Effect of light and humus on survival and height growth of ash (*Fraxinus excelsior* L.) seedlings

TABARI, M., LUST, N. & NEIRYNCK, J.

Laboratory of Forestry, University of Gent, Belgium.

Abstract

In 1997, 300 3-month-old ash (*Fraxinus excelsior* L.) seedlings were removed out of the three different humus types (100 seedlings from each humus type) in the experimental forest of Aelmoeseneie (University of Ghent) with a closed canopy, in north of Belgium. Humus types were described as active mull with pH of 5.3-6.5, acid mull with pH of 4.4-5.2 and moder mull with pH of 3.8-4.3. Seedlings were transplanted in plastic pots, filled by the original soil, and placed under five levels of light intensity (2.5, 10, 18, 28 and 92%), inside and outside the forest. Only with 92% light intensity seedlings were watered as necessary to avoid any appreciable water deficit.

The results after 1 growing season revealed that seedlings attained a very high survival rate (95.3%). Survival was the highest when seedlings grew under semi-closed canopy (10, 18, and 28%) and also outside the forest at the 92% light intensity, compared with those under closed canopy (2.5%). It also confirmed that ash seedlings are shade tolerant, but with little growth.

Height growth indicated an increasing growth response to nutrient availability with increasing light intensity. In fact, minimum height growth was observed in lower light intensities (2.5 and 10%) and the maximum value in higher light intensities (28 and 92%). height growth of ash seedlings increased at humus types of active and acid mull, compared with moder mull.

At the end of the first growing season, lack of differences in survival rate and height growth, produced under 18, 28 and 92% light intensity, revealed that training the seedlings under semi-closed canopy (18 and 28%) has a preference to those under relatively full daylight (92%) associated with watering. Therefore, the first year observations showed that ash seedlings, either in view of stem quality and growth or with regard to the facilities of maintenance, are preferable to be trained under intermediate light intensities (preferably 28%), at the high nutritional humus (active and acid mull).

1. Introduction

Generally, survival and growth of the ash (*Fraxinus excelsior*) seedling, as oak (*Quercus robur*) and beech (*Fagus sylvatica*), has been still a complicated problem in the Aelmoeseneie Experimental

Forest, in north of Belgium. Ash seedling within the ash stand at the humus type of active mull with a pH ranging between 5.2-6.5 does not only grow well but also has a very low survival rate. The low growth and survival rate are also observed within the oak and beech stand at the humus type of moder mull. Many of the decisive limiting factors related to the survival and growth in this forest probably are: light deficiency and quantity, and also nutrient deficiency and increasing acidification of the topsoil.

Soil and humus conditions, as well as chemical soil characteristics, directly or indirectly influence the regeneration results (Lust, 1994). A thick raw humus layer, characteristic for many spruce stands, strongly hampers natural regeneration. Nutrient deficiency complicate the process and especially the increasing acidification of the upper 5 cm soil layer, often with a pH_{KCl} lower than 3.0, strongly hinders not only the germination but also the development of primary roots, while it favors the development of fungi (Gehrmann and Ulrich, 1983). According to Bressem (1988) low pH values seem to increase the aggressiveness and pathogenicity of the soil fungi. In literature the importance of light intensity, nutrient availability and humus type of soil on growth and also requirements of the ash tree seedlings were reported as following.

Generally, ash may germinate in profusion on heavy wet soils because it only needs a small depth of well-drained soil on which to becomes established. It obtains the best growth on calcareous loams of pH 7 to 8 which are moist, deep, well drained and have a high content of available nitrogen (Savil, 1991). Ash is usually absent (Garfitt, 1989) from sites where the pH of the surface soil is less than 4.4, and less frequent on other acid soils and in drier regions. Concerning the ash seedling, Thill (1970) reports that it grows well where the soil is loam, cool associated with a nearly neutral pH. Manshard (1993) also states that nutrient demands of the ash seedlings grown in the same soil in forest nurseries are comparable to oak and beech, especially for nitrogen and potassium. Stern and Roche (1974) point out that soil factors are the most frequent reason for tree species occurring where they do, yet the importance of soil properties as niche factors is much less well known than that of climatic factors.

The relative importance of light as an ecological factor for the survival and growth of seedlings was discussed by Jarvis (1963). In accordance with Mosandl et al., (1988) it can be confirmed that the canopy density is crucial factor which regulates density, species composition and height development of the regeneration. In very heavily stocked mature stands with canopy density covering more than 75%, establishment of regeneration of maple, beech, fir, and spruce is difficult. when the canopy density is reduced to, for example, 60%, the naturally regenerated plants have a better opportunity to survive.

Ash seedling is less shade tolerant than that of beech but more than sycamore (*Acer pseudoplatanus*) and oak (*Quercus robur*). This shade tolerance appears to persist for only a few years (Kerr, 1995). On shaded woodland floors it shows marked persistence but little growth. When gaps are formed, however the seedlings respond rapidly to the increased light (Wardle, 1959). Generally, ash during its seedling stage is also highly shade-tolerant (Van Miegroet and Lust, 1972), whereas even after up to 30 years of suppression with very slow growth (less than one cm per year), seedlings may resume normal growth after opening of the canopy.

It can be therefore concluded that growth, development and survival of the ash seedlings depend on the radiation supply and soil physico-chemical factors, especially nutrient availability and acidification (pH) either at the surface and or depth of soil. Since the condition of these attributes (survival and height growth) within the existing natural stands is not satisfactory, therefore this study is also aimed to assess the survival rate and the height growth of the ash seedlings of this forest, subject to three different humus types, originated from the forest soil, and five levels of light intensity. The seedlings were transplanted in pots outside and inside the forest (under closed and semi-closed canopy).

2. Materials & methods

Three different humus types namely active mull with pH of 5.3-6.5, acid mull with pH of 4.4-5.2 (within the ash stand) and moder mull with pH of 3.8-4.3 (within the oak - beech stand) were chosen each one at a small and homogeneous district, in the experimental forest with a closed canopy (crown closure > 95%). In early of July 1997, 300 3-month-old ash seedlings (100 seedlings in each humus type) were selected according to the following characteristics.

- two leaves in addition to the cotyledons;
- height from 10 to 15 cm;
- healthy and lacking the disease and pest;
- high vitality;
- healthy terminal bud.

Ash seedlings associated with tap and lateral roots surrounded by the soil, were carefully excavated of the ground in the early morning, by a cylindrical core of 10 cm diameter and 15 cm height. Each seedling, immediately after removal out of the ground, was placed in plastic pots of 20 cm diameter and 30 cm height. The rest of pots volume was filled by the soil, dug out of around the seedling roots. In each pot a few mm of litter was also placed on top of soil, whereas its amount depended on the thickness of litter in each forest soil type, which part of seedling roots were laid in. Litter thickness in turn for active mull was 2-4 mm, for acid mull 3-8 mm and for moder mull 50-100 and even 150 mm.

After transplanting, the potted seedlings were transferred to places with different light intensities. Light readings, carried out by a Lux-meter unit (Weston Illumination Meter), gave the average

values of 2.5, 10, 18, 28 and 92 % light intensities of full day light respectively for the five levels of shading (Table 1). The readings being taken during overcast and sunny weather for 4 weeks between 08:00 and 20:00 in July and August 1997 (during the period of full leaf development in the canopy) to obtain continuous values both for complete overcast and cloudless days. The experimental design (Fig. 1) consisted of 5 light blocks in the order 2.5, 10, 18, 28 and 92% light intensities. Within each block 3 different types of humus (fifteen combinations) occurred with 5 pots of any humus type and four seedlings in each pot. Four seedlings in the cotyledon stage were transplanted in each pot in early July. At the 92 per cent light intensity 5 seedlings withered within the first weeks and were immediately replaced. In order to shield the seedlings from strong evatransporation in the 92% light intensity, watering of seedlings was carried out. Timing and the amount of watering, were not regular in fact watering was only made when necessary to avoid any appreciable water deficit.
At the end of the first growing season (late October 1997), but before leaf fall, the following measurements for the ash seedlings were recorded:

1) survival rate;
2) height growth.

The data were analysed by one-way and two-way analysis of variance (ANOVA). Differences between different terms of the ash seedlings were analysed and evaluated at the 5% level of significance, using Tukey's studentized range. Some tests also showed that the variance was not independent of the mean values for treatments; therefore a transformation was carried out on the data before analysis. However, if homogeneity of variances was not obtained, a nonparametric Kruskal-Wallis test for analysis of variances and Mann-Whitney's test for comparison of means were performed. The measurable factors were also subjected to analysis of variance for a factorial design.

Table 1. Average values (%) of the light intensities in five places during 4 weeks, (July and August 1997)

Places	Reading times				Mean light intensity
	8.00-9.00	12.00-13.00	16.00-1500	19.00-20.00	
1	2.3	2.8	2.7	2.1	2.5
2	10	12	11	7	10
3	17	21	20	14	18
4	27	32	28	25	28
5	90	98	94	86	92

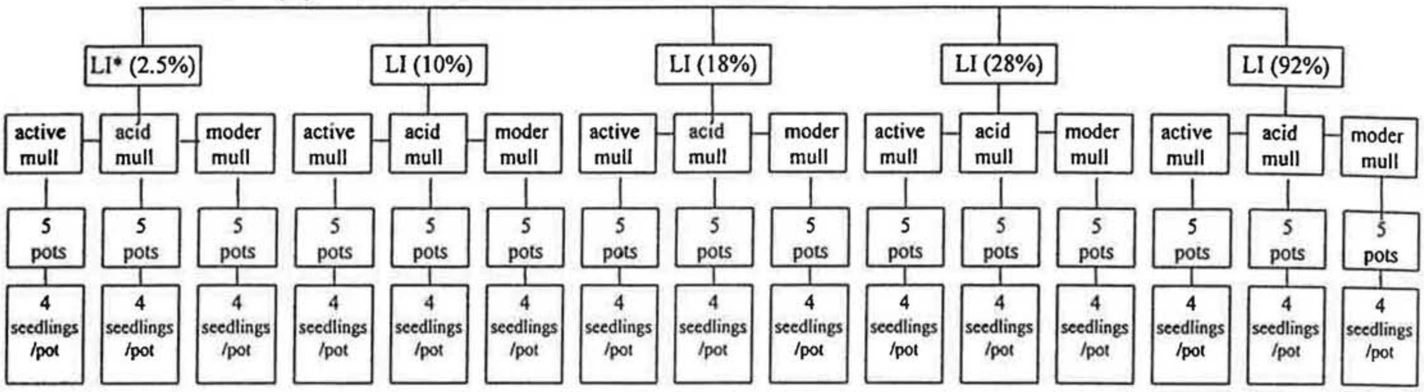

Figure 1. Experimental design of the ash seedlings in three types of humus and five levels of light intensity.
LI = light intensity

3. Results

3.1. Survival rate

Original and transformed data for survival rate of the ash seedlings were not normally distributed. As also homogeneity of variances could not be obtained (Table 1.1), a nonparametric test (Kruskal-Wallis) was carried out. According to this test, there were no significant differences in survival rate among the ash seedlings for 15 combinations (5 levels of light intensity and 3 humus types) (d. f. = 14, P = 0.116). In fact in each block (light regime), there were also no marked differences of this attribute at the three humus types (Fig. 2). The mean survival rate of the 15 light-humus combinations, after one growing season, with a range between 80 and 100%, amounted to 95.3%.

Survival was marginally affected by light intensity (d. f. = 4, P = 0.059). When the differences between the survival rate of the different light intensities were assessed by a Mann-Whitney test and at the 5% level of significance, it appeared that the survival rate under closed canopy (2.5% light intensity) was significantly lower than those under 10, 18, 28% light intensities (Fig. 3) (Table 2). Survival rate in 92% light intensity had an intermediate position but it did not differ with those in all the lower radiation levels.

No clear differences could be also found among the mean survival rate at the various humus types (Kruskal-Wallis, d. f. = 2, P = 0.443) (Table 3). In fact it was indicated that humus type did not influence the survival rate.

As a whole, the results of the first growth' season over all treatments revealed that the mean mortality rate was very low. In other words, even in low nutrient availability (moder mull humus) and in low light supply (closed canopy), seedlings at the end of the first growing season benefited from a high survival rate.

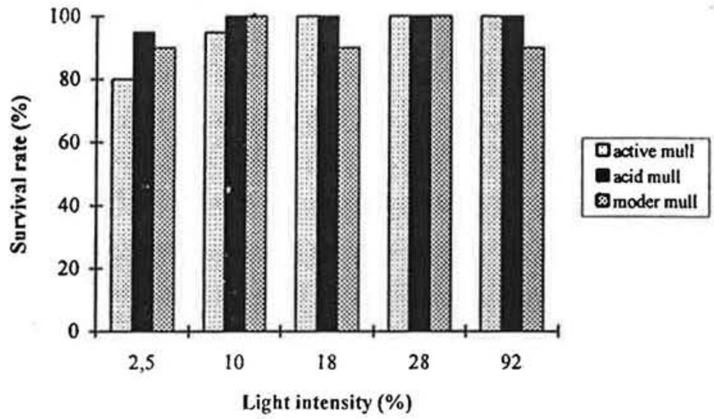

Figure 2. Survival rate of the ash potted seedlings at the five levels of light intensity and three types of humus. (Mean = 95.3%, SE = 1.4, Coefficient of Variation of the experimental error or CV = 12.7%).

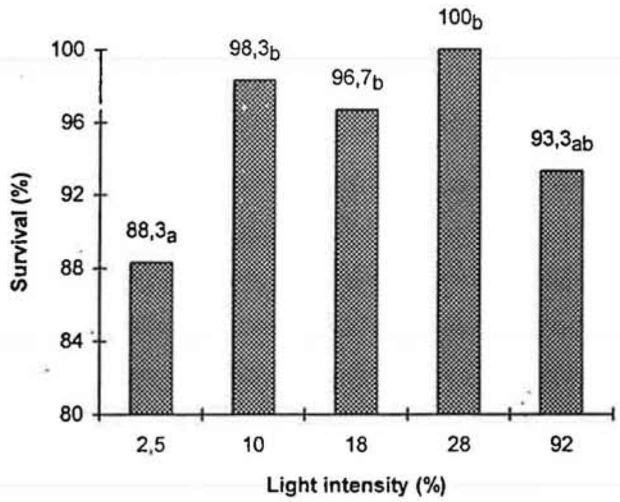

Figure 3. The mean survival rate of the ash seedlings in five levels of light intensity (at the three humus types combined).

Means followed by the different letters in subscript indicate significant differences in survival rate between light levels (the homogeneous groups have the same letters), using Kruskal-Wallis test for analysis of variances (χ^2 = 11.50, d. f. = 4, P = 0.021), and Mann-Whitney test for multiple comparisons of means.

Table 2. Significant differences of the mean survival rate of the ash potted seedlings located in five levels of radiation, using Mann-Whitney's test

	P value				
Light intensity (%)	2.5	10	18	28	92
2.5		0.032*	0.049*	0.007*	0.278 ns
10	0.032*		0.962 ns	0.317 ns	0.276 ns
18	0.049*	0.962 ns		0.317 ns	0.326 ns
28	0.007*	0.317 ns	0.317 ns		0.073 ns
92	0.278 ns	0.276 ns	0.326 ns	0.073 ns	

* significant at the 0.05 probability level.

n s non significant

Table 3. Survival rate (mean ± standard error) of the ash seedlings at the three types of humus (in all light intensities combined), using nonparametric test (Kruskal-Wallis, χ^2 = 1.63, d. f. = 2, P = 0.443)

Humus type	Active mull	Acid mull	Moder mull
Mean survival rate (%)	95 ± 2.5	98 ± 1.4	93 ± 3.1

3.2. Height growth

The current study showed that while combining all humus types combined, height growth of the ash seedlings increased with rising light intensity (ANOVA, d. f. = 4, P = 0.00) (Table 4). On the other hand, when all light intensities being pooled, height growth also varied at the different humus types (ANOVA, d. f. = 2, P = 0.00) (Table 5). In fact light and humus, each one separately, remained significant (P < 0.05) effect on height growth.

Furthermore, the results on height growth of the ash seedlings indicated an increasing growth response to nutrient availability (in each humus type) with increasing light intensity or developing crown canopy , especially at the acid and active mull (Fig.4).

Generally, in each humus type, minimum height growth was observed in lower light intensities (2.5 and 10%) and the maximum value in higher light intensities (28 and 92%).

Comparison of means, using Tukey's studentized range at the 5% level of significance after inverse (1/height growth) transformation, revealed that at the active mull, height growth of seedlings in 92 and 28% light levels were higher than those at 2.5 and 10% light intensities (see Fig. 4). Height growth at 18% light intensity had an intermediate position, whereas it did not differ with those at the lower and higher radiation levels. Likewise, at the acid mull, height growth was higher in open (92%) and semi-closed canopy (28 and 18%) than in high-shade levels (10 and 2.5%). At the moder mull, Tukey's test, performed on the log. transformation data exhibited that this attribute in 10% light had the lowest and at 28 and 92 % the highest value. Height growth at 2.5 and 18% light intensities presented an intermediate position, whereas it did not differ with those in other three light levels. Generally, at the end of the first growing season, maximum height growth measured for ash seedlings at the active mull was about 3 cm and at the acid mull between 4 to 6 cm and at the moder mull never reached 2 cm.

Table 6 exhibits comparison of means in term of height growth for the ash seedlings grown at the 15 light-humus combinations. Generally, the greatest height growth appeared in turn with 63.5 and 56.7 mm at the acid mull under 92 and 28% light intensities. Thereafter, seedlings growing at the active under 92 and 28% light intensities demonstrated the greatest value compared with all the other light-humus combinations. Nevertheless, seedlings at the acid mull under 18% light performed an intermediate position in this characteristic measured between former and latter light-humus combinations (Mann-Whitney's test).

At the all humus types pooled, according to Tukey's test after inverse transformation, the seedlings growing under 92 and 28% light intensities (without clear differences) benefited from a greater height growth compared with those in intermediate (18, 10 %) and highest shading levels (2.5%) (Fig. 5).

In all light intensities combined, Tukey's test after inverse transformation, demonstrated that height growth at the acid mull was significantly higher than that at the active and moder mull humus (Table 7).

Table 4. Analysis of variance for the relationship between height growth of the ash tree seedlings and light factor (all humus types combined)

Source	d. f.	Sum of squares	Mean square	F	P
Main effect	4	29816.52	7454.13	18.61	0.00
Explained	4	29816.52	7454.13	18.61	0.00
Residual	281	112560.7	400.57		
Total	285	142377.2	499.57		

Table 5. Analysis of variance for the relationship between height growth of the ash tree seedlings and humus factor (all light types pooled)

Source	d. f.	Sum of squares	Mean square	F	P
Main effect	2	29215.69	14607.85	36.52	0.00
Explained	2	29215.69	14607.85	36.53	0.00
Residual	283	113161.5	399.86		
Total	285	142377.2	499.57		

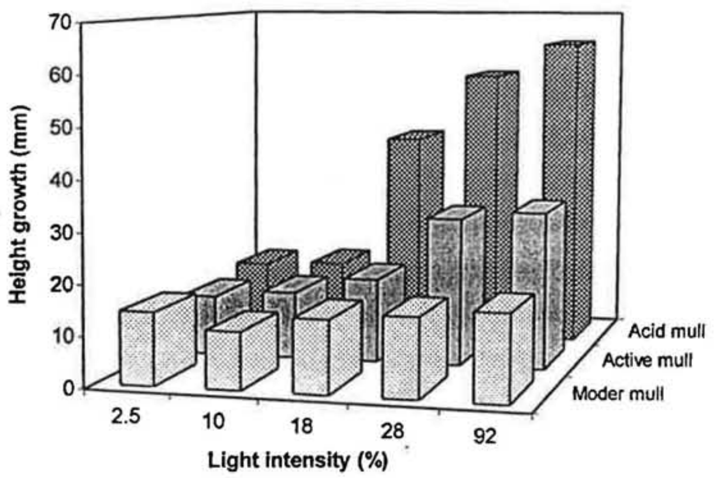

Figure 4. Height growth (in mm) of the ash seedlings in different humus types and light intensities.

Table 6. Statistical test for differences between the means of height growth of the ash potted seedlings, grown in 15 light-humus combinations, using Mann-Whitney's test, (P < 0.05)

The horizontal line (—) displays the homogeneous groups. A is active mull, B is acid mull and C is moder mull.

Combination	B-92	B-28	B-18	A-92	A-28	C-92	A-18	C-28	B-10	C-18	C-2.5	B-2.5	A-10	A-2.5	C-10
Mean height growth (mm)	63.8	56.7	42.8	31.5	29.8	17.1	16.8	15.6	14.6	14.4	14.4	14.0	13.4	12.0	11.3

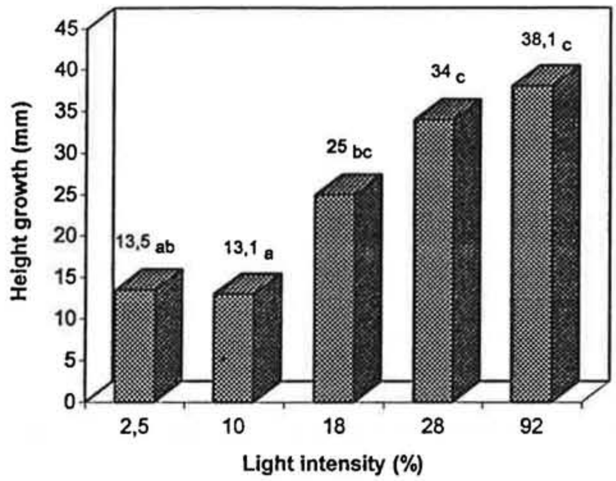

Figure 5. Mean height growth of the ash seedlings at five levels of light intensity (at the three humus types combined).

Means followed by the different letters in subscript indicate significant differences in height growth between light levels, using inverse transformation data after one-way ANOVA test, d. f. = 4, P =0.00 (for the analysis of variances at the 5% level of significance), and Tukey's studentized range (for multiple comparison of means).

Table 7. Height growth (mean ± standard error) of the ash seedlings at the three types of humus (all light intensities pooled)

Humus type	Acid mull	Active mull	Moder mull
Height growth (mm)	$38.4 \pm 3.0_a$	$21.1 \pm 1.6_b$	$14.5 \pm 0.7_b$

Mean ± SE followed by the different letters in subscript indicate significant differences of the characteristic investigated between humus types, using one-way ANOVA test (d. f. = 2, P value = 0.00), inverse transformation data and Tukey's test at the 5% probability level.

4. Discussion

Survival

The current study revealed that light marginally affected survival rate. In closed and semi-closed canopy and also in highest level of radiation the rate of mortality was not considerable. In other words, seedlings during and at the end of the growth' season attained a very high survival rate (95.3%). When humus types were combined, seedlings under semi-closed canopy (10, 18 and 28%) indicated quite a better survival rate than those under closed canopy (2.5%). When five light intensities were combined, survival rate did not statistically differ among the various humus types. On the other hand, The higher mortality in 92% light intensity, especially at the moder mull (thick litter layer) was probably due to the stronger evatransporation on warm summer days and or as a result of being attacked by damping-off fungi.

The preference of the semi-closed canopy to closed canopy (for the lower mortality rate) is due to the fact that under the former crown canopy seedlings produced the longer shoots and more frequent number of buds and branches in comparison to those under the latter crown canopy. Therefore, it can be stated that semi-closed canopy could almost better ensure the survival rate.

Concerning the above mentioned, it can be stated that ash is tolerant to the shade and easily sustains the shade at the first year. This is supported by Gurney (1958), Warlde (1959), Van Miegroet and Lust (1972), Savil (1991), Kerr (1995), who suggested that ash during its seedling phase is shade tolerant, but with little growth.

Ash seedlings suffer from high mortality in the field and lower shrub layers (cf. Diekmann, 1994). This does not seem to apply to *Acer platanoides* which, together with *Ulmus glabra*, shows a strong regeneration even in the shrub and lower tree layers. Stern (1989) stated that two-storey high forest with ash overstorey was less satisfactory, however, because of lack of light. It was seen that copious natural seedlings occurred under full canopy of sycamore, ash and beech but height growth did not exceed 15 cm. Canopy density is the crucial factor (Mosandl et al., 1988) that regulates density, species composition and height development of the regeneration. When the canopy density is reduced to, for example, 60%, (Edwards, 1987) the naturally regenerated plants have a better opportunity to survive. This corresponds with a removal of about 25% of a closed stand and leading to a ground vegetation covering approximately 20-30% of the soil. In fact, this supports our results that ash exhibited a substantial survival rate in semi-closed canopy (10, 18 and 28%) compared with those in dense canopy (2.5%).

Height growth

The present investigation also indicated that, at the all humus types combined, height growth of the ash seedlings increased with rising light intensity. In all light intensities pooled, it also varied at the different humus types. In fact light and humus, each one separately, had a significant effect ($P < 0.05$) on height growth. This is in agreement with the work of Helliwell (1979), who reported that soil and light intensity on the height growth of the some broad-leaved species especially 2-year-old ash *(Fraxinus excelsior)* seedlings remained highly significant ($P < 0.01$) effect. The results of the current study also are in accordance with those of Huss and Stephani (1978) and Koss (1989). Their results on height growth of beech seedlings also indicated an increasing growth response to soil supply with increasing light intensity or opening crown canopy. Brix (1971), Reed et al., (1983) also found that growth of Douglas-fir was enhanced with increasing nitrogen fertilization at high but not at low light levels.

There was also no marked increase in height growth of the ash seedlings with increasing light between 2.5% and 10% light intensity. In reality, it presented the very poor growth of the seedlings even under 10% light intensity. Helliwell (1965), concerning the *Acer pseudoplatanus* and *A. platanoides,* similarly reported the poor growth (between about 3% and 20% of full light) at most of the forest sites.

Trumper (1958) obtained a better growth of beech seedlings in the forest by adding lime to the soil as a consequence of reduced pH-value. Our experiments with ash seedlings also showed that height growth increased with reduced acidity (pH > 4.4) at the humus types of active and acid mull (compared with moder mull). This reduction in growth of the seedlings was probably related to poor nutrient supply originating from slow litter decomposition (Madsen & Larsen 1997).

The very poor growth under 2.5% light intensity showed that light was probably the most limiting factor of the height growth under the closed canopy. In this relation, Wardle (1959) pointed out that *Fraxinus* seedling on the shaded woodland floors showed marked persistence but little growth. When gaps were formed, however, the seedlings responded rapidly to the increased light. Schmidt (1996) also stated that height growth was closely correlated with the light available, whereas seedling density and proportions of *Fagus sylvatica* and valuable hardwoods *Fraxinus excelsior, Acer platonoiedes* and *A. pseudoplatanus* depended on conditions prevailing before the gaps were made. AFM van Hees (1997) also reported that beech *(Fagus sylvatica)* and oak *(Quercus Pedunculate)* seedling responded similarly to shading, with reduced height. Logan (1966), working with *Pinus banksiana, P. resinosa, P. strobus,* and *Larix lariciana,* all pioneering species, as opposed to the successors species used in the experiment, found that maximum height in the first years, was attained below full light intensity.

As finding of Madsen & Larsen (1997) the reduced growth of ash in high carbon content at the moder mull can be related to poor nutrient supply originating from very slow litter decomposition.

The nutritional and physical factors of active and acid mull humus probably are also the main causes of differences in height growth of seedlings.

In each humus type, the greatest height growth was produced under 92, 28 and 18% light intensities. At the end of the first growing season, lack of differences in height growth produced under 18, 28 and 92% light intensities quietly revealed that training the seedlings especially under semi-closed canopy was more beneficial than those under relatively full daylight (92%) associated with watering. Therefore, The first year observations showed that seedlings either in view of the stem quality, growth and or with regard to the facilities of maintenance are preferable to be trained under intermediate light intensities (preferably 28%), at the higher nutritional humus (active and acid mull).

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