REGENERATION PATTERNS AND PROBLEMS IN MIXED FORESTS

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ABSTRACT

Knowledge on natural regeneration in mixed stands is scarce. In natural forests all kind of interactions lead to an excellent natural regeneration. Two regeneration strategies appear : gap succession and advance growth succession.

Four critical factors can be distinguished in the process of natural forest regeneration : stand condition, weather situation, soil condition and biotic factors.

Forestry can significantly contribute to a successful natural regeneration by creating suitable ecological conditions. Crown density should be reduced to 60 % and secondary thinnings may only be executed after the establishment and consolidation of the seedlings. Soil preparation should be done to avoid soil compaction and raw humus formation as well as improve chemical and physical soil conditions. At present fencing is practically unavoidable.

1. INTRODUCTION

Natural forests are characterized by two main features : a mixture of species and a natural regeneration, unlike most of the presently managed forests, which feature monospecific stands and artificial regeneration.

Natural monospecific forests are in Europe probably only found near the timber line and in extreme habitats, such as peat bogs. But even here one may occasionally encounter mixtures. The richest mixed forests in Europe are the alluvial hardwood forests of the upper Rhine valley, with twenty to thirty woody plants and eight or more tree species in the upper canopy alone. Generally, however, the mixture consists of two or three species. The forests may form one or several storeys, or are irregular. One has to distinguish between homogeneous and heterogeneous mixtures. The former normally produce intermediate microclimatical conditions with respect to a successful natural regeneration, while the latter are likely to create a patchwork of microclimates, provoking abundant natural vegetation (Barkman, 1992).

Slovenia, Cimpersek (1988) found that regeneration was not successful after logging. It was more successful after patch clear felling than after regeneration felling.

With respect of stand condition it should finally be stressed that dead wood is an important germination site (Lack, 1991).

Besides the internal stand features, also external factors such as altitude, slope and effective temperature can determine the establishment, survival and development of natural seedlings (Valkonen, 1992; Paramonov, 1987). In Northern Finland natural regeneration of Scots pine and Norway spruce has been successful up to 350 m altitude, but it has taken 10-15 years to reach the desired stocking level.

3.2. Weather situation

It is well known that the weather conditions affect in many ways the regeneration results. It determines on the one hand the creation, production, preservation and germination of the seeds and on the other hand the development and parasitizing of the seedlings.

The phenomenon was especially investigated with beech (Dimitri et al., 1988). The temperature sum of June and July of the previous year is important. Warm and dry weather in this period normally leads to a good seed production in the next year, provided no weather extremes occur in the meantime. After seedfall the weather can have a decisive impact on beach regeneration when :

- due to very mild temperatures, germination starts strongly from the mid of January;
- due to a humid and warm climate, the development of harmful fungi is heavily stimulated;
- due to low air and soil humidity, the fruit cores or the germinating seeds are drying out;
- due to late strong frosts up to 80% of the germinating beechnuts are frozen.

The weather, of course, cannot be influenced by silvicultural measures. Yet stand conditions can strongly affect the impact of general weather situations.

3.3. Soil condition

Soil and humus conditions,as well as chemical soil characteristics, influence directly and indirectly the regeneration result.
Soil compaction, e.g. due to logging activities, makes regeneration almost impossible. Accordingly, hauling equipment should be restricted to a permanent network of skidding lanes, have wide tyres or tracks and operate on an adequate cushion of brushwood (Hofman, 1992). A thick raw humus layer, characteristic for many spruce stands, strongly hampers natural regeneration. Nutrients deficiency complicate the processes and especially the increasing acidifiction of thc upper 5 cm soil layer, often with a pH lower than 3.0, strongly hinders not only the germination but also the development of primary roots, while it favours the development of fungi (Gehrmann and Ubrich, 1983). The

abundant regeneration in the mixed mountain forest in the Alps of Eastern Bavaria is certainly partially due to the calcareous soil, unlike the complete lack of beech regeneraton on acidified soil of the Forest of Soignes in Belgium (Muys et al., 1988).

In connection with soil condition there is the ground vegetation. Natural regeneration is often inadequate or completely missing beause of competition of an abundant ground vegetation. Moreover it indirectly affects regeneration by interaction through phenomena such as mice damage or fungi attacks.
Successful natural regeneration cannot be expected on areas with a dense ground vegetation. Therefore clear felling must be avoided.
Mosandl et al. (1988) found that establishment, survival and growth of seedlings were not threatened as long as ground vegetation covers less than 40 %. Johnson et al. (1989) concluded that the abundance of red oak in a herbicide treated clearcut suggests that the key to regenerate red oak may be competition control and not necessarily a long regeneration period. Fhrener (1989) stresses the necessity to carry out weed control early, so that the natural regeneration can benefit from the June sun.

Ground vegetation should be used for provoking a succesfull regeneration. It can be used as an indicator of soil suitability for regeneration. Observation of the ground vegetation can help to determine where and how to intervene by felling.

3.4. Biotic factors

A lot of experiments have already proven that the principal problem for natural regeneration is damage by game and that it is very difficult in many forest areas to achieve natural regeneration under present conditions (Ott et al., 1991).
Some authors, however, although stressing browsing damage, put the impact into perspective, at least to some extent. So Mosandl and El Kateb (1988) found that the number of seedlings and saplings was also outside the fenced area more than sufficient for a good natural regeneration, provided there was a suitable crown density. A big part of the plants, however, were damaged by game. Especially fir and maple were browsed, unlike beech and Norway spruce, which were hardly damaged. The browsing degree mainly depended on plant height, which on its turn was determined by crown density. Browsing was relatively low under a dense cover, whereas it was very significant under a strongly opened canopy. Dangerous situations occurred on clearcuts. Also Robic and Boncina (1990) put into perspective the role of herbivorous ungulates, after having studied the composition and structure of natural young growth of beech and silver fir in the mixed Dinaric fir-beech forests. Indeed, as height increment of young trees is suppressed by the canopy trees, they concluded that young silver firs may be exposed to browsing for several decades in unfenced areas.
Nevertheless one has generally to conclude that, at present, satisfactory natural regeneration can only be achieved by fencing.

Besides of all kind of macro-organisms, micro-organisms also can strongly affect the regeneration result. In this respect, fungi are the most important and their occurrence is strongly linked with the thickness of the raw humus layer. It is proved that the infection of beechnuts depends on the site quality (pH and content of organic material) and on climate, especially in November-December. Later on, seedlings are often attacked, on the raw humus level, during humid-warm weather conditions.
Further on, significant damage can be caused by birds and rodents. Seedlings are in the first season increasingly threatened by louses, insects and especially by snails. If they survive, they are still for several season the subject of mice damage. So, Cimpersek (1988) found that mice were causing considerable damage to beech regeneration.
Nevertheless one should not forget the benefifical help for secondary seed dispersal by rodents. In this respect, Forget and Milleron (1991) noted, that seed removal and seed burial rates were strongly affected by features of forest habitats and/or forest age.

Forest fire deserves special attention with regard to forest regeneration. It is often very useful in temperate zones (Lust, 1988) and almost indispensable in boreal zones. Komarova (1989) reports about natural regeneration by seed after a major autumn fire in the Soviet Far East and mentions that regeneration by seed was intensive on areas where the litter had been destroyed. Rapid colonization of burned areas was associated with active germination of seeds preserved in the soil. On their side, Williams and Johnson (1992), investigating the factors affecting recruitment of *Pinus pungens* in the southern Appalachian Mountains, conclude that the result suggest that optimal recruitment and population maintenance of *P. pungens* in pine/oak forests are unlikely in the absence of fire.

4. KEYS TO SUCCESS

Based on extensive published litterature Ott et al.(1991) made a detailed comparison of the ecological factors influencing seed production, germination, seedlings establishment, growth and and survival of natural regeneration of tree species in the montane zone and the subalpine spruce zone in Switzerland. Herein the necessary conditions for the regeneration of mixed forests are described as follows :

1. Decisive limiting and minimal factors : light deficiency and quantity, competition of ground vegetation and game damage. Application of local optimal canopy density; avoiding of too early and too heavy thinning; no gap or clear fellings. Rule of tumb : thinning until crown density 60% combined with ground vegetation density 20-30 %. Once enough seedlings are established, significant stronger thinnings are needed. Browsing is the overall dominating problem.

2. Aggravating limiting factors : water supply and seed years. No drying up of the soil and a relative air humidity of 50-60 %. Use of rare seed years of beech.

3. Other affecting factors: rodents, insects, snails, seedling fungi, allelopathic interactions, etc.

For Edwards (1987) the keys to success include a suitable seedbed, adequate seed supply, sufficient moisture and freedom from excessive competition.
So it is evident that forestry can contribute to the natural regeneration process. It has mainly to focus on three points :

- canopy density;
- soil preparation;
- game damage control.

Several experiments have proved that almost all tree species find favourable generation conditions when the canopy density is reduced to 60 %, corresponding with a removal of about 25 % of a closed stand and leading to a ground vegetation covering approximately 20-30 % of the soil. Anyway regeneration must be established before the stand is opened up, in order to compete with ground vegetation. Regulation of mixture can be achieved by determining the initial light quantities and by the periodicity and degree of secundary thinnings.

Soil preparation contains a double aspect. From the one hand the forest soil must be protected against compaction, while from the other hand some active measures against unfavourable conditions should be taken. The latter aims to improvement of both he chemical and the physical soil characteristics.

According to Bressem (1988) soil pH affects the fungal flora on the fallen beech mast, low pH values seem to increase the aggressiveness and pathogenicity of the soil fungi. Best germination and development of primary roots, cotyledons and shoot : root ratio are achieved with soil pH values of about 4.3. (KCl). Plant development is severely inhibited by pH values of 3.0 and pH values greater than 6.0 are unfavourable for the overwintering of the mast. Liming improves the germination rate and seedling development and appears to reduce the virulence of important soil fungi. Timing of the liming is decisive. It should be done 15-20 years, or at latest 3-5 years, before starting to regenerate the beech. Liming in the mast year itself will impair the overwintering of the seeds. A targetted application of fertilizer and/or lime at the start of the second growing season promotes seedling development (See also Dimitri and Bressem, 1988).

All experiments show a positive effect of soil cultivation on establishment and preservation of seedlings. Dohrenbusch (1990) concluded that it was very helpful in improving conditions for survival of overwintering beech seeds and in favouring development of the young plants. Especially two methods are to be recommended. Soil injuring, by scarification, can be executed on the full area or on part of it and is to be considered as an extensive measure. Unlike intensive soil cultivation by strip removal of the topmost humus layer, that incorporates the seed into the mineral soil, reduces mast loss, preserves viability, reduces seedling losses and improves seedling development (Bressem, 1988).

Finally it should be stressed once more that, at present, satisfactory natural regeneration requires almost always fencing. However Bressem (1988) found that the greatest losses of previously healthy (beech) seedlings occur in June/July of the first growing season, mainly as a result of insect damage. Therefore appropriate control may be necessary. The same can be concluded with oak seedlings, which are often very heavily attacked by Oidium fungi.

5. SUMMARY

Knowledge on natural regeneration processes in mixed stands is scarce. Generally, natural regeneration does not occur frequently and the regeneration circumstances have strongly deteriorated the last decades, due to acidification.
In natural forests all kind of interactions between the biotic and abiotic world normally lead to an excellent regeneration. Two regeneration strategies clearly appear : gap succession and advance growth succession. Disturbances are dominated by small canopy gaps, created by death of some trees.
Four critical factors can be distinghuished in the natural regeneration process.

1. Stand condition. Seed availability is a first requirement, but normally no problem. Canopy density is a crucial factor, regulating density, composition and development of regeneration. Vertical stratification favours well shaped crowns. Gap size is to be considered as a comprehensive indicator of the microclimate. External factors such as altitude and slope, should also be taken into account.

2. Weather situation. It determines the creation, production, preservation and germination of the seeds and the development of the seedlings.

3. Soil condition. Soil compaction, nutrient deficiencies and increasing acidification strongly hinder regeneration. An abundant ground vegetation must be avoided.

4. Biotic factors. Game damage is often seen as the principal problem for natural regeneration. Besides other macro- and micro-organisms do play also an important role : birds, rodents (mice), fungi. Forest fire deserves special attention, mainly in boreal zones.

Forestry can significantly contribute to the success of natural regeneration, by creating suitable ecological factors for germination and seedling development.

- Canopy density should be reduced to 60 %, corresponding with a removal of 25 % of the closed stand. Further opening of the stand is only allowed when the regeneration is established and able to compete with ground vegetation.
- Soil preparation should focus on the one hand to avoid bad circumstances e.g. compaction and raw humus layer and on the other hand to improve chemical and physical features. Two methods are to be recommended : an extensive soil scarification or an intensive strip removal of the topmost humus layer.
- Fencing.

6. REFERENCES

Barkman, J.J., 1992. Canopies and microclimate of tree species mixtures. In : Cannell et al. (Eds). The ecology of mixed species stands of trees. Blackwell Scientific Publications, 181-188.

Borchert, M., Davis, F., Michaelsen, J., Oyler, L., 1989. Interactions of factors affecting seedling recruitment of blue oak (*Quercus douglasii*) in California. Ecology 70, 2, 389-404.

Bressem, U., 1988. Versuche zur Förderung und Erhaltung der Buchennaturverjüngung. Forschungsberichte - Hessische Forstliche Versuchsanstalt, 5, 193 p.

Burschel, P., H. El Kateb, J. Huss and R. Mosandl, 1985. Die Verjüngung im Bergmischwald. Forstw. Cbl., 104, 65-100.

Burschel, P., El Kateb H. and Mosandl, R., 1992. Experiments in mixed mountain forests in Bavaria. In : Kelty et al. (Eds). The ecology and silviculture of mixed-species forests, Kluwer Academic Publishers, 183-215.

Carraro, G., Schutz, J.P., 1990. Importanza ecologica delle querce autochtone e prospettive selvicolturale nell'Insubria. Schweiz. Zeitschr. f. Forstwesen, 141, 4, 265-294.

Cho, D., Boerner, R., 1991. Canopy disturbance patterns and regeneration of Quercus species in two Ohio old-growth forests. Vegetatio, 93, 1, 9-18.

Cimpersek, M., 1988. Ecology of natural regeneration in subpannonian forests. Lesno Gospodarstvo Zbornik Gozdarstva in Lesarttiva, 31, 121-183.

Dimitri, L., Bressem, U., 1988. Einige Bemerkungen zum Ankommen und zur weiteren Entwicklung der Buchen - Naturverjüngung. Forst und Holz, 43, 2, 32-37.

Dohrenbusch, A., 1990. Die Verjüngungsentwicklung der Buche (Fagus silvatica L.). Bericht einer langfristigen Beobachtung im Solling. Schriften aus der Forstlichen Fakultät der Universität Göttingen und der Niedersächsischen Forstlichen Versuchsanstal, No. 97, 70 p.

Doucet, R., 1988. La régénération préétablie dans les peuplements forestiers naturels au Québec. Forestry Chronicle, 64, 2, 116-120.

Edwards, M.B., 1987. Natural regeneration of Loblolly pine. A loblolly pine management guide. General Technical Report - Southeastern Forest Experiment Station, USDA Forest Service, No. SE - 47, 17 p.

Efremov, R., 1987. Natural regeneration in the beech forests of the Bugludzhan complex. Gorsko Stopanstvo Gorska Promishlenost, 43, 5, 9-11.

El Kateb, H., 1990. Der Einfluss waldbaulicher Massnahmen auf die Sprossgewichte von Naturverjüngungsflanzen im Bergmischwald. Biometrische Auswertung eines walbauliches Versuches. M. Sc. thesis, Univ. of Stellenbosch, 193 p.

Fiedler, C.E., Mc Caughey, W.W., Schmidt, W.C., 1985. Natural regeneration in Intermountain Spruce-fir forests - a gradual process. Research paper, USDA Forest Service, No. INT-343, I, 12 P.

Forget, P.M., Milleron, T., 1991. Evidence for secondary seed dispersal by rodents in Panama. Oecologia, 87, 4, 596-599.

Frehner, M., 1989. Beobachtungen zur Einleitung der Naturverjüngung an einem nordexponierten Steilhang im Subalpinen Fichtenwald. Schw. Zeitschr. f. Forstwesen, 140, 11, 1013-1022.

Friedman, J., Hutchins, A., Li, Cy., Perry, D.A., 1989. Actinomycetes inducing phytotoxic or fungistatic activity in a Douglas-fir forest and in an adjacent area of repeated regeneration failure in southwestern Oregon. Biologica-Plantarum, 31, 6, 487-495.

Frivold, L.H., 1986. Natural regeneration of birch and Norway spruce on clearfelled areas in the East Norwegian Lawlands in relation to vegetation type and moisture. Meddelelser fra Norsk Institut for Skogforskning, 39, 67-84.

Gehrmann, J., Ulrich, B., 1983. Der Einfluss des sauren Niederschlages auf die Naturverjüngung der Buche. Sonderheft der Mitteill. der Lölf : Immissionsbelastungen von Waldökosystemen, 32-36.

Hofmann, R., 1992. Bodenschaden durch den Einsatz kleiner und grosser Vollernter. Forsttechnische-Informationen, 44,3, 17-20.

Johnson P.S., 1992. Oak overstory reproduction relations in two xeric ecosystems in Michigan. Forest Ecology and Management, 48, 3-4, 233-248.

Johnson, P.S., Jacobs, R.D., Martin, A.J., Godel, E.D., 1989. Regenerating northern red oak : three successful case histories. Northern Journal of Applied Forestry, 6(4), 174-178.

Komarova, T.A., 1989. Regeneration by seed on recently-burned sites in southern Sikhote-Alin. Lesovedenie, 2, 51-59.

Kubin, E., Kemppainin, L., 1991. Effect of clearcutting of boreal spruce forest on air and soil temperature conditions. Acta Forestalia Fennica, No. 225, 42 p.

Lack, A.J. 1991. Dead logs as a substrate for rain forest trees in Dominica. Journal of Tropical Ecology, 7, 3, 401-405.

Leemans, R., 1991. Canopy gaps and establishment patterns of spruce (Picea abies (L.) Karst.) in two old growth coniferous forests in central Sweden. Vegetatio, 93, 2, 157-165.

Lemée, G., 1987. Dynamique de fermeture par régénération et évolution morphométrique du hêtre dans les vides d'une forêt non exploitée (réserves biologiques de la forêt et de Fontainebleau). Bulletin d'Ecologie, 1987, 18, 1, 1-11.

Leinonen, K., Leikola, M., Peltonen, A. Räsänen, P.K., 1989. Natural regeneration of Norway spruce in Pirkka-Häme Forestry Board District, southern Finland. Acta Forestalia Fennica, No. 209, 53.

Lokhmato, N., Grechukha, V., 1988. Natural regenertion of oak woodlands and its utilization. Lesovodstvo i Agrolesomelioratsiya, 76, 16-21.

Lust, N., 1988. Analysis of a natural regeneration of Scots pine forest in the High Campine after a fire. Silva Gandavensis, No.53, 3-28.

Mitscherlich, G., 1971. Wald, Wachstum und Umwelt. II. Band : Waldklima und Wasserhaushalt. J.D. Sauerlander's Verlag, Frankfurt am Main.

Mosandl, R, 1984. Löcherhiebe im Bergmishwald. Forstliche Forschungsberichte München, No.61, 298 p.

Mosandl, R. und H. El Kateb, 1988. Die Verjüngung gemischter Bergwälder - Praktische Konsequenzen aus 10 jähriger Untersuchungsarbeit. Forstw. Cbl., 107, 2-13.

Muys, B., Van Den Berge, K., Roskams, P., Maddelein, D., Meyen, S., 1988. Analysis of natural regeneration in a 200 years old beech stand. Silva Gandavensis, No. 53, 61-81.

Ott, E., F. Lüscher, M. Frehner, P. Brang, 1991 Verjüngungsökologische Besonderheiten im Gebirgsfichtenwald im Vergleich zur Bergwaldstufe. Schw. Zeits. f. Forstwesen, 11, 879-904.

Paramonov, E., 1987. The effect of slope aspect on the regeneration of Pinus sibirica. Lesnoe Khozyaistvo, 12, 29-31.

Rackham, O., 1992. Mixtures, mosaics and clones : the distribution of trees within European woods and forests. In : Cannell et al. (Eds.). The ecology of mixed species stands of trees, Blackwell Scientific Publications, 1-20.

Robic, D., Boncina, A., 1990. Composition and structure of natural young growth of beech and silver fir in the mixed Dinaric fir-beech forest with exclusion of herbivorous ungulates. Zbornik Gozdarstva in Lesartva, 36, 69-77.

Saniga M., 1987. Natural regeneration of forest stands in the state forests of central Slovakia and reasons for its low proportion. Lesnicky Casopis, 33, 3, 229-234.

Uspenskii, E., 1987. The forest regeneration process beneath the canopy of birch and aspen forests in the central Volga region. Izvestiya Vysshikh, Uchebnykh Zovedenii, Lesnoi, Zhurnal, 3, 116-118.

Valkonen, S., 1992. Forest regeneration at high altitudes in Northern Finland. Folia Forestalia, No. 791, 84 p.

Weinsein, A., 1984. Acorn productions and seedling crop in *Quercus calliprinos*. La-Yaaran, 34, 1-4.