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[Research]

Some criteria of regeneration density in young beech populations

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ABSTRACT

Some criteria of density in beech saplings were 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). Five sample plots, each 2x2m in 3 transects (a total of 15 plots in each gap, x 10 gaps), were laid out from the center to the edge of the gap and under the old growth stand in the upper, middle and lower parts of the gap. Three collective criteria (i) number of saplings (Nm^{-2}), (ii) mean distance of saplings and (iii) crown competition factor and one individual criterion (growth space) were investigated within the sample plots. Results showed that the density of beech saplings was not homogenous. The number of saplings (Nm^{-2}) had wide amplitude, which varied between 2.5 and 54.8 and the mean distance of saplings varied between 14.5 and 68.0 cm. The crown competition factor varied between 1 (100%) and 5 (500%) indicating five times of overlapping in crown space of saplings, while the growth space of the studied beech saplings varied between 1.2 and 12.0.

Keywords: *beech, crown competition factor, density, growth space, regeneration.*

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 it is intraspecific and strongly depends on age of trees and structure of the stands (Otto, 1994; Nyland, 1996). Competition for light, water and nutrients depends largely on the stem number per unit area and the crown form of the trees, as Miller (1953) emphasized in his studies on the role of responsible environmental factors on the form of young beeches. One result of competition among plant species of the forest is the development of vertical structure of the vegetation (Barnes et al., 1998). Crown classes and growing space illustrate the results of intense competition in the stands. Distance-independent competition measures explain variation in the height and diameter squared growth of trees (Biging & Dobbertin, 1995).

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 their homogeneity are factors that should be considered by foresters during tending and thinning operations for density regulation. Although there is usually no special spatial distribution pattern of natural regeneration, in most cases it could be considered a quadratic or triangular pattern existing among the saplings (Schütz, 1990).

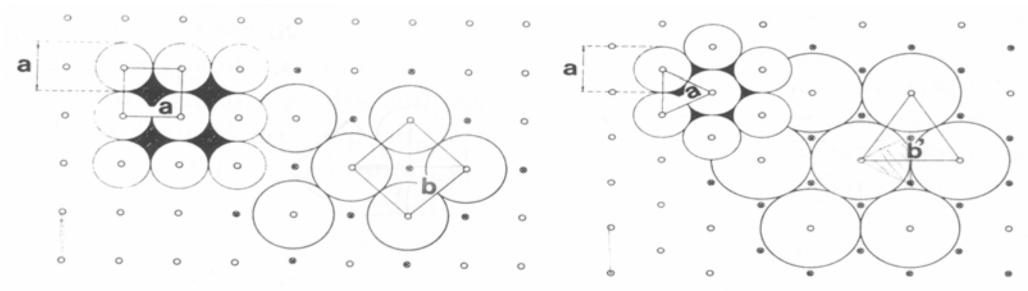

Fig 1. Spatial distribution pattern, left quadratic and right triangle pattern (after Schütz, 1990).

Various measures for describing stand density or competition criteria have been developed; such as crown width of trees (Ebert & Deuschle, 2000), mean distance of trees, ratio of mean tree diameter to stand basal area (D:BA) (Reid, 2006) and competition indices for evaluating inter- and intra-specific interactions between trees (Vanclay, 2006). Additional to these criteria, the Crown Competition Factor (CCF) is introduced as a very applicable factor (Krajicek et al., 1961; Schweiger & Sterba, 1997). 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 width 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. Tabbush and White (1988) found a highly significant linear relationship between crown width and breast height diameter in Sitka spruce trees.

The hypothesis of this study is that the regeneration density and competition between saplings varies in different parts of the gaps and 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 regulation of density in young beech stands.

MATERIALS and METHODS

Beech saplings were 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 Width (CW = distance between the tip of the longest branches) of each beech sapling, which is an important factor to describe the growth efficiency and competition in stands (Condés & Sterba, 2005), were assessed within 5 sample plots, each 2x2m, in 3 transects and a total of 15 plots in each gap (x 10 gaps), that were laid out from the center to the edge of the gap and under the old growth stand as well. Transects were established in the upper, middle and lower parts of each gap.

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

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) which describes density and its maximum value is regarded to be independent of tree species, stand age and stand structure (Krajicek et al., 1961; Schweiger & Sterba, 1997) calculated by using equation [2] (Schütz, 1984 and 1990) as follows:

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

where MCW is the Mean Crown Width

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

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

where CW is Crown Width 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, using the architectural model of beech (Sagheb-Talebi, 1995), only 9 years old saplings (median) were selected and data were analyzed statistically by using SAS software.

Maximum, minimum, mean and median of data were calculated and a regression analysis is used for the relation between stem number and mean distance of saplings.

RESULTS

Results showed that the density of beech saplings was not homogenous and various competition conditions were 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).

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

Criteria	min.	max.	mean	median
Stem Number (N m^{-2})	2.5	54.8	13.4 ± 1.8 §	8.3
Mean Distance of Saplings (MDS) (cm)	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%)

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 ($p<0.001$) in two studied models (Table 2 and Fig. 2).

Table 2. Regression analyze between stem number per square meter (N) and mean distance of saplings (MDS); models a and b

Model a) $MDS = \beta_0 + \beta_1 . Log(N)$

N	F-value	Prob>F	R^2	Factor	Coefficient	T-value	Prob>T
143	468.98	0.0001	0.97***	constant	74.39	118.4	0.0001
				Log (N)	-38.10	-63.8	0.0001

Model b) $MDS = \beta_0 + \beta_1.N + \beta_2.N^2$

N	F-value	Prob>F	R^2	Factor	Coefficient	T-value	Prob>T
143	720.31	0.0001	0.91***	constant	58.83	76.0	0.0001
				N	-2.45	-25.2	0.0001
				N^2	0.03	15.6	0.0001

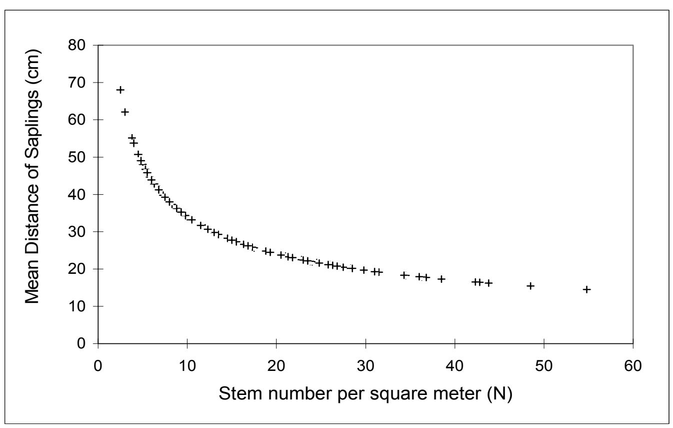

Fig 2. Relationship between stem number per square meter (N) and mean distance of saplings (MDS) within the sample plots

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.

The growth space (GS) of beech saplings varied between 1.2 and 12.0 with an average of 5.0 ± 0.1 (Table 1), and it was higher under the old growth stand than in the gap center (Fig.3). 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.

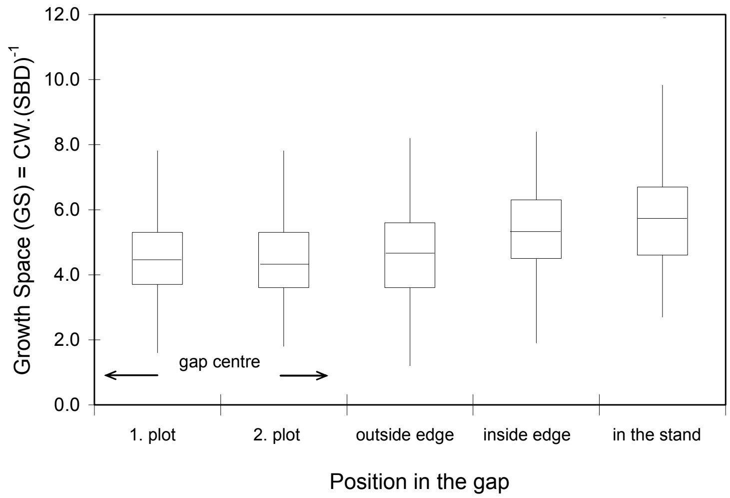

Fig 3. Distribution of Growth Space (GS) of beech saplings within the position in gap

DISCUSSION

Offering sufficient growth space for developing the crown and root is very essential for young trees. Availability of site growth resources and regulation of density affect the stem growth and stand development positively, as shown in die studies on 1- and 3-year-old natural upland hardwood stands (Schuler & Robinson, 2006). Tree density has a great influence on the number of recruits (Wolf, 2005) and diameter and basal area of trees are directly affected by stand density which indicates the competition in the stand (Cancino, 2005).

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. A suitable density and appropriate shaded area will offer ground conditions with sufficient moisture and light to ensure successful early growth of seedlings and saplings, but without excessive competition from other vegetation (Page & Cameron, 2006). Not only on the above ground environment, but also underground there would be more root competition in the dense stands. Therefore a balance must be reached for given species on a given site through appropriate density control. 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; sometimes it could even cause mistakes. Because of plagiotropic crown (Hallé & Oldeman, 1970; Roloff, 1986) and small stem base diameter among saplings grown under the mature trees and crown closure of the old growth stand, this criterion was higher under the old growth stand than in the gap center.

On the contrary the crown competition factor could be more useful to illustrate the density and competition of the stand. Monserud and Sterba (1996) showed different values of CCF for Norway spruce in even- and uneven-aged forest stands in Austria. Further, Schweiger and Sterba (1997) used CCF in their studies and showed that the stand characteristics are related to regeneration and to this factor as well. Condés and Sterba (2005) indicate that a CCF of 100 is a stand where there is no competition, while a CCF of 200 indicates that competition-induced mortality starts and a CCF of 400 is usually not exceeded because it represents equilibrium between growth and mortality. We calculated a CCF of 480 in our study for the very dense beech saplings. In 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.

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شاخص‌های تراکم تجدید حیات در توده‌های راش جوان

خ. ثاقب طالبی، ژ.ف. شوتز

چکیده

چند شاخص تراکم نهالهای راش در جوامع جنگلی (به ویـژه *Galio odorati-Fagetum typicum*) در منطقـه نیمه کوهستانی اطراف زوریخ (سوییس) مطالعه شد. پنج قطعه نمونه 4 متر مربعـی (2 x 2 متـر)در 3 ترانـسکت در قسمتهای بالایی، میانی و پایینی(جمعا 15 پلات) در 10 روشنه از مرکز تا حاشـیه روشـنه و در زیـر درختـان تـوده مجاور حاصل از اجرای شیوه جنگلشناسی تدریجی- روزنه‌ای (Femelschlag) تعبیه شـدند. سـه شـاخص تـراکم گروهی: 1) تعداد نهال (در مترمربع)، 2) فاصله متوسط نهالها و 3) ضریب رقابت تاجی و یک شاخص انفرادی (ضریب فضای رشد) در قطعات نمونه بررسی و محاسبه شدند. نتایج نشان داد که تراکم نهالهای راش در قطعات مورد بررسی همگن نبوده است. تعداد نهال در واحد سطح بین 2/5 تا 54/8 در مترمربع و فاصـله متوسـط نهالهـا بـین 14/5 تـا 68/0 سانتیمتر نوسان داشت. ضریب رقابت تاجی بین 1 (100٪) و 5 (500٪) تغییـر مـی‌کـرد کـه بیـانگر 5 برابـر همپوشانی فضای تاج نهالهاست، در حالی‌که ضریب فضای رشد نهالهای مورد مطالعه بین 1/2 تا 12/0 متغییر بود.