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), 40species 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 complicate 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 Reply's K(r) function, defined so that λ*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.

$$K(r) = \frac{1}{N} * \frac{1}{N} * \sum_{i=1} \sum_{j \neq i} Kij$$

Where Kij =1 if the distance between i and j is less than r, and o otherwise.

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

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

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 Hapkins 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 (*xi*) from the random point to the nearest organism, and the distance (*zi*) from the organism to its nearest neighbor.The density estimator that utilizes T-square distances (z_i) has a different formula:

$$\hat{N}_4 = \frac{2n}{\pi \sum (z_i^2)}$$

where $\hat{N}_4$ = 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 :

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

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

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_4	0.000038	16.22	0.0000381	0.0000382
N_T	0.00021	2156	0.000111	0.00191
N_T (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 cac 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.

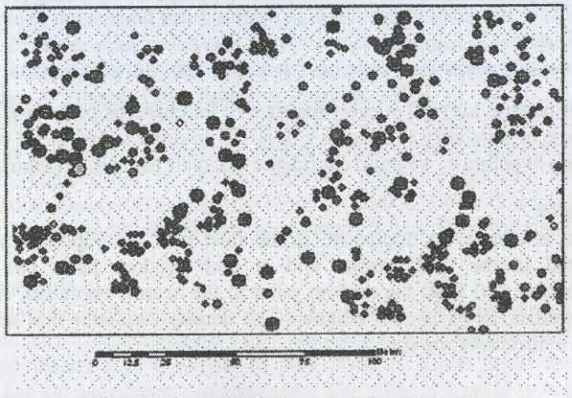

Figure1. Trees distribution map in beech stand

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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 succesional 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 m^3/ha(e.g. in old-growth beech forests, the average dead wood volume reaches 136 m^3/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 m^2 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 m^3/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.

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 preponderent (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 an 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 m^3/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 (Rübel, 1932; Horvat, Glavač & Ellenberg, 1963; Diekman et al., 1998; Neuhäuslová et al., 1998; Dierschke, 2000; Bohn & Neuhäusl, 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 *Schirmschlagbetrieb*/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 (Průša, 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* ssp.) 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; Tesař & Truhlář, 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

- 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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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 Löf 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 cheep possibility to establish beech stands (Gommel 1994, Leder and Wagner 1996, Baumhauer 1996). Nevertheless, in one third of all cases where direct seedling 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 Löf 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, Löf and Welander 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 therefore the option for future high quality timber (Willoughby et a. 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), Städtler and Melles (1999), Ammer et al. (2002), Leder et al. (2003), Nörr (2004), Madsen and Löf (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 Löf (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), Löf et al. (2004), Madsen and Löf (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, Löf et al. (2004), Löf and Welander (2004), Willoughby et al. (2004), Löf 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.

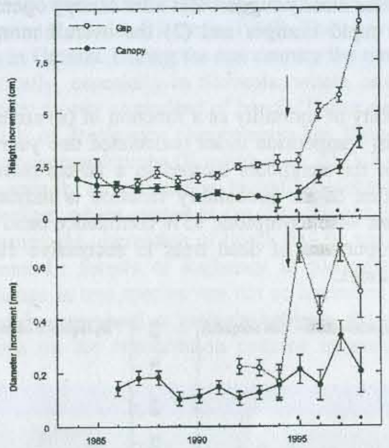
Effects of light availability and local competition on seedling growth

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 ±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

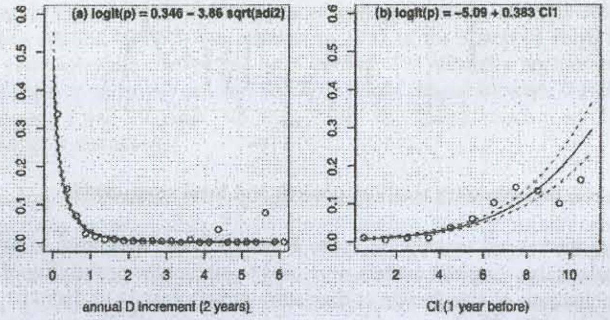
In many mature beech stands, a bank of seedlings exists. We have shown that this advance regeneration is able to recover rapid growth after canopy opening. However, questions remain about the morphological quality of the advance regeneration. Most seedlings that grew under closed canopy developed a typical 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.

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 Graoully 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.

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, Mlinšek 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.

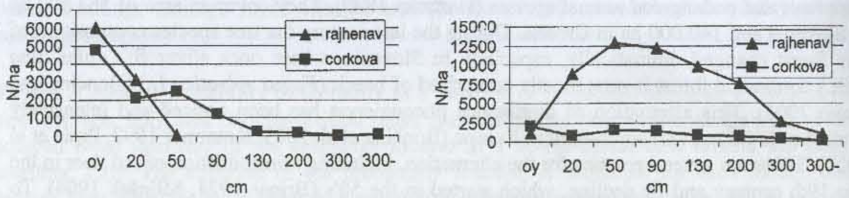
Materials and Methods

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 m^2 square plots, which we used to examine the density and species composition of regeneration and light conditions using fisheye photography. To test the differences between the sites and plot types we used the standard t-test and Kruskall-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 Corkova 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 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).

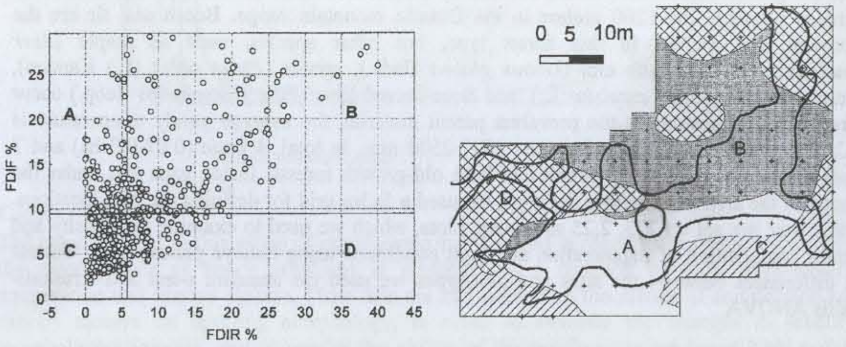


Figure 2 (right) shows the spatial pattern of the four types of plots. The locations of the groups indicate that there is, at least to some extent, a connection between groups defined by radiation and other ecological factors, such as precipitation, temperature, humus decomposition rate, and soil moisture, 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	B	C	D	
Rajhenav	(N = 71)	(N = 147)	(N = 147)	(N = 70)	p
regeneration %	63	72	43	48	0,0000
ground vegetation %	17	10	15	13	0,0000
beechoy N/ha	6385	3447	1935	889	0,0001
firoyn 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	(N = 81)	(N = 88)	(N = 87)	(N = 82)	p
regeneration %	21	24	16	17	0,8012
ground vegetation %	46	40	37	31	0,0067
beechoy N/ha	1481	1162	4138	1355	0,5813
firoyn 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 (Löf et al. 2004, Madsen and Löf, 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 (Bentsen, 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 petrea*), Japanes 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).

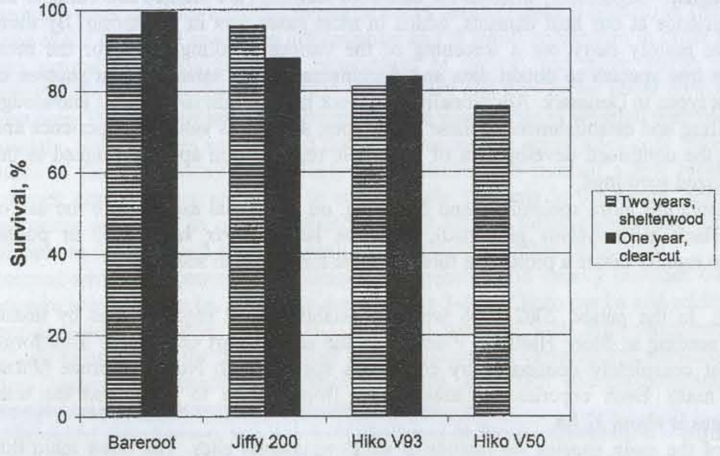
Fodder-fields are established and feeding the deer (roe deer – *Capreolus capreolus* - and red deer – *Cervus elaphus*) with sugar beets is carried out to reduce the browsing pressure at the regenerations. Additionally, deer are marked with GSM-GPS-collars to study their preferences for e.g. the regenerations 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 season 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 cm^3 Jiffy7® 3. generation overall air pruned container type.
Hiko V93: A 93 cm^3 2. generation tray system with drainage whole in the bottom.
Hiko V50: A 50 cm^3 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 sever 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 *Inseptisols* and *Alfisols*.
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 m^2.
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 m^2 with an average of 217 m^2 and a median of 172 m^2. The maximum of gap frequency is reached within the 100 m^2 size. Gaps up to 300 m^2 are about 81% of gaps recorded.

Shape frequency distribution is shown in figure1. 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 fungee 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 sizes 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 m^2 can be created by harvesting for establishing of natural regeneration.

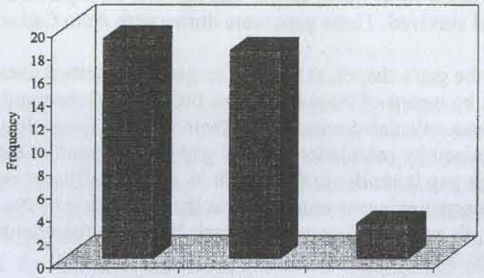

Figure 1. Gap shape frequency

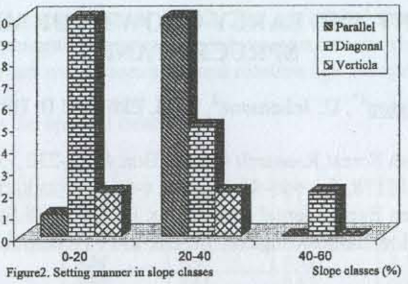

Figure2. Setting manner in slope classes

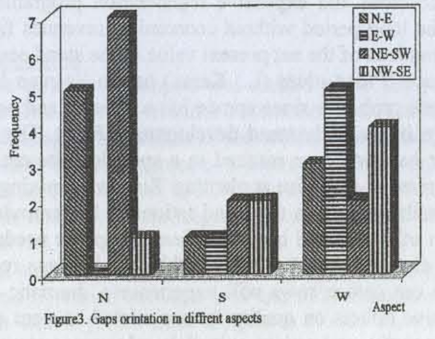

Figure3. Gaps orintation in diffrent aspects

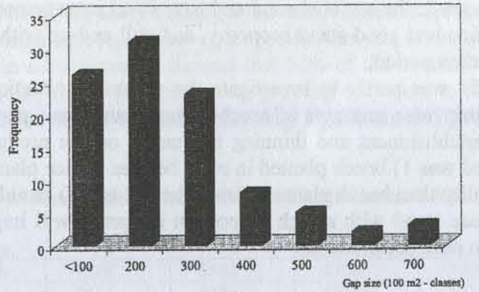

Figure4. Gap frequency distribution seperated in 100 m2 - size classes.

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ESTABLISHMENT AND EARLY GROWTH OF MIXED BEECH AND SPRUCE STANDS

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Introduction

When establishing new beech (*Fagus sylvativa* 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]	1	-	0,50	0,43	0,38	0,57	0,63
Prop of b.r. next to s.r.[1]	-	-	0,67	0,67	0,67	0,50	0,40

[1] 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

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 height[1] (meters)	Beech	29,8	29,8	29,8	29,8
	Spruce	21,2	28,9	21,2	28,9
Volume[1] (m3 ha-1)	Beech	322	339	367	344
	Spruce	114	274	142	319
Average growth[1] (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 Value[2] (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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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 (Robakowski 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.

Materials and Methods

In a deciduous stand of North-eastern France (Graoully 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 1m. 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 changed significantly in both species. But seedlings of beech exhibited a slight increase of light-saturated CO_2 assimilation (Asat reached 7.10 µmole m^{-2} s^{-1}) and stomatal conductance (gsat reached 0.14 mole m^{-2} s^{-1}), compared to seedlings that remained under close canopy (S plants, Asat and gsat were 5.52 µmole m^{-2} s^{-1} and 0.10 mole m^{-2} 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 µmole m^{-2} s^{-1} and 0.37 mole m^{-2} 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} kg s^{-1} m^{-2} 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-cutted 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:

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

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 (Lüpke 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.

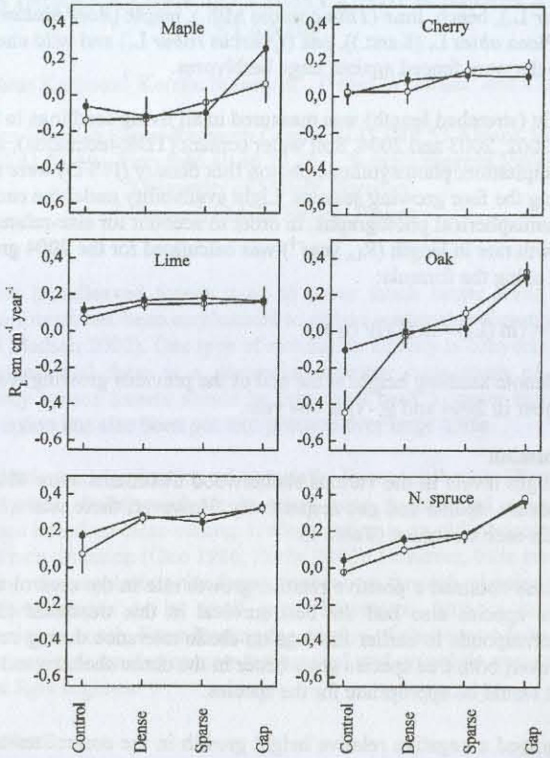

Figure 1: Relative growth rate in length 2003 to 2004 in maple, cherry, lime, oak, beech and Norway spruce, four blocks and four shelterwood treatments. Filled symbols denote permethrin treated seedlings and open symbols not treated seedlings. Ash is excluded in the figure. Mean ± SE.

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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.

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.)

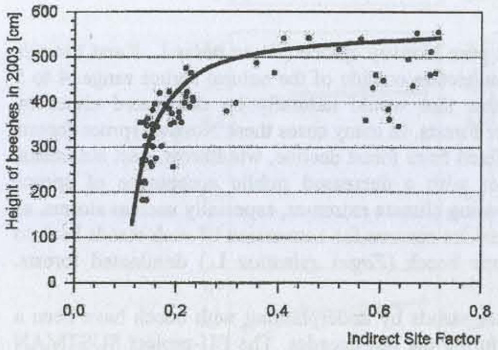

Figure 1: Relation between height growth of the investigated beeches and their light conditions

The non-linear relation between height growth of young trees and the incident radiation is described in literature very often (Mosandl 1984, Brunner 1993, Sagheb-Talebi 1996). Lüpke and Hauskeller-Bullerjahn (2004) used for their investigation the photoysnthetic 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.

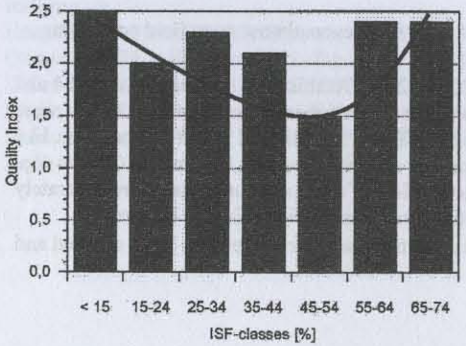

Figure 2: Quality (branchiness, stemform, inclination of tree top) of the investigated beeches in relation to their light conditions. A high value for quality index is equal with poor quality.

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 *hlb* [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 (Splechtna 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] $qv = a_0 + a_1 * CI$

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

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

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

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
hlb	*CI_P*	0,470	4,580		1p	0,88
n=154	*CI_P*	0,085	4,260		1	0,79
	CI_BD	2,953	2,690	1,720	4p	0,51
	CI_BD	2,143	4,927		4	0,23
	CE_H	5,171	12,879		3p	0,93
	CE_H	2,735	37,647	0,320	3	0,34
	CE_C66	5,615	2,563		3p	0,68
	CE_C66	2,655	2,422		3	0,21
asix	*CI_P*	161,280	17,142	54,958	3p	0,89
n=154	*CI_P*	100,532	2,699		3	0,44
	CI_BD	96,172	39,830	61,050	3p	0,89
	CI_BD	44,331	368,348	50,689	3	0,38
	CE_H	58,890	216,590		1p	0,80
	CE_H	46,780	171,500		1	0,74
	CE_C66	61,282	0,920		2p	0,60
	CE_C66	25,100	87,580		1	0,30
hf	*CI_P*	4,212	3,518	2,528	4p	0,86
n=92	*CI_P*	2,770	6,930	1,465	4	0,49
	CI_BD	3,226	8,777		4p	0,42
	CI_BD	2,478	-0,743		3	0,12
	CE_H	4,706	9,313	1,745	3p	0,90
	CE_H	3,577	2,143		3	0,35
	CE_C66	2133,000	0,001	-2127,000	4p	0,32
	CE_C66	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:

[5] $hlb = a_0 * \mathrm{EXP}(-a_1 * CE\_H) * CI\_P$

[6] $asix = (b_0 + b_1 * \mathrm{CE\_H}) * a_0 * \mathrm{EXP}(-a_1 * \mathrm{CI\_P})$

[7] $hf = \mathrm{EXP}(-b_1 * CE\_H) * (a_0 * (1\text{-}\mathrm{EXP}(-a_1 * CI\_P)) + a_2)$

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	Parameter estimates				
		r^2	a_0	a_1	a_2	b_0	b_1
hlb	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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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 Femel-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 *Galio 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:

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

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

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

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

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.

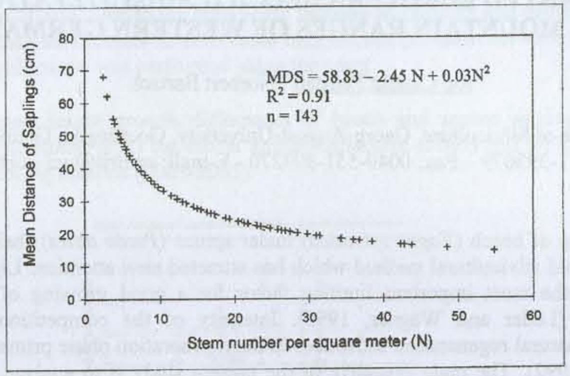
The growth space (GS) of beech saplings varied between 1.2 and 12.0 with an average of 5.0 ± 0.1 (Table 1). The growth space under the old growth stand was higher than in the gap center. This is because of plagiotropic crown and small stem base diameter among saplings grown under the mature trees and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

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 silviculterists 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 causes 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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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 new 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

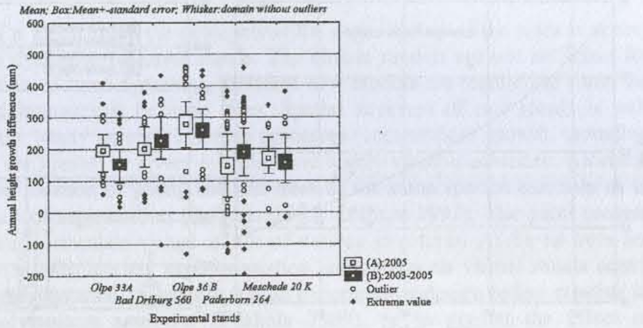
The research was carried out in five Norway spruce stands (80-100 years old) with underplanted European beech (15-16 years old), located in the Sauerland (at an elevation of 485-570 m a.s.l) and closed to Paderborn (350-385 m a.s.l) in Western Germany. The annual average temperature is approximately 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 m^2 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. Understory 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 that penetrates the overstory 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 overstory 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%).

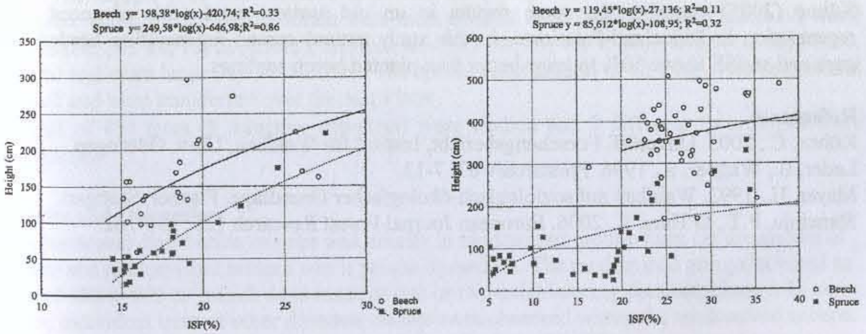
Apart from several spruces at Paderborn, the spruce saplings were smaller than the beech saplings. Annual beech height increment was in 2005 on average 2.8 (Bad Driburg) to 5 (Olpe 33) times greater than the spruce. However, height increment was lower for beech than for spruce (Fig 1). Annual height 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 comparasion 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 Sauerland (Olpe, Meschede) (Fig. 2, left), at an elevation difference of 200 m.

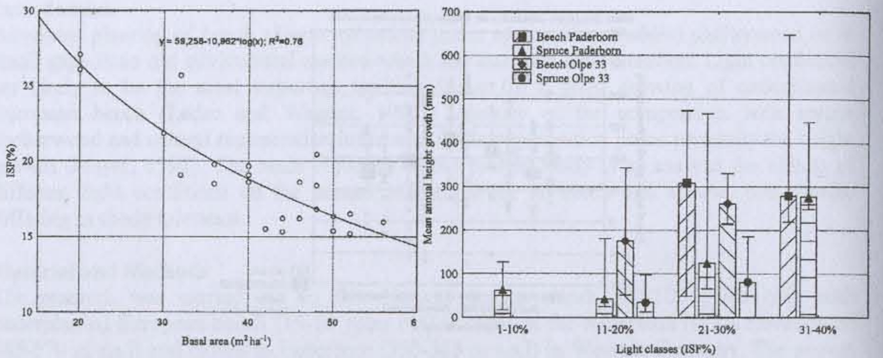
Figure 2: Scatter plots and logarithmical regression models for height (Olpe 33: left, Paderborn: right) as a function of light (ISF).



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 m^2 ha^{-1}) (Fig. 3, left) and Olpe 36 ($R^2 = 0,56$) (ISF: 17-28% = BA: 52-24m^2 ha^{-1}), moderately correlated for Meschede ($R^2 = 0,36$)

(ISF: 13-27 % = BA: 48-22 $m^2 ha^{-1}$) and Paderborn ($R^2 = 0,24$) (ISF: 15-38% = BA: 36-15 $m^2 ha^{-1}$) and weakly correlated in the Bad Driburg stand ($R^2 = 0,05$) (ISF: 18-28% = BA: 46-20 $m^2 ha^{-1}$). Under stand conditions with levels of available light from 15 to 25% ISF (BA: 55-20 $m^2 ha^{-1}$) 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 (XLT >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 m^2 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.

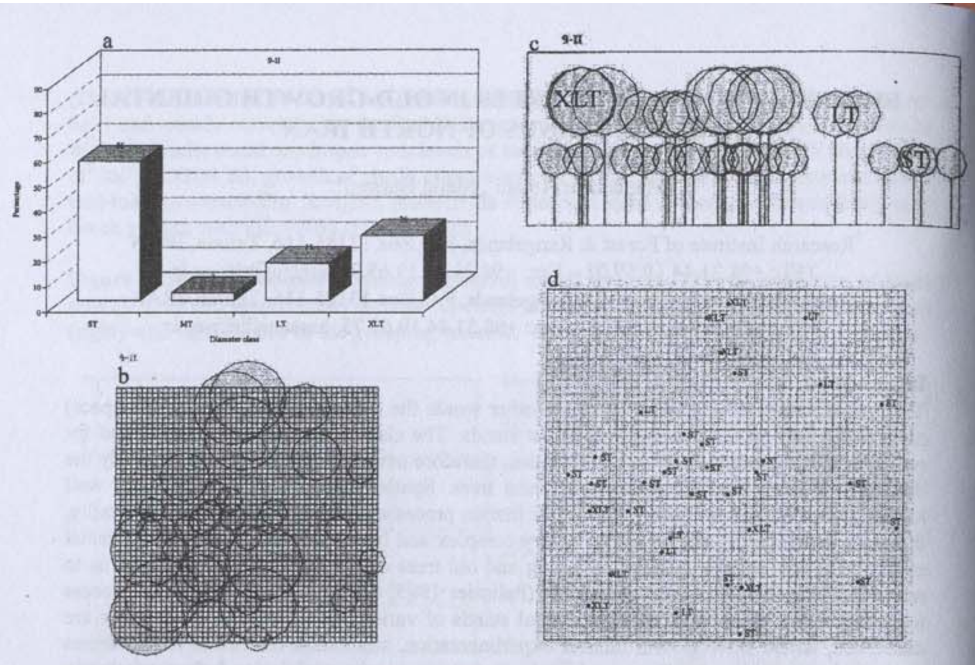

Figure 1 shows the a. Mathematical structure (histogram), b. horizontal profile, c. Vertical profile and d. point pattern map of the type 7, for example.

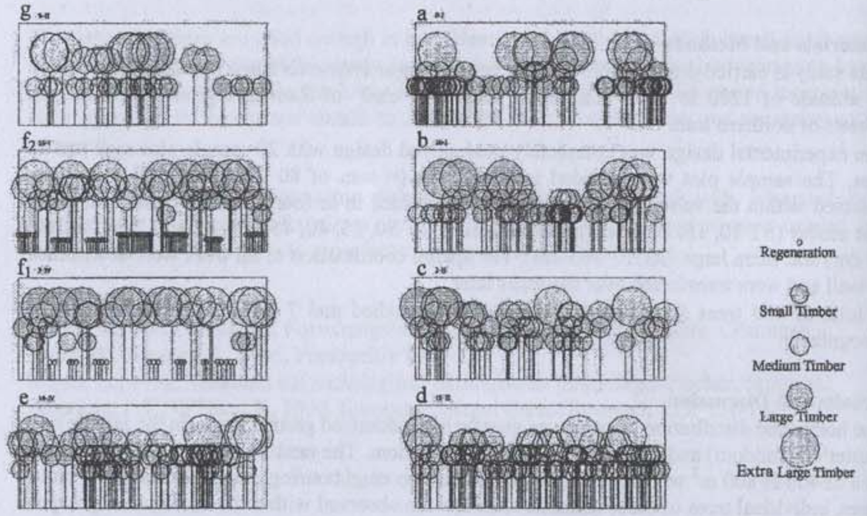

Figure 2 shows the vertical profile a) Initial uneven–aged or young stands in regeneration stage, b) Typical uneven–aged stand, c) uneven–aged stands tending to even-aged from and homogeneity, d) even–aged like (=regular) stand in ST/MT classes, e) even–aged stand in MT classes, f_1) even–aged in LT/XLT classes with extreme XLT class, f_2) even–aged in LT/XLT classes with extreme LT class, g) temporary decay stage.

Studding 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 thicket 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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RESTABLISHMENT 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 m^2 to 500 m^2 area gaps are better for reproduction. Shahnavazi(2000) showed that regeneration gaps area vary from 80m^2 to 1230m^2 in the virgin and natural Beech stands. Those gaps for European Beech *(Fagus sylvatica)* with 384m^2 to 1467m^2 areas (Emborg et al. 1990) are nearly similar. Considering that, degraded gaps have an areas nearly 1500 m^2 and often more than 0.5 ha, how can we restablish Beech natural regeneration in degraded areas?
On this basis, 5400m^2 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 designe is given as a randomized block experiment with four replicates.Each plot has an area of 144m^2 (12x12m) including a border of 2m around the plot and totally 5400m^2 which protected from game and livestock grazing.Within each plot, 25m^2 (5x5m)were selected for data collection based on numeration and height measurment of seedling species composition during two years(2004-2005) after site preparation.

Results and Discussion

List of restablished 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.

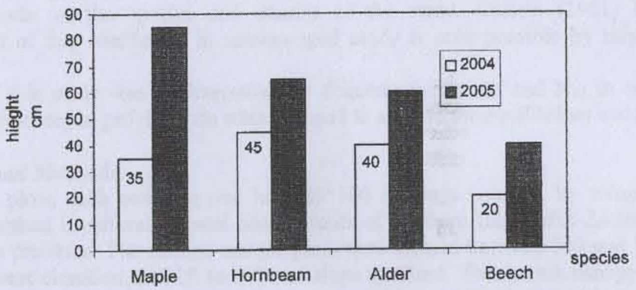

Figure1. Mean height growth of natural regenerated species in *Shoorab* experimental area

The primarily results clearly show that restablishment 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 restablishment.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 restablished seedlings exceed of 22000 per hectare.