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[Research]

Influence of gap size and development stages on the silvicultural characteristics of oriental beech (*Fagus orientalis* Lipsky) regeneration

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ABSTRACT

We studied 11 gaps covered with beech saplings (< 1.30 m tall) in a reserve compartment (compartment 139, district one, Langa forest, watershed 36: Kazemrood) of the Caspian beech forest in N Iran. Two transects, each 2 m wide, were laid along the longest (N-S) and shortest (E-W) axis of each gap. Five micro sample plots, each 4 m^2, were established: one at the center, and one at each corner. Qualitative and quantitative characteristics of saplings with a diameter at breast height less than 7.5 cm were examined in the micro sample plots. Analysis of variance (ANOVA) and Kruskal-Wallis test were performed using SPSS software for quantitative characteristics, and chi-square test for qualitative characteristics. Results indicated that medium-sized (200-500 m^2) gaps promote the growth of oriental beech saplings of desirable silvicultural forms during decay and initial stages.

Keywords: *beech, close to nature, sapling, seedling, silviculture, untouched, Caspian/Hyrcanian forest, northern Iran.*

1. INTRODUCTION

Researchers have historically recognized the significance of natural disturbances as part of an overall process that helps contribute to and maintain aspects of forest structure and community dynamics. The creation of gaps within forests is one of the most important events in the natural aging process of a forest. Gaps play an important role in establishing resource allocation, in altering microclimate dynamics, and ultimately in determining how effectively resources are recycled and distributed (Lowman & Rinker, 2004).

Developmental stages are a response to natural and anthropogenic disturbances, and are shaped by various rates of regeneration, growth, and mortality (Rubin *et al*., 2006).

Maximum gap size is measured at the end of decay development stage whereas in the optimal phase gap size decreases. Beech regeneration establishment is better in small gaps and with increase of gap size establishment of other species is better than beech regeneration (Emborg *et al.*, 2000). Density of regeneration is usually highest in the decay stage and lowest in the optimal stage among different development stages (Korpel, 1995).

Comparative studies of gap-phase regeneration in managed and natural beech forests in Europe showed that light level differs between gap sizes and positions (Wijdeven, 2003).

Many factors help determining the nature of microclimate in a forest gap. The most obvious is the gap size. In general, with increasing gap size, the influence on forest microclimate increases (Lee, 1978; Chazdon and Fetcher, 1984; Lawton, 1990; Denslow and Hartshorn, 1994).

Naaf and Wulf (2007) showed that number of plant species increases with increasing gap size and light availability. Herbivory caused a reduction of competition by tree regeneration and was therefore responsible for higher species number, too. Species composition is relatively homogenous but significantly determined by gap size, light availability and herbivory. With more favorable light conditions, an increasing proportion of generalist species occurred within gaps.

This study examines the qualitative and quantitative characteristics of oriental beech (*Fagus orientalis* Lipsky) regeneration in gaps of different sizes within development stages in unmanaged beech stands. Our results will help in planning the application of nature-based management for beech forests.

Our results could provide information and could help us to get more knowledge about development stages and the structure of the stand for further silvicultural decisions which could be used in natural-based non-management of beech stands. For example, how big should be the gap? And how is the growth process of beech regeneration in different development stages?

2. MATERIALS AND METHODS

2.1. Study site

This study was carried out in the reserve compartment (139) of District One (Langa forest, Watershed 36, Kazemrood) of the Caspian beech forest in northern Iran (Fig. 1). The compartment (43 ha; N 36°32´15˝ - 36°35´ 10˝; E 51°02´ 25˝ - 51°05´ 05˝ ;) is composed of irregular multi-aged pure beech forest at elevations between 1350 and 1650 m. No silvicultural practice has been carried out in this reserve area. The soil type is forest brown with pH between 5.2 and 6.1. The annual precipitation and mean annual temperature are 1300 mm and 8 °C, respectively. The information is derived from Management plan of the study area (Anon., 2000).

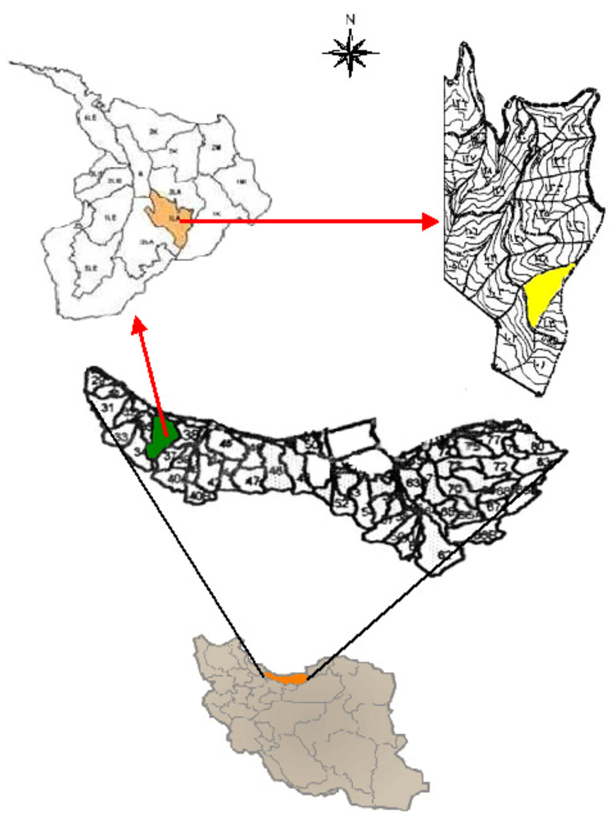

Fig 1. Location of the studied sites

2.2. Field method

We studied eleven natural gaps of different sizes (97 to 1365 m^2) containing beech regeneration shorter than 1.30 m in height. Development stages were identified according to Korpel (1995). Regeneration was divided into two groups: i) seedlings shorter than 15 cm and ii) saplings taller than 15 cm, with diameter at breast height (dbh) less than 7.5 cm. Silvicultural characteristics of all saplings with a dbh less than 7.5 cm were determined in the micro plots. In each gap, transects (each 2m wide) were laid along the longest and shortest axis. Micro sample plots (2×2 m) were established in the center and four corners of each gap (Fig. 2). Gaps were almost similar in shape (roughly ellipsoid), therefore the micro plots were always situated in N-S and E-W direction on short and long axis of the gaps. Schütz (1990) classified gaps at small (<200 m^2), medium (200-500 m^2), large (500-1000 m^2), and very large (1000-1500 m^2) area. According to Schütz's classification it should be mentioned that 2 of our 11 natural gaps were categorized within the small group, 8 gaps in the medium sized groups, no gaps within large sized groups and only one gap within the very large group.

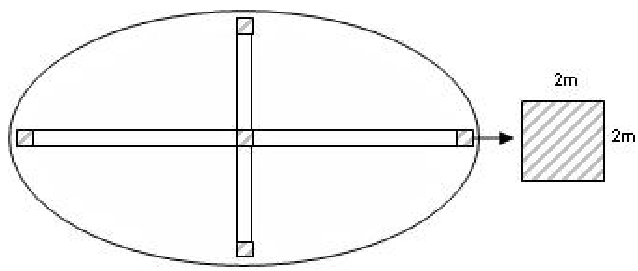

Fig 2. The position of micro plots within a gap

Quantitative characteristics included stem base diameter (SBD), sapling height (SH), length of spring shoot (LSS), crown width (largest distance between two largest branches, CW), and length of the uppermost internodes (LUI = distance between uppermost lateral bud and terminal bud on the main stem). Furthermore, the growth space factor (GSF = CW × SBD $^{-1}$, after Sagheb-Talebi and Schütz, 2006) was calculated. In addition, the age of each sapling was determined by counting the internodes on the main stem (Fig. 3, Roloff, 1986). Qualitative parameters included health (healthy and unhealthy: affected by environmental factors, or by browsing on the stem and terminal buds), mode of branching (unforked, forked, or broom shaped) (Marvie Mohadjer, 1975 and 1976; Sagheb-Talebi, 1996), and stem form (orthotropic or plagiotropic).

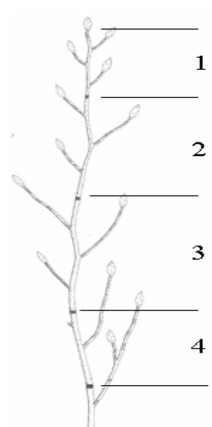

Fig 3. Illustrating of internode used for counting age of saplings (Slightly altered after Roloff, 1986)

2.3. Statistical analysis

Statistical procedures were applied using SPSS V16.0: i). normalization of data was tested by chi-square test; ii) analysis of variance (ANOVA) and Kruskal-Wallis test were applied for quantitative characteristics (normal data by ANOVA and data that dose not have normal distribution by Kruskal-Wallis test); iii) comparisons of averages for quantitative parameters were made by Tukey test; and iv) a chi-square test was used for qualitative characteristics.

3. RESULTS

3.1. Effect of development stages and gap size on the quantitative characteristics of multi-aged saplings

Analysis of variance for quantitative characteristics by development stages showed significant differences for all but LSS and LUI parameters. SBD, SH and LSS of saplings varied from 0.94 to 1.6 cm, 68 to 131.5 cm, and 2.8 to 6.0 cm, respectively. LUI, CW and GSF of saplings varied from 1.1 to 1.9 cm, 55.3 to 92.1 cm and 54.0 to 59.1, respectively. Kruskal-Wallis test showed that the differences between mean age among development stages are statistically significant. Tukey test showed significant differences (ρ =0.05) between averages of SBD, SH, CW of saplings, and GSF among development stages (Table 1).

Table 1. Comparison of averages for quantitative parameters of multi-aged saplings in development stages

Parameters	Development stages				
	Initial	Optimal	Decay	F[1]	Kruskal-Wallis
Age (year)	6.5±0.2a	6.6±0.6a	9.4±0.5b	---	26.346**
Stem base diameter (cm)	0.97±0.05a	0.94±0.1a	1.6±0.1b	17.740**	---
Sapling height (cm)	75.5±4.3a	68±10.5a	131.5±10.3b	18.875**	---
Length of spring shoot (cm)	6.0±0.5a	2.8±0.5a	5.3±0.7a	2.752^{ns}	---
Length of uppermost internode (cm)	1.9±0.1a	1.1±0.2a	1.9±0.2a	2.980^{ns}	---
Crown width (cm)	58.5±3.4a	55.3±8.6a	92.1±6.8b	13.506**	---
Growth space factor	54.0±1.3a	58.5±2.5a	59.1±1.7a	3.294*	---

[1] Analysis of variance (ANOVA) mean of quantitative parameters.
Letters a and b indicate significant differences between means after a post-hoc Tukey test, p = 0.01. Mean values are always expressed ± standard error. * (ρ=0.05), ** (ρ =0.01) and ns = not significant.

There were statistically significant differences (ρ=0.05) between averages of SH, LSS and LUI in the gap sizes for multi-aged saplings. The highest LSS and LUI were measured at the large gaps (1000-1500 m²), whereas the highest SBD, SH and CW for multi-aged saplings were measured at the small gaps (<200 m²). There was no statistically significant difference for GSF among different gap sizes (Table 2).

Table 2. Comparison of averages for quantitative parameters of multi-aged saplings in gap size

Parameters	Gap size (m²)				
	<200	200-500	1000-1500	F[1]	Kruskal- Wallis
Age (year)	10.2±1.1b	7.4±0.2a	6.7±0.8a	---	7.646*
Stem base diameter (cm)	1.9±0.2b	1.1±0.05a	1.2±0.2a	10.947**	
Sapling height (cm)	130.3±20.2b	88.9±4.5ab	72.5±8.6a	4.473*	---
Length of spring shoot (cm)	4.6±0.8a	5.4±0.4a	12.3±5.3b	5.111**	---
Length of uppermost internode (cm)	1.5±0.2a	1.8±0.1a	2.3±0.5a	1.230^{ns}	---
Crown width (cm)	104.1±14.8b	64.3±3.1a	58.0±9.2a	8.118**	---
Growth space factor	55.5±3a	56.7±1.0a	48.4±5.2a	1.310^{ns}	---

[1] Analysis of variance (ANOVA) mean of quantitative parameters.
Letters a and b indicate significant differences between means after a post-hoc Tukey test, p = 0.01. Mean values are always expressed ± standard error. * (ρ=0.05), ** (ρ =0.01) and ns = not significant.

The sample plots included saplings of different ages (between 3 and 25 years), with the numbers per cohort associated with the abundance of seed production in different masting years in that spread of ages might result in differences of measured characteristics between saplings in the sample. So we evaluated the frequency of individuals by age classes. Saplings with ages between 5 and 7 years were most common (Fig. 4).

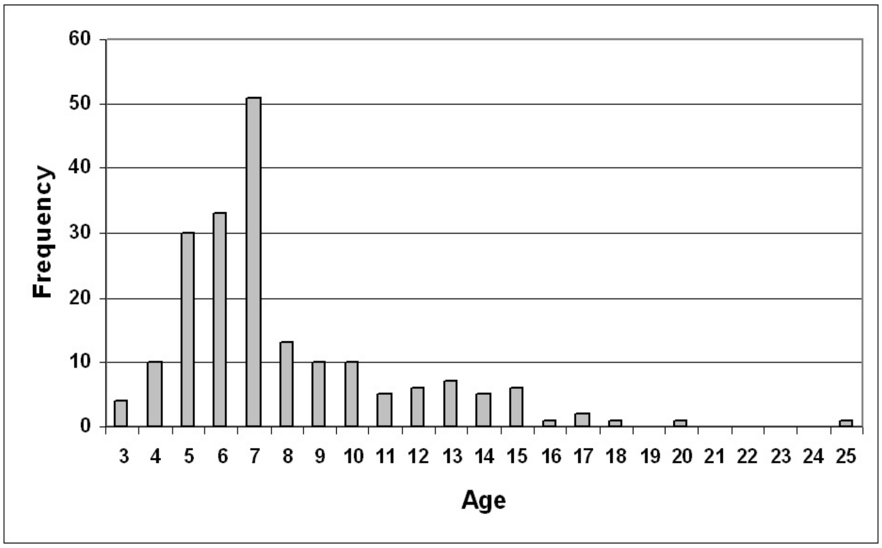

Fig 4. Age frequency of beech saplings in the studied micro plots

We applied regression analysis between age and quantitative characteristics of beech saplings to show whether measured characteristics change with sapling age. Regression analysis showed that significant relationships exist between sapling ages with quantitative parameters (i.e. SBD, SH, and CW; Figures 5, 6 and 7). Therefore, we separated saplings with age of 5 to 7 from the remainder of the sample (called multi-aged) and designated them as single-aged saplings.

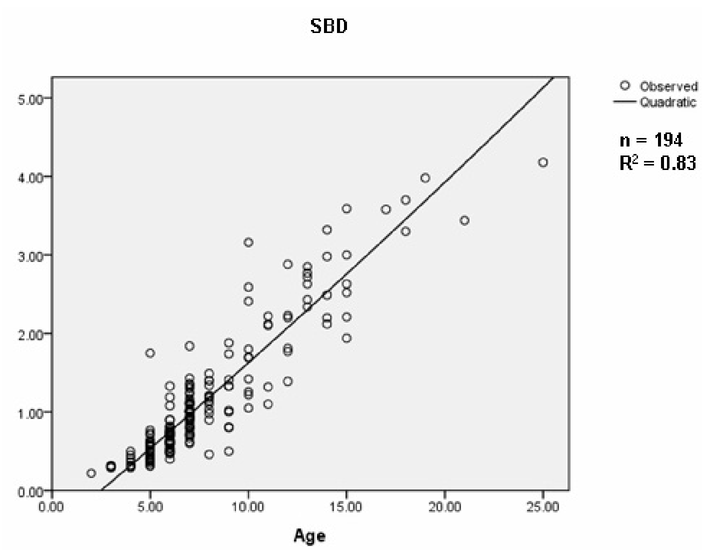

Fig 5. Regression analysis between age and stem base diameter of saplings

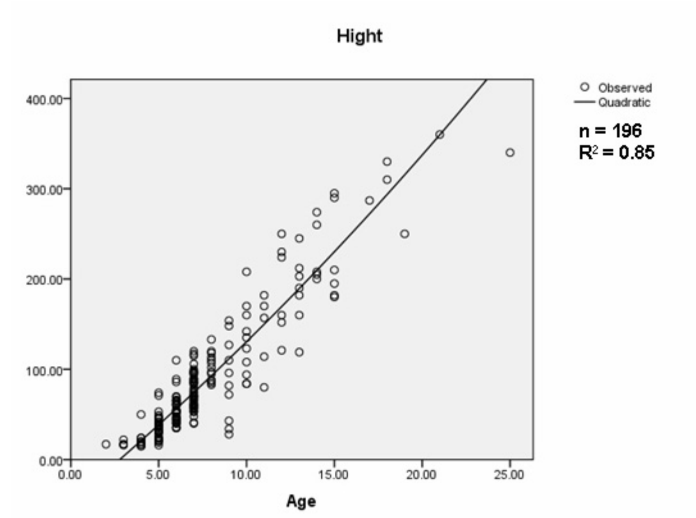

Fig 6. Regression analysis between age and height of saplings

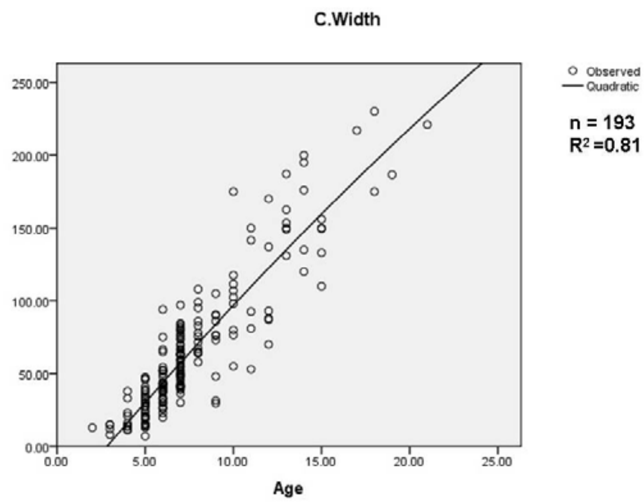

Fig 7. Regression analysis between age and crown width of saplings

3.2. Effect of development stages and gap size on the quantitative characteristics of 5- to 7-year-old saplings

We found statistically significant differences (ρ =0.05) between averages of LSS, LUI and SH among development stages for saplings of the single-aged (5 to 7 years old) cohort. Among quantitative characteristics, SBD, SH and LSS of saplings varied from 0.6 to 0.8 cm, 42.4 to 62.9 cm, and 2.9 to 6.2 cm, respectively. LUI, CW and GSF of saplings varied from 1.1 to 2.0 cm, 38.7 to 47.9 cm, and 57.6 to 63.3, respectively (Table 3).

There were statistically significant differences (ρ=0.05) between averages of SBD and SH of saplings at the different gap sizes. The maximum mean of SBD (1.2 cm) and tallest sapling (72.5cm) were found at the large gaps (Table 4).

3.3. Effect of gap size and development stages on the qualitative characteristics of saplings

Among multi-aged beech saplings, gap size and development stages had significant effects on the plagiotropy, but no significant effect on the mode of branching and healthiness (Table 5).

Table 3 Comparison of averages for quantitative parameters of 5- to 7-year-old saplings in development stages

Parameters	Development stages			
	Initial	Optimal	Decay	F[1]
Stem base diameter (cm)	0.8±0.03a	0.6±0.08a	0.8±0.08a	2.142^{ns}
Sapling height (cm)	62.9±2.8b	42.4±4.9a	56.5±4.1ab	3.453*
Length of spring shoot (cm)	6.2±0.6b	3.2±0.7a	2.9±0.5a	6.606**
Length of uppermost internode (cm)	2.0±0.1b	1.1±0.2a	1.2±0.2ab	6.969**
Crown width (cm)	47.9±2.2a	38.7±5.8a	44.1±3.5a	1.195^{ns}
Growth space factor	57.6±1.6a	63.3±3.8a	58.3±2.7a	0.972^{ns}

[1] Analysis of variance (ANOVA) mean of quantitative parameters. Letters a and b indicate significant differences between means after a post-hoc Tukey test, p = 0.01. Mean values are always expressed ± standard error. * (ρ=0.05), ** (ρ =0.01) and ns = not significant.

Table 4 Comparison of averages for quantitative parameters of 5- to 7-year-old saplings in gap size

Parameters	Gap size (m^2)			
	<200	200-500	1000-1500	F[1]
Stem base diameter (cm)	0.6±0.08a	0.8±0.03ab	1.2±0.2b	4.080*
Sapling height (cm)	42.1±5.4a	60.6±2.4ab	72.5±10.2b	3.189*
Length of spring shoot (cm)	4.3±1.0a	5.0±0.5a	4.9±0.1a	0.089ns
Length of uppermost internode (cm)	1.4±0.4a	1.7±0.1a	2±0.5a	0.480ns
Crown width (cm)	33.7±5.8a	46.9±1.9a	40.4±3.4a	2.036ns
Growth space factor	52.3±6.6a	58.7±1.3a	48.4±6.7a	2.169ns

[1] Analysis of variance (ANOVA) mean of quantitative parameters. Letters a and b indicate significant differences between means after a post-hoc Tukey test, p = 0.01. Mean values are always expressed ± standard error. * (ρ=0.05), ** (ρ =0.01) and ns = not significant.

Table 5 Effect of studied parameters on the qualitative characteristics of multi-aged and the 5- to 7 year-old saplings (chi-square test)

	Multi-aged saplings		5- to 7 year-old saplings	
	Gap sizes	Development stage	Gap sizes	Development stage
Plagiotropy	0.0003**	0.0037**	0.9215 ns	0.0946 ns
Mode of branching	0.4542 ns	0.1591 ns	0.0593 ns	0.6966 ns
Healthiness	0.7674 ns	0.3248 ns	0.4168 ns	0.0921 ns

** (ρ =0.01) and ^{ns} (not significant)

As Figure 8 illustrates, the proportion of plagiotropic saplings is obviously higher than orthotropic ones in the decay stage than in the initial and optimal stages. Plagiotropic saplings were obviously more frequent at the small- and medium-sized gaps. In very large gaps, however, orthotropic saplings were more abundant than plagiotropic ones (Fig. 9).

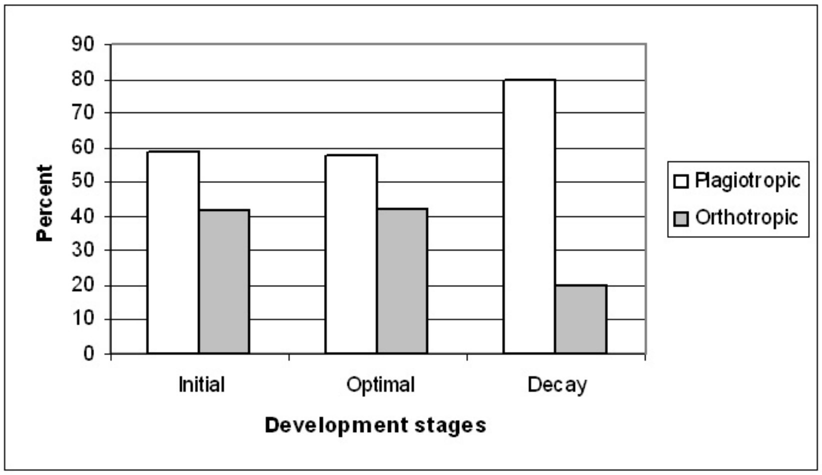

Fig 8. Proportion of stem form of multi-aged saplings along different development stages

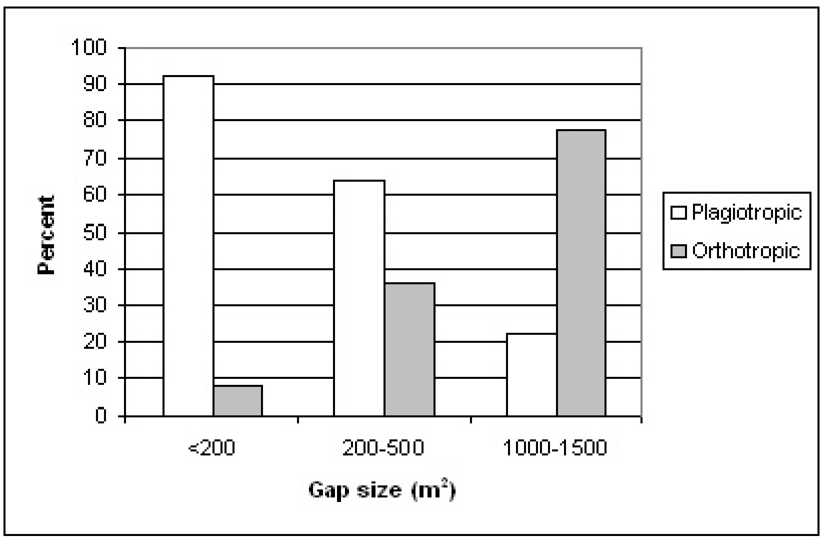

Fig 9. Proportion of stem form of multi-aged saplings in gap sizes

4. DISCUSSION

Korpel (1995) argues that growth speed of saplings in the initial stage is higher than in other stages and those saplings are tending to move to higher height classes. In this research, averages of silvicultural characteristics of single-aged saplings in the initial stage were more than other stages, but the averages of silvicultural characteristics of multi-aged saplings were more in the decay stage. The reason could be the higher age of saplings in decay stage.

Emborg et al. (2000) conclude that maximum gap size is found at the end of decay stage and minimum gap size at optimal phase. Maximum and minimum gap sizes in our study were encountered at initial stage (i.e. following decay stage). We may deduce that large gaps in the study site were created first in the decay stage some years ago.

Gap size seems to be the main factor affecting the growth of seedlings. The better seedling establishment and growth in large gaps are likely to be the combined consequences of i) increased light and water availability and ii) the decreased litter accumulation or quick decomposition (Zhu *et al.*, 2003). With an increase in gap size, the stress of competitions for moisture and nutrient from surrounding mature trees in the gap area is decreased. This is also good for seedling growth in the gaps (Madsen and Larsen, 1997). Emborg *et al.* (2000) showed that establishment of beech regeneration in small gap is better and the frequency of light demand species was increases with increasing of gap size. In our research, the maximum mean number of beech saplings in micro plot was in medium gaps. Shahnavazi et al.'s (2005) study confirms our results.

There were significant differences between averages of silvicultural characteristics among different gap sizes and averages of characteristics showed positive related with increasing of gap size. Huth and Wagner (2006) showed that both height and diameter, as determinants for development, were influenced by seedling age and gap size. In 4-year-old birch seedlings significant differences ($P<0.001$) in height and diameter between gap size classes were demonstrable. As light condition in optimal stage is insufficient for seedling development, canopy gaps created in this stage will be closed faster compared to other development stages, hence, regeneration disappears soon or late (Korpel, 1995; Emborg et al, 2000). Thus, gaps created in decay and initial stage should be considered as appropriate for regeneration development.

Comparative studies of gap-phase regeneration in managed and unmanaged beech forests in Europe showed that light levels differ between gap sizes and positions within gap (Wijdeven, 2003). Many factors help determining the nature of the microclimate in a forest gap. The most obvious is the size of the gap (Lee 1978; Chazdon and Fetcher 1984; Lawton 1990; Denslow and Hartshorn 1994). Although there are some similarities between European and oriental beech, but there are also some difference between these two species of one Genus. Oriental beech is more shade tolerant than her European sister and could stay longer under the shade of mature stand. Besides the vegetation period in the Caspian region is longer and the temperature is warmer than in northern latitudes of Europe, which facilitates longer growth for oriental beech.

5. CONCLUSION

Our results showed that among 5- to 7-years-old saplings, higher values of SBD and SH were obtained within very large sized gaps. Considering that only one gap was categorized in this group, we can not generalize the results; therefore it would be better to focus more on medium sized gaps (200-500m^2). Table 4, shows that the differences of these two parameters are not statistically significant between small and medium sized gaps, however the values of SBD and SH are slightly higher in the medium sized gaps. This situation is also obvious for other studied parameters. Overall, one can conclude that providing small and medium large sized gaps should be more preferred in managing of oriental beech stands (Hyrcanian forests) for a proper nature-based silviculture.

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اثر اندازه روشنه و مراحل تحولی بر مشخصه‌های کمی و کیفی تجدید حیات راش شرقی (*Fagus orientalis* Lipsky)

پ. پرهیزکار، خ. ثاقب طالبی، ا. متاجی، م. نمیرانیان

چکیده:

تحقیق حاضر در قطعه شاهد سری یک طرح جنگلداری لنگا در حوضه آبخیز شماره ۳۶ (کاظم رود) از جنگلهای خـزری انجام شده است. ۱۱ روشنه با محدودیت ارتفاع نهالهای کوتاه‌تر از ۱/۳۰ متر انتخاب شدند. مساحت روشـنه‌هـا از طریـق محاسبه سطوح بیضوی انجام شد. دو ترانسکت به عرض ۲ متر و در طول قطرهای بزرگ و کوچک بیـضی در داخـل هـر روشنه تعبیه شدند. جهت مطالعه تجدید حیات، ۵ میکروپلات ۴ مترمربعی در داخـل هـر روشـنه در امتـداد ترانـسکتها تعبیه شد (یک میکروپلات در مرکز و چهار میکروپلات در چهار حاشیه روشنه‌ها). مشخصات کمی و کیفی کلیه نهالها در میکروپلاتها برداشت شد. تجزیه و تحلیل داده‌ها با استفاده از نرم افزار SPSS صـورت گرفـت. بـرای داده‌هـای کمـی از آنالیز واریانس ANOVA و آزمون کروسکال-والیس استفاده و مقایسه میانگین داده‌های کمی با استفاده از آزمون توکی انجام شد. برای آنالیز داده‌های کیفی از آزمون کای‌اسکور استفاده شد. نتایج نشان دادند که روشنه‌های با سطوح متوسط (۲۰۰ تا ۵۰۰ مترمربع) در مراحل تحولی پوسیدگی و اولیه شرایط مناسبتری برای رشـد نهالهـای راش در جنگلـشناسی نزدیک به طبیعت بوجود می‌آورند.