stubs (Petrescu 1963; Negulescu and Săvulescu 1965; Stănescu 1979; Schütz 1990; Schütz and Bamola 1996);
- other authors view the species as having a *medium* and even *low ability* for natural pruning (Mathey 1929; Hubert and Courraud 1998; Joyce *et al.* 1998). Dead branches remain attached to the trunk for 10 years (on average) and the same number of years is required to cover the short stubs left after the fall of branches (Schütz 1990).

Many of the European beech trees in young Romanian stands used for tending purposes show a rather slow natural pruning and persistence of lower branches. Therefore, an experiment was established to examine the effects of artificial pruning on wound occlusion and wood quality of pruned trees.

Materials and Methods

In May 2001 a cleaning-respacing experiment was carried out in a 15-year old, pure and even-aged European beech stand (sub-compartment 99A, Management Unit III Budila, Teliu Forest District, Brașov County, Romania). Two experimental blocks were established:

- block I with four plots of 25 sq.m. each (5 x 5 m);
- block II with four plots of 100 sq.m. each (10 x 10 m). In both blocks, plot 4 was kept as control whereas cleaning-respacing interventions of different intensities were performed in plots 1, 2, and 3.

In addition to removal of undesired trees (e.g. low quality, forked, with cankers, wounds, too dense, etc.) in plots 1-3 of each block, a certain number of the trees left (73 individuals, of which 18 in block I and 55 in block II) were pruned with pruning saws. 29 branches were pruned in block I and 71 branches in block II.

The basic data collected from these 73 trees and 100 branches in 2001 included:

- diameter at breast height (d.b.h.);
- location of each branch removed (height from the ground level);
- bole diameter at branch height;
- 2 axes (vertical and horizontal) of all wounds produced by pruning.

In April 2006 all these trees and wounds were re-measured for: (a) d.b.h., (b) bole diameter at pruned branch height, (c) horizontal and vertical axes of all pruned branches. In addition, 5 trees (with 5 wounds) in block I and 7 trees (with 9 wounds) in block II were cut down at ground level.

Results and Discussion

a. Geometrical form of pruned branches

The length of vertical axis (Va) ranged between 1.4 cm and 8.9 cm while the length of horizontal axis (Ha) ranged between 1.1 cm and 6.5 cm. 81 per cent of pruned branches had Ha shorter than 3.0 cm and only 3 per cent of them were longer than 5.0 cm.

In terms of Va:Ha ratio 93 out of the 100 pruned branches were of *elliptical* form, with Va:Ha higher than 1, and the other 7 pruned branches were of *circular* form (Va:Ha = 1).

b. Closure of pruned branches

Four years after pruning 73 per cent of wounds were perfectly (fully) occluded (Table 1).

Table 1: Partially and fully occluded pruned branches

	Pruned branches with horizontal axis of.....cm (no.)						Total (no.)		
	1.1-2.0	2.1-3.0	3.1-4.0	4.1-5.0	5.1-6.0	6.1-7.0	PO	FO	
POa	FOb	PO	FO	PO	FO	PO	FO	PO	FO
8	34	12	27	2	8	2	4	2	1
							27	73	

Note: POa = partially occluded; FOb = fully occluded

The majority (74 per cent) of partially occluded wounds has reduced their area with at least 50 per cent. Wounds with Ha of maximum 3 cm accounted for 74 % of wounds still open. Such wounds were located especially on low diameter (mostly less than 4 cm) trees, less vigorous (Kraft classes III-IV) and slow growing trees (with d.b.h. increments as well as radial increments at wound heights close to 0 cm).

All three wounds with Ha longer than 5 cm were still non-healed over, reducing their area between 28 and 97 per cent. These wounds, as well as the majority of still open wounds with horizontal axes longer than 3 cm, are located at lower heights from ground level (less than 80 cm).

c. Wood quality in pruned trees

Wood colouration is mostly confined to the inner part (up to the central stem core) of branches removed during pruning for both perfectly occluded and still open wounds. Only in very few cases brown traces developing downwards the wound were detected, with a length of maximum 10 cm. In all cases no traces were detected upwards the wound.

The growth rings that developed after pruning were perfectly healthy in both fully and partially occluded wounds, without any form of colouration or rot.

Our findings are in agreement with results from previous similar studies in Europe (e.g. Soutrenon 1990, 1991, 1993, 1996). This experiment suggests that the Shigo's theory of compartmentalization (Shigo and Marx 1977) may also apply to European beech trees subjected to artificial pruning.

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