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Introduction of suitable species for planting in gaps of different size (case study: Loveh forest, Golestan, Iran)

Pejman PARHIZKAR[1]*, *Khosro* SAGHEB-TALEBI[1], *Yaser* SHAHINI[2], *Maryam* TEIMOURI[1]

[1]*Research Institute of Forests and Rangelands, Agricultural Research, Education and Extension Organization (AREEO), Tehran, Iran*

[2]*Department of Forestry, Faculty of Forest Science, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran*

**Corresponding author: Parhizkar@rifr-ac.ir*

Abstract

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This study was carried out in Loveh forest, north of Iran. We measured the quantitative characteristics of seedlings including collar diameter (measured at 1 cm above the soil surface), height, and current annual height increment and calculated the mean annual increments of height and diameter. Ten gaps with the same climatic, edaphic and topographic conditions were selected. In each gap, two transects, 2 m wide, were laid along the longest (North-South) and the shortest (West-East) axis. Nine sampling microplots, 4 m^2 area, were established: one at the centre, four at the edges and four under the canopy within the transects. Results showed that the highest frequency of seedlings was seen in medium-size gaps (200–500 m^2). Quantitative characteristics of oak seedlings were better in small and medium-size gaps. There was a significant difference in the length of spring shoots, mean annual increment of height and mean annual increment of diameter between the species. Hornbeam, wild service and wild cherry seedlings are recommended for faster gap recovery, as the results showed that these species had the highest values of studied variables.

Keywords: canopy gap; length of spring shoots; mean annual increment of diameter; mean annual increment of height; seedling

In general, natural forest ecosystems located in the north of Iran do not have the same climatic and edaphic conditions. The presence of different factors may produce different climatic conditions at meso and micro scales which may have significant effects on regeneration establishment. Many factors change microclimate conditions in a forest gap; the gap size is the most important one. In general, an increase in the gap size intensifies its impacts on forest microclimate (Lee 1978; Chazdon, Fetcher 1984; Brokaw 1985; Lawton 1990; Denslow, Hartshorn 1994). For instance, light intensity in large gaps is higher than in small ones, which causes an increase in temperature. A higher amount of solar radiation in large gaps increases soil temperature and water evaporation from the soil surface and therefore decreases soil moisture. With an increase in the gap size, the stress of competition for moisture and nutrients from surrounding mature trees in the gap area is decreased. This is also good for seedling growth in the gaps (Madsen, Larsen 1997). There is also a positive correlation between gap size and wind effects (Lowman, Rinker 2004; Abdollahi 2014). Parhizkar et al. (2011b) revealed that silvicultural characteristics of *Fagus orientalis* Lipsky regenerations improved in medium-size gaps (200–500 m^2).

Gap formation changes the quantity of received light which affects nutrient and water availability

(Ritter et al. 2005; Galhidy et al. 2006). Naaf and Wulf (2007) showed that by increasing the gap size and consequently light intensity, the number of species increases. Species composition was relatively homogeneous but significantly determined by gap size, light availability and herbivory. Sagheb-Talebi et al. (2002) showed that beech regeneration growth characteristics and form improved in large (more than 1,000 m^2) and medium (200–500 m^2) gaps, respectively.

The maximum and minimum diversity and richness indices of species were related to very large (more than 600 m^2) and small (less than 200 m^2) gaps, respectively. The highest evenness indices were seen at medium (200–400 m^2) and large (400 to 600 m^2) gaps, whereas the lowest evenness indices were seen at small and very large gaps (Shabani et al. 2011). Relative soil moisture was significantly different across the gap size and light intensity classes, whereas organic matter and nitrogen values did not change significantly (Taati et al. 2015).

It has been proved that the gap has an effect on the rate of leaf litter decay. Most researchers believe that an increase of the gap size increases the decomposition rate (He et al. 2016; Li et al. 2016) but some reported decreased decomposition (Sariyildiz 2008).

Wijdeven (2003) reported that light amount or intensity in Dutch beech forests depends on the size and location of gaps. Nagel et al. (2010) showed that there was no relationship between overall regeneration density and gap size, indicating that most individuals established prior to the gap formation.

The aim of this study was to determine impacts of gap size on growth characteristics of the regeneration of forest trees species in northern forests of Iran in order to introduce suitable species into rehabilitation practices.

MATERIAL AND METHODS

This study was carried out in Loveh forest (49°01'30''E to 49°02'00''E and 37°13'40''N to 37°14'13''N), north of Iran. This forest is covered with semi-humid deep brown forest soil with pH value 6.8–7.8 (CM soil). Mean annual precipitation and annual temperature are 524 mm and 12.2°C, respectively (Anonymous 2001).

By a forest survey, 10 gaps with the same climatic, edaphic and topographic conditions were selected (the number of small and large gaps was 3 and the number of medium gaps was 4) and their areas were calculated by assuming the ellipsoid shape of gaps (Sagheb-Talebi 1996; Hojati 1999; Parhizkar et al. 2011a, b). According to Schütz (1990) and Marvie Mohajer (2006) the gaps were divided into 3 size classes: small (less than 200 m^2 area), medium (200–500 m^2 area) and large (greater than 500 m^2 area). In each gap, two perpendicular strips of 2 m in width are used to determine the gap boundary. The microplots were selected in the intersection of two strips (one microplot), in main aspects of the gap boundary including north, south, east and west (four microplots) and in main aspects of adjacent closed canopy including north, south, east and west (four microplots). Totally 10 gaps and 80 microplots were evaluated in the studied area. It should be 90 microplots in 10 sampled gaps. But ten microplots were located on rocks which were not sampled.

The age of seedlings was determined according to the growth architecture method in each species using debris of the terminal bud on the stem and age of branches (Sagheb-Talebi et al. 2008).

The quantitative characteristics of seedlings including collar diameter (at 1 cm above the soil surface), height, species frequency, length of spring shoots (LSS), and current annual height increment were measured. The mean annual increment of height (MAIH) and diameter (MAID) was calculated by dividing height and collar diameter by the age of each seedling. The number of even-aged seedlings was not sufficient for statistical analysis. Then to remove the age effect, we divided collar diameter and height by age.

Data analysis was done by using the boxplot procedure to determine and delete outlier data (Fotouhi Ardakani 2002). The normality of data was checked by χ^2 test and analysed by one-way ANOVA. The abnormal data were analysed by the Kruskal-Wallis test. Mean comparisons were carried out using Tukey's test for parametric variables.

RESULTS

Species frequency

Out of the 80 studied microplots, 25 microplots were located in gaps smaller than 200 m^2, 30 in gaps of 200–500 m^2 in size and 25 microplots in gaps larger than 500 m^2. There were 581 seedlings there (147 seedlings in gaps smaller than 200 m^2, 306 in gaps of 200–500 m^2 in size and 128 seedlings in gaps larger than 500 m^2). The frequency of seedlings of different species is shown in Table 1.

Table 1. Frequency of species in different gap sizes

Gap size (m^2)	Mean of seedlings in microplot	Number of microplots	Frequency of species						Total
			oak	hornbeam	Cappadocian maple	wild service	wild cherry	field maple	
< 200	5.88	25	82	25	16	17	3	4	147
200–500	10.2	30	109	83	33	34	25	22	306
> 500	5.12	25	52	22	24	9	12	9	128
Total		80	243	130	73	60	40	35	581

Table 2. Comparison of the mean length of spring shoots of different species in different gap sizes

Gap size (m^2)	Length of spring shoots (cm)					
	oak	hornbeam	Cappadocian maple	wild service	wild cherry	field maple
< 200	4.3 ± 0.3^b	8.2 ± 0.2^a	2.8 ± 0.1^b	5.4 ± 0.8^a	4.1 ± 0.5^a	7.5 ± 1.6^a
200–500	6.4 ± 0.3^a	10.2 ± 0.1^a	4.5 ± 0.05^a	7.7 ± 0.7^a	9.8 ± 1.1^a	7.3 ± 0.6^a
> 500	6.5 ± 0.4^a	8.6 ± 0.2^a	6.1 ± 0.06^a	7.4 ± 1.3^a	12.9 ± 2.4^a	7.7 ± 0.9^a
F^+	16.412^{**}	1.654^{ns}	5.410^{**}	2.080^{ns}	2.058^{ns}	0.056^{ns}

$^+$ANOVA mean of quantitative parameters (different letters indicate significant differences between means after *post hoc* Tukey's test, $\rho < 0.01$), mean values always expressed as ± standard error, $^{**}\rho < 0.01$, ns – not significant

Table 3. Comparison of the mean annual increment of height between species in different gap sizes

Gap size (m^2)	Mean annual increment of height (cm)					
	oak	hornbeam	Cappadocian maple	wild service	wild cherry	field maple
< 200	6.2 ± 0.06^b	10.1 ± 0.9^a	6.1 ± 0.7^a	7.6 ± 0.9^b	7.8 ± 3.0^a	5.1 ± 1.5^a
200–500	7.3 ± 0.05^a	10.6 ± 0.5^a	7.5 ± 0.6^a	10.8 ± 0.7^a	9.3 ± 0.8^a	8.3 ± 0.6^a
> 500	6.8 ± 0.06^{ab}	12.2 ± 1.2^a	6.5 ± 0.5^a	11.2 ± 2.0^a	11.0 ± 1.1^a	8.2 ± 0.7^a
F^+	4.549^*	1.179^{ns}	1.263^{ns}	3.708^*	1.064^{ns}	2.441^{ns}

$^+$ANOVA mean of quantitative parameters (different letters indicate significant differences between means after *post hoc* Tukey's test, $\rho < 0.05$), mean values always expressed as ± standard error, $^*\rho < 0.05$, ns – not significant

Comparison of species relative frequency (RF) in different gap sizes showed that oak is the most frequent species in all gap sizes. The highest RF of wild service and oak seedlings was in small gaps (< 200 m^2 in size), the maximum RF of hornbeam and field maple seedlings was observed in medium gaps (200–500 m^2 in size) and maximum RF of Cappadocian maple and wild cherry seedlings was determined in large gaps (> 500 m^2 in size) (Fig. 1).

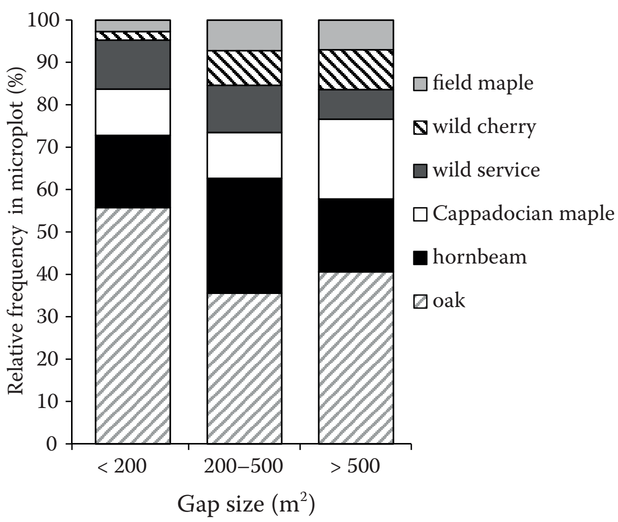

Fig. 1. Relative frequency of observed species in different gap sizes

Length of spring shoots

Mean comparison of LSS showed no significant differences between different gap sizes, except oak and Cappadocian maple seedlings (Table 2).

Mean annual increment of height

There was no significant difference in MAIH between different species in different gap sizes except oak and wild service seedlings. The highest value of MAIH was measured in medium-size gaps for oaks and in large ones for wild service seedlings (Table 3).

Mean annual increment of diameter

Since the data on annual increment of diameter in oak showed abnormal distribution, they were analysed by the Kruskal-Wallis test. The effect of gap size on MAID was significant in oak seedlings (Table 4).

Results showed that the gap size had a significant effect on MAID. The highest value of this variable was determined for hornbeam and Cappadocian maple seedlings in medium-size gaps and for wild service, wild cherry and field maple seedlings in large gaps (Table 5).

Mean comparison of all variables showed that there was a significant difference between species. The highest value of LSS was observed in wild cherry (12.1 ± 1.3 cm) and hornbeam (10.5 ± 0.6 cm). The highest value of MAIH was calculated in hornbeam (10.2 ± 0.4 cm) and wild cherry (9.6 ± 0.6 cm). The highest value of MAID was calculated for wild service seedlings (0.17 ± 0.006 cm) (Table 6).

Table 4. The effect of gap size on the mean annual increment of diameter in oak seedlings (analysed by the Kruskal-Wallis test)

	Gap size
χ^2	6.971
df	2
Significance	0.031*

*$P < 0.05$

DISCUSSION

Gap formation in forests is the result of wind damage, landslide, tree harvesting and natural process of aging and death of trees. The gap size depends on the number of harvested or fallen trees and alters ecological conditions of created microclimate (Denslow, Hartshorn 1994; Lowman, Rinker 2004; Ritter et al. 2005; Galhidy et al. 2006). Tree species have different ecological demands and their response differs due to the gap size (Naaf, Wulf 2007).

Gaps are classified according their area. Abdollahi (2014) classified gaps to medium (200–500 m^2) and large (> 500 m^2). Zolfaghari et al. (2011) classified gaps to very small (0–12.5 m^2), small (12.5–50 m^2), medium (50–113 m^2) and large (> 113 m^2). Mohebbi (2012) categorized them to small (< 200 m^2), medium (200–400 m^2) and large (> 400 m^2). In this research, according to Schütz (1990) and Marvie Mohajer (2006) gaps were divided into 3 size classes including small (less than 200 m^2), medium (200–500 m^2) and large (greater than 500 m^2) classes.

The highest frequency of seedlings was observed in medium-size gaps (200–500 m^2), which is in conformity with Abdollahi (2014) findings, who observed maximum survival of oak seedlings in medium gaps (200–500 m^2) in Gorgan forests. On

Table 5. Comparison of the mean annual increment of diameter between different species in different gap sizes

Gap size (m^2)	Mean annual increment of diameter (cm)				
	hornbeam	Cappadocian maple	wild service	wild cherry	field maple
< 200	0.13 ± 0.011^b	0.09 ± 0.004^b	0.14 ± 0.006^b	0.11 ± 0.01^b	0.12 ± 0.01^b
200–500	0.16 ± 0.007^a	0.15 ± 0.009^a	0.18 ± 0.009^{ab}	0.13 ± 0.007^{ab}	0.12 ± 0.006^b
> 500	0.15 ± 0.02^{ab}	0.13 ± 0.009^a	0.18 ± 0.02^a	0.18 ± 0.01^a	0.16 ± 0.02^a
F^+	3.691*	8.052**	3.171*	5.903*	3.994*

$^+$ANOVA mean of quantitative parameters (different letters indicate significant differences between means after *post hoc* Tukey's test), mean values always expressed as ± standard error, *$\rho < 0.05$, **$\rho < 0.01$

Table 6. Mean comparison of studied parameters for studied species

	Oak	Hornbeam	Cappadocian maple	Wild service	Wild cherry	Field maple	F^+
LSS (cm)	5.7 ± 0.2^b	10.5 ± 0.6^a	6.6 ± 0.7^b	7.0 ± 0.5^b	12.1 ± 1.3^a	7.3 ± 0.5^b	15.149**
MAIH (cm)	6.8 ± 0.2^b	10.2 ± 0.4^a	6.8 ± 0.4^b	9.6 ± 0.6^a	9.6 ± 0.6^a	7.8 ± 0.6^b	20.614**
MAID (cm)	0.15 ± 0.003^{ab}	0.16 ± 0.006^{ab}	0.13 ± 0.006^b	0.17 ± 0.006^a	0.15 ± 0.007^{ab}	0.13 ± 0.008^b	3.926**

$^+$ANOVA mean of quantitative parameters (different letters indicate significant differences between means after *post hoc* Tukey's test, $\rho < 0.01$), mean values always expressed as ± standard error, **$\rho < 0.01$

LSS – length of spring shoots, MAIH – mean annual increment of height, MAID – mean annual increment of diameter the contrary, Mohebbi (2012) did not find any relation between gap size and frequency of oak seedlings. Tabari et al. (2005) showed that the gap size did not have any significant effect on the frequency of beech, hornbeam and velvet maple regenerations. Zolfaghari et al. (2011) showed that density of regeneration decreased with an increase of the gap size. Saeb et al. (2012) reported a decreasing trend of seedling frequency by increasing the gap size above 500 m^2. They suggested that small gaps (< 200 m^2) provided the best conditions for hornbeam seedlings with regard to frequency and seedling quality. Vahedi et al. (2009) showed in Khanykan forest (Noshahr, north of Iran) that the number of seedlings significantly decreased in large gaps (> 500 m^2). Zoghi et al. (2012) reported that the maximum number of hornbeam seedlings was observed in medium-size gaps (150–300 m^2). Different results originate from different scales in gap size classification. Emborg et al. (2000) showed that the establishment of beech regeneration in small gaps is better and the frequency of light-demanding species increases with an increase of the gap size.

Our results showed that quantitative characteristics of oak seedlings improved in small and medium-size gaps. Mohebbi (2012) also showed that quantitative and qualitative characteristics of oak seedlings improved in small and medium-size gaps. Abdollahi (2014) reported that seedling height increased with an increase of the gap size.

The gap size did not have any significant effect on LSS and MAIH of hornbeam seedlings but the highest MAID was observed in medium-size gaps. Zoghi et al. (2012) reported the maximum height and LSS of hornbeam seedlings in large gaps (300–600 m^2). Vahedi et al. (2009) showed that the maximum mean height of hornbeam seedlings was measured in large gaps.

This difference probably originates from various topographic conditions in the studied areas. According to our results, we recommend using hornbeam seedlings in recovery practices in 200–500 m^2 gaps.

There was a significant difference between quantitative characteristics of particular species. Among all species, the lowest value of measured parameters was observed in Cappadocian maple. Abdollahi (2014) showed that Cappadocian maple had the slowest growth in the same conditions and gap size in comparison with other species. The findings of Sadati and Mostafanejad (2008) revealed that Cappadocian maple was beaten in competition with other species.

Increasing light by increasing the harvest gap size should increase the growth of shrub-herb vegetation and its competitive impacts on tree seedlings, but should also increase tree seedling growth, with responses varying among species (Walters et al. 2016). The growth situation of *Pinus tabulaeformis* Carrière seedlings in different habitats was in the order of big gap in shady slope > big gap in sunny slope > small gap in sunny slope > small gap in shady slope > understory in sunny slope > understory in shady slope (Han et al. 2012). 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*) decreased litter accumulation or quick decomposition (Zhu et al. 2003).

CONCLUSIONS

For Cappadocian and field maple seedlings, the highest values of some of the studied parameters were recorded in large and medium-size gaps. These species are proper in recovery practices in large and medium-size gaps, whereas wild cherry could be a suitable species only in the recovery of large gaps. When the rehabilitation should be done in a very short time, hornbeam, wild service and wild cherry seedlings are recommended in rehabilitation practice, the frequency of species should be selected very carefully to save the current *Querco-Carpinetum* association.

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