http://silvaworld.org
SilvaWorld
e-ISSN: 2822-6127
PRENSİP
https://prensip.gen.tr

RESEARCH ARTICLE

Silvicultural View of the Honowski Light Factor: Anatolian Black Pine (*Pinus nigra* J.F. Arnold subsp. *pallasiana*) Example

Ercan Oktan[1] • Yasin Çağrı Doğmuş[2]

[1]Karadeniz Technical University, Faculty of Forestry, Department of Forest Engineering, Trabzon/Türkiye
[2]General Directorate of Forestry, Ankara/Türkiye

ARTICLE INFO

Article History
Received: 17.02.2025
Accepted: 03.03.2025
First Published: 28.03.2025

Keywords
Aspect
Growth
Honowski Light Factor
Natural regeneration
Pinus nigra

ABSTRACT

Factors affecting success in natural regeneration studies are important for healthy and sustainable management of the regeneration. The number, distribution, growth and development characteristics of the regeneration are the parameters used as success criteria. In this study, the growth and development characteristics of natural juveniles of Anatolian black pine (*Pinus nigra* J.F. Arnold subsp. *pallasiana*) were investigated depending on the "Honowski Light Factor" values in the same habitat conditions. In this context, four sample areas (50 m x 150 m = 7500 m^2) were taken. A total of four stands were divided into two groups as areas where final cutting was done and areas where final cutting was not done. One of these two groups of stands selected is located in a shady aspect, the other in a sunny aspect. While the values with well and under the good growth potential revealed statistically significant ($p<0.05$) relationships based on the joint interaction of aspect and stand structure, statistically insignificant ($p>0.05$) relationships emerged between the values with not good and very low growth potential. In the study, the saplings with "well" and "under the good" growth potential were found mostly in the shady aspect where final cutting was done. Saplings with "not good" and "very low" growth potential were found mostly in sunny aspects where no final cutting was made. The reasons for this distribution can be shown as the fact that saplings in the sampled areas were not found in equal amounts in the area. Therefore, the high competition between saplings in sunny aspects has been limiting in the growth and development of saplings. In this context, it was revealed that the number of individuals in the stand should be taken into consideration while adjusting the light intensity in silvicultural applications. The use of the Honowski Light Factor values in the determination of the light needs of the saplings in Anatolian black pine natural regeneration studies reveals that it can be useful in the numerical evaluation of the assessments. At the same time, it has been revealed that the aspect factor should also be taken into account for the correct management of the process of gaining biological independence of saplings. In this context, more research should be conducted on regeneration biology and sapling dynamics evaluated within stand dynamics.

Please cite this paper as follows:
Oktan, E., & Doğmuş, Y. Ç. (2025). Silvicultural view of the Honowski Light Factor: Anatolian black pine (*Pinus nigra* J.F. Arnold subsp. *pallasiana*) example. *SilvaWorld*, *4*(1), 36-47. https://doi.org/10.61326/silvaworld.v4i1.339

1. Introduction

Natural regeneration studies play an important role in the sustainable renewal of forests and the creation of long-lived forest ecosystems (Chazdon & Guariguata, 2016). Protection and sustainable management of forests are primarily achieved by understanding the factors that ensure the successful renewal of species (Chai & Wang, 2016). Obtaining the desired efficiency in regeneration studies depends on bringing sufficient number and quality of sapling to the area and providing suitable growing conditions (Sıvacıoğlu et al., 2008;

Correspondence
E-mail address: oktan@ktu.edu.tr

Çalışkan et al., 2014). This requires the selection of methods suitable for the biology and ecology of the species. Similarly, defining the stand establishment and growing environment conditions is also extremely important in determining silvicultural interventions.

Stand structural features hold the most important place in the examination, evaluation and planning of forest ecosystems. Stand structural features are used in expressing the ecological needs and regeneration features of all flora and fauna. Stands, which are considered the smallest part representing the forest, are very important in determining their structural status. Stand establishment features are tree species, diameter, height and age distributions, density, closure, and these features indicate the existence, growth and development potential of the plants forming the stand. As a result, the existence of any species in the stand or its good or bad development depends on the determination of how much it is related to these stand elements (Oktan, 2015; Cui et al., 2022). Therefore, revealing the stand establishment provides a theoretical basis for determining the operation suitable for nature and for silvicultural applications to be carried out in practice (Zhang et al., 2021).

Stand establishment reflects regeneration dynamics, microclimate conditions (wind, humidity, precipitation), ecological characteristics of the ecosystem (light, temperature, water, soil nutrient status, water, etc. resource conditions) and competitive power among species (Nguyen et al., 2022). Therefore, when all changes that silvicultural interventions will cause in the specified stand characteristics are evaluated, it is revealed that the seedling is under the influence of many factors. Light, together with water and nutrients, is an important growth factor that determines the success of regeneration. Light plays an effective role on the germination energy and duration of fallen seeds and the development of emerging seedlings. Light is well correlated with other important abiotic and biotic factors (Grant, 1997; Madsen & Larsen, 1997; Balcı, 2008; Balandier et al., 2009; Gaudio et al., 2011). Juveniles of different tree species require different amounts of light to survive and grow successfully. Shade-tolerant species can potentially regenerate better in the dark understory than less tolerant ones. In this context, correct and nature-appropriate silvicultural interventions in natural regeneration methods are directly related to the light requirements of the species. Water, temperature and soil nutrient status within the stand are other important factors, but all of them are related to light availability to some extent (Barbier et al., 2008). The most important factor that controls the light in the overstory, intermediate and understory of the stand (Barnes et al., 1998) and determines the competition between plant species in the stand is the canopy cover (Smith et al., 1997). The relationship between the canopy cover and the temporal and spatial distribution of light reaching the lower floor is important. Because this relationship can change depending on the disturbance, succession, harvest and silvicultural practices in the forest. In this sense, it is very important to determine how changes that may occur due to silvicultural practices affect the number and distribution of seedlings in the substrate and their growth and survival potential (Wright et al., 1998).

In natural regeneration studies, the status of seedling depends on many biotic and abiotic factors (Lv et al., 2023). For instance, regeneration is strongly associated with local topography (Redmond & Kelsey, 2018). Elevation, slope and aspect affect species composition, regeneration density and survival (Kerr, 2000). Again, soil nutrients affect species regeneration (Bharathi & Prasad, 2017). Species composition of forest canopy directly affects species richness and regeneration composition and indirectly through canopy structure (Ádám et al., 2013). The relative importance of influencing factors on natural forest regeneration is uncertain and inconsistent across different field conditions. Therefore, it is very important to elucidate the characteristics of forest regeneration and determine the response of saplings to the influencing factors.

Anatolian black pine is an important tree species that spreads over a very wide area in Türkiye due to its ability to survive in difficult conditions. It is the species that can enter steppe areas the most within its wide distribution area in Türkiye. Anatolian black pine establishes pure and mixed stands in Türkiye. Anatolian black pine is semi-light tree and can remain under shelter for a long time in good sites (Yılmaz & Kalkan, 2019). Regeneration success and seedling growth in Anatolian black pine forests are generally achieved by the shelter method (Köseoğlu & Kara, 2019; Odabaşı et al., 2004). Due to its wide distribution area and economic value, many studies have been conducted on its silvicultural, ecological and biological properties (Kalıpsız, 1963; Saatçioğlu, 1979; Eruz, 1984; Polat et al., 2014; Ertuğrul & Bilir, 2020; Ayan et al., 2021). However, although there are many studies on the regeneration of Anatolian black pine (Ertuğrul & Bilir, 2020; Güner, 2001; Köseoğlu & Kara, 2019), there are not many studies on the relationship between light and the sapling based on their growth and development period. In the studies conducted, how much light should be given at which stage in natural regeneration studies has been revealed based on general evaluations. On the other hand, a numerical criterion that reveals how light affects the growth and development of saplings has not been clearly established. However, due to the biology of Anatolian black pine, light demand should be evaluated very well in natural rejuvenation studies. The Honowski Light Factor (HLF) is mostly used as a measure of the growth potential of seedlings under pressure in coniferous trees. Therefore, in this study, the effects of the Honowski Light Factor and aspect change were investigated based on the growth and development status of natural saplings of Anatolian black pine.

2. Materials and Methods

2.1. Material

2.1.1. Study area

This study was carried out in a total of 24.2 hectares of pure Anatolian black pine natural regeneration area within the borders of Korucuk Forest Sub-district Directorate of Simav Forestry Operation Directorate in Kütahya province in the Inner Aegean Region of Türkiye (Figure 1). The research area consists of 13.9 hectares of final cutting was not made and 10.3 hectares of final cutting was made areas. The research area is located between 39º18'35'' - 39º32'23'' north latitudes and 28º55'26'' - 29º06'56'' east longitudes. While selecting the research area, natural regeneration areas in the same slope group and elevation levels were taken into consideration with the help of management and silviculture plans. The study was carried out in four sample areas with a total size of 50 m x 150 m (7500 m^2) to best represent the area (Table 1). The determined areas were divided into two group groups as regeneration areas with final cutting and regeneration areas without final cutting, and potential areas were revealed.

Figure 1. Location of study area in Türkiye (Δ) .

Table 1. General information about sample areas.

Sample area no	Sub-district Directorate	Main tree species	Area (m^2)	Elevation (m)	Aspect	Slope (%)	Location
1	Korucuk	*Pinus nigra*	7500	1375	W	46	Yayla Tepe
2	Korucuk	*Pinus nigra*	7500	1365	NE	44	Yayla Tepe
3	Korucuk	*Pinus nigra*	7500	1315	NE	41	Eskiyurt
4	Korucuk	*Pinus nigra*	7500	1325	NW	42	Eskiyurt

2.2. Method

2.2.1. Sampling

The locations and sections where the pure Anatolian black pine natural regeneration areas where the study was carried out were determined using the ESRI ArcGIS10.5 program from the geographic information system (GIS) programs. Sample areas were selected in the sections where the pure Anatolian black pine natural regeneration areas were located with the conscious sampling method. A total of 4 (four) stands were selected, 2 (two) of which were final cutting made and the other 2 (two) were separated as areas where final cutting not made Again, these two groups of stands were separated as one of them was shaded and the other was sunny. Accordingly, 1 of the four sample areas was selected as cut and shaded, 1 was not cut and shaded, 1 was cut and sunny, and 1 was not cut and sunny. Sample areas were taken as 50 m x 150 m (7500 m^2) in size, taking into account parameters such as diameter, height and age of individuals and sapling in the tree layer forming the stand.

2.2.2. Determination of stand establishment characteristics

Forest establishment characteristics, in a very general definition, are the distribution of biomass in the horizontal and vertical directions in the area. This distribution is the vertical and horizontal spatial distribution of plant species, diameter, height and age distributions that form the overstory, intermediate and understory layers. However, considering that the plans to be made according to this general definition will also be very general, the establishment of stands, which are considered to be the smallest part of the forest, should be revealed in detail in order to determine the components of the forest in a more detailed and quantifiable way.

In order to determine the individual characteristics of trees and natural saplings in the sample areas, measurements (breast height diameter ($d_{1.30}$), root collar diameter ($d_{0.30}$), age, height (h), species characteristics, crown starting height, branch lengths (E-W-N-S), coordinates (abscissa and ordinate values), double bark thickness, main shoot length (length of main shoot), side shoot lengths (lengths of side shoots in East, West, North, South directions) were recorded in the land purchase report cards. In order to reveal stand establishments, horizontal and vertical stand profiles were drawn for each sampling area.

2.2.3. Determination and classification of Honowski Light Factor

Honowski Light Factor (HLF) was used to present the growth potential measure of seedlings. The ratio of the main shoot (terminal) (T) length to the lateral shoot (L) length, as revealed by Fabijanowski et al. (1974), has been used as a measure of the growth potential of sapling under pressure in mostly coniferous trees. This factor is called H=T/L "Honowski Light Factor". Honowski Light Factor and evaluation measures are given below (Schütz, 2001, referring to Fabijanowski et al., 1974) (Figure 2).

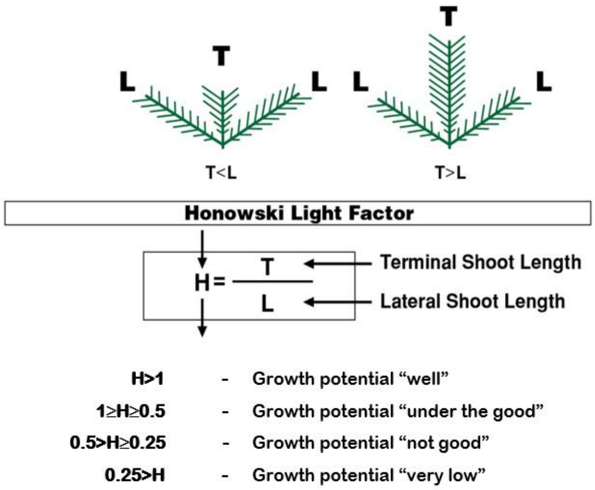

Figure 2. Honowski Light Factor (Schütz, 2001).

3. Results and Discussion

In the study, measurements were carried out in a total of 4 sample areas of 50 m x 150 m (7500 m^2), and the findings obtained from each sample area (diameter distribution, height distribution, age distribution, tree species, mixture, number of trees and saplings per hectare, closure rates) are given in table 2.

In this context, sample areas 1 and 2 were separated as rejuvenation areas where no final cutting was done, and sample areas 2 and 3 were separated as regeneration areas where final cutting was done. When the data in Table 2 is evaluated, there are significant differences in terms of stand structure (canopy closure rates, number of trees and saplings per hectare, diameter-height and age distribution for trees and saplings, etc.) in the four sample areas (Table 2).

Table 2. Results regarding stand characteristics in sample areas.

Sample area no	Main tree species	Stand mixture	Number of trees per hectare (number)	Number of sapling per hectare (number)	Tree floor diameter ($d_{1.30}$) frequency (cm)	Tree floor age frequency	Sapling diameter ($d_{0.30}$) frequency (mm)	Sapling height frequency (cm)	Sapling age frequency	Tree floor canopy closure (%)
1	*P. nigra*	Pure	97	3199	24.10-72.20	34 -118	6-82	10-350	1-20	0.29
2	*P. nigra*	Pure	87	1293	24.40-64.30	68 -152	3-90	30-405	3-32	0.37
3	*P. nigra*	Pure	4	4003	28.20-56.10	58-98	4-82	4-600	1-19	-
4	*P. nigra*	Pure	3	2850	52.10-54.20	85- 88	5-92	19-300	3-18	-

After seed cutting; when we look at the findings in the stands where the final cutting was done and not done, it is revealed that there are differences especially between the number of Anatolian black pine saplings and the growth potentials of the saplings in each sample area. In this context, vertical and horizontal stand profiles were drawn to determine the spatial distribution of saplings in the sample areas within the area (Figure 3). When the stand profiles are taken into consideration, it is revealed that these distributions are not homogeneous and in this sense, the growth potentials of the saplings in the area are different.

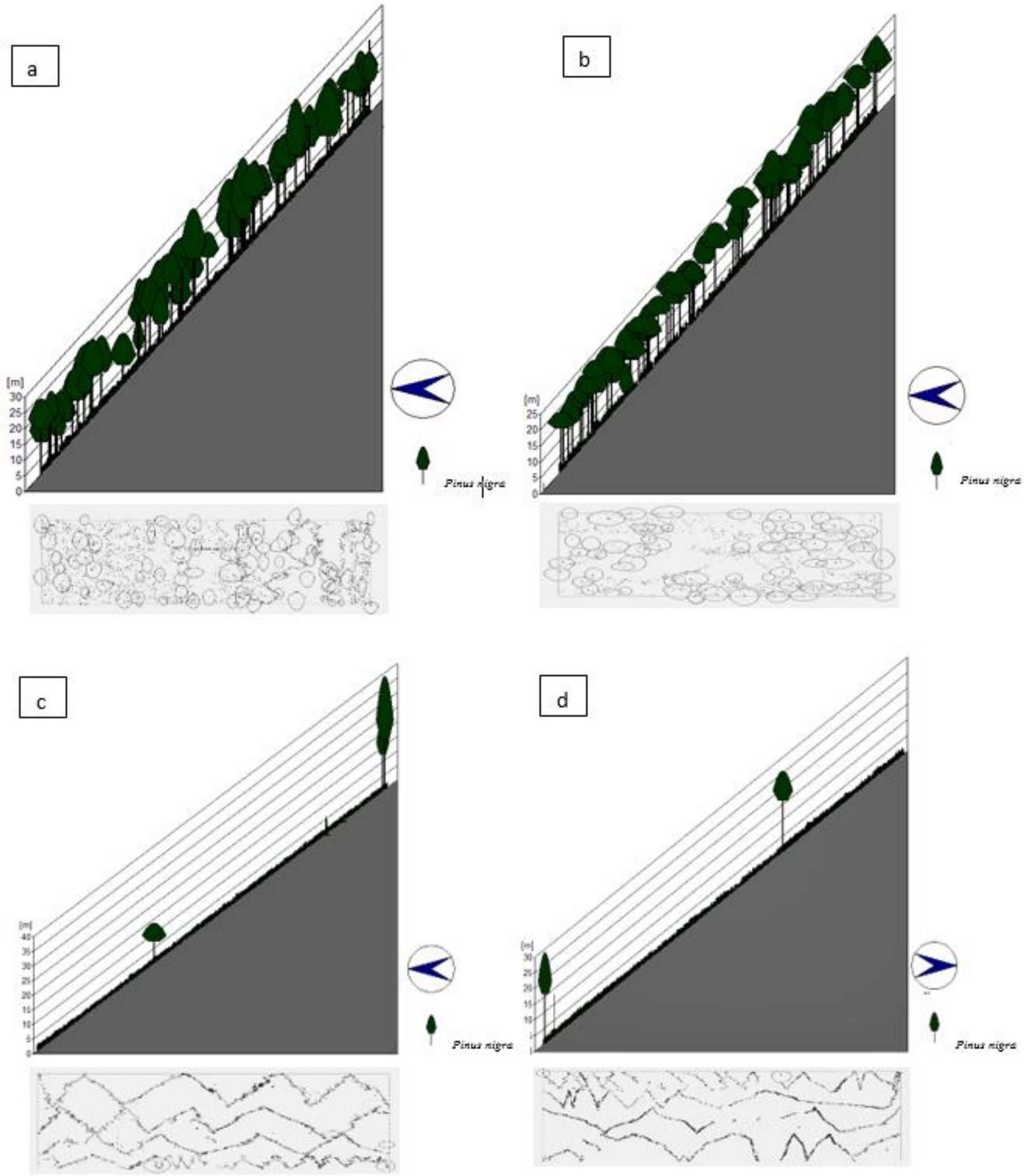

Figure 3. Vertical and horizontal stand profiles of all sample areas: Sample area 1 (a), Sample area 2 (b), Sample area 3 (c), Sample area 4 (d).

When the stand measurement values (Table 2) and stand profiles (Figure 3) in sample areas taken from points representing the stands in the study areas were evaluated; in sample area 1, the diameter ($d_{1.30}$) distribution of individuals in the tree layer varies between 24.10 cm and 72.20 cm and the age distribution varies between 34 years and 118 years. The root collar diameters ($d_{0.30}$) of the saplings vary between 6 mm and 82 mm, their heights vary between 10 cm and 350 cm and their ages vary between 1 year and 20 years. The number of saplings in the shrub layer is 3199 per hectare. In sample area 2, the diameter ($d_{1.30}$) distribution of individuals in the tree layer varies between 24.40 cm and 64.30 cm and the age distribution varies between 68 years and 152 years. The root collar diameters ($d_{0.30}$) of the saplings range from 3 mm to 90 mm, their heights range from 30 cm to 405 cm and their ages range from 3 years to 32 years. The saplings in the bush layer are 1293 per hectare. In sample area 3, there are 4 individuals in the tree layer and the diameter ($d_{1.30}$) distribution of the individuals varies between 28.20 cm and 56.10 cm and the age distribution varies between 58 years and 98 years. The root collar diameters ($d_{0.30}$) of the saplings range from 4 mm to 82 mm, their heights range from 4 cm to 600 cm and their ages range from 1 year to 19 years. The saplings in the bush layer are 4003 per hectare. In sample area 4, there are 3 individuals in the tree layer and the diameter ($d_{1.30}$) distribution of the individuals varies between 54.20 cm and 52.10 cm and the age distribution varies between 85 years and 88 years. The root collar diameters of the saplings ($d_{0.30}$) range from 5 mm to 92 mm, their heights range from 19 cm to 300 cm and their ages range from 3 years to 18 years. There are 2850 saplings per hectare in the shrub layer. While the tree layer closure degree was 0.29 in sample area 1, it was found to be 0.37 in sample area 2.

The stand structure (with and without final cutting) has created differences between the growth potentials of the saplings, especially in terms of diameter. The areas where final cutting was made showed a good development with more individuals in the higher diameter level compared to the areas where final cutting was not made. However, in terms of distribution to height levels, the situation is in favor of the areas where final cutting has not been done. Therefore, it was understood that possible light starvation on sapling in sample areas where final cutting was not done triggered height competition and caused more tall sapling to be obtained. In fact, Balcı (2008) stated in his study that plants need light to perform sufficient photosynthesis and that in order to meet their needs, they sometimes turn to light to grow in height and sometimes to direct their leaves towards light to achieve the necessary growth. In the study investigating the effect of different degrees of precommercial thinning applied to Anatolian black pine on growth, it was stated that the interventions were effective on the development of the trees except for height increment (Bayar & Deligöz, 2019). Again, Carus and Çatal (2010) determined that different thinning degrees in a young Taurus cedar stand established by planting had a statistically significant effect on diameter and volume increase, but were not effective on height increase. The availability of resources and suitable microclimate in forests depend on sufficient light conditions and affect the development and survival of seedlings (Barbier et al., 2008). The fact that diameter development is good and the number of living individuals is high in the areas where final cutting is done also shows this situation. On the other hand, when it is considered that a proportional growth-development course between diameter and height is required for correct sapling development, it is also possible to say that possible delays in final cutting time will negatively affect sapling quality. When it is accepted that the intervention intensity in stands where the cutting was done is higher than in stands where the cutting was not done, the results obtained from the study are consistent with the literature.

The average period of abundant seed year repetition detected in the Anatolian black pine stands where the study was carried out is three years. When the distributions of sapling age levels are examined, it is concluded that the sapling age frequencies coming to the area show quite significant relationships with the abundant seed year repetition process. In fact, it has been determined that the weighted age frequencies increase significantly with sapling coming to the area in the abundant seed year and the second abundant seed year experienced after the seed cutting, both in the areas where the final cutting was made and in the areas where the final cutting was not made. Güner (2001) stated that more than one abundant seed year experienced during the regeneration works process makes significant contributions to the regeneration success.

The Honowski Light Factor was calculated by measuring the main shoot (terminal) and lateral shoot of all saplings in the sample areas. The Honowski Light Factor values calculated for all sample areas in the study ranged from 0.05 to 13. Accordingly, the Honowski Light Factor; It varies between 0.05 and 13 ($\bar{x}$=1.19, σ = 0.469) in sample area 1, between 0.05 and 13 ($\bar{x}$=1.23, σ = 0.509) in sample area 2, between 0.05 and 13 ($\bar{x}$=1.16, σ = 0.408) in sample area 3, and between 0.05 and 13 ($\bar{x}$=1.19, σ = 0.438) in sample area 4. The calculated values are classified into four groups as well (1), under the good (2), not good (3) and very low (4) according to their growth potential. The findings regarding the growth potentials of the saplings in the sample area determined based on the Honowski Light Factor are given in Figure 4 below.

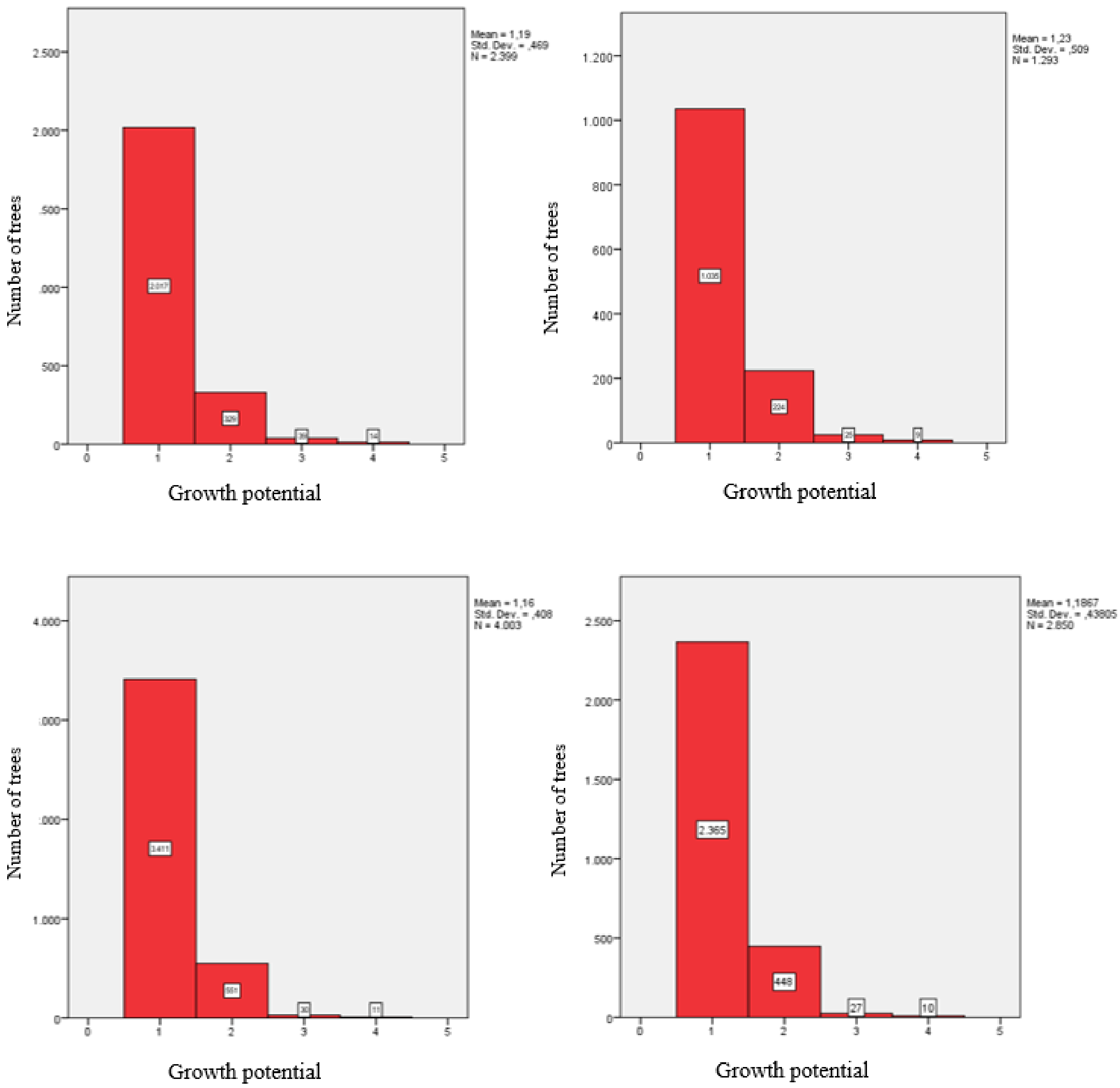

Figure 4. Distribution of growth potentials of sample areas (1: Growth potential is well; 2: Growth potential is under the good; 3: Growth potential is not good; 4: Growth potential is very low).

The calculated values were classified as well (1), under the good (2), not good (3) and very low (4) according to their growth potential. Chi-square test was performed to determine whether this distinction changed according to aspect and stand structure. According to the test results, values with well and under the good growth potential were found to be statistically significant (*p<0.05*) based on the joint interaction of aspect and stand structure. However, individuals with not good and very low growth potential were found to be statistically insignificant (*p>0.05*) based on the joint interaction of aspect and stand structure. In the classifications made according to the Honowski light factor, comparisons were made in four sample areas according to whether individuals with "well, under the good, not good and very low" growth potential were final cutting or not final cutting and whether these areas were in shady or sunny aspects (Figure 5). The comparisons made were queried as follows: sunny and shady aspects without final cutting, sunny and shady aspects with final cutting, shady aspects with final cutting and without final cutting, sunny aspects with final cutting and without final cutting.

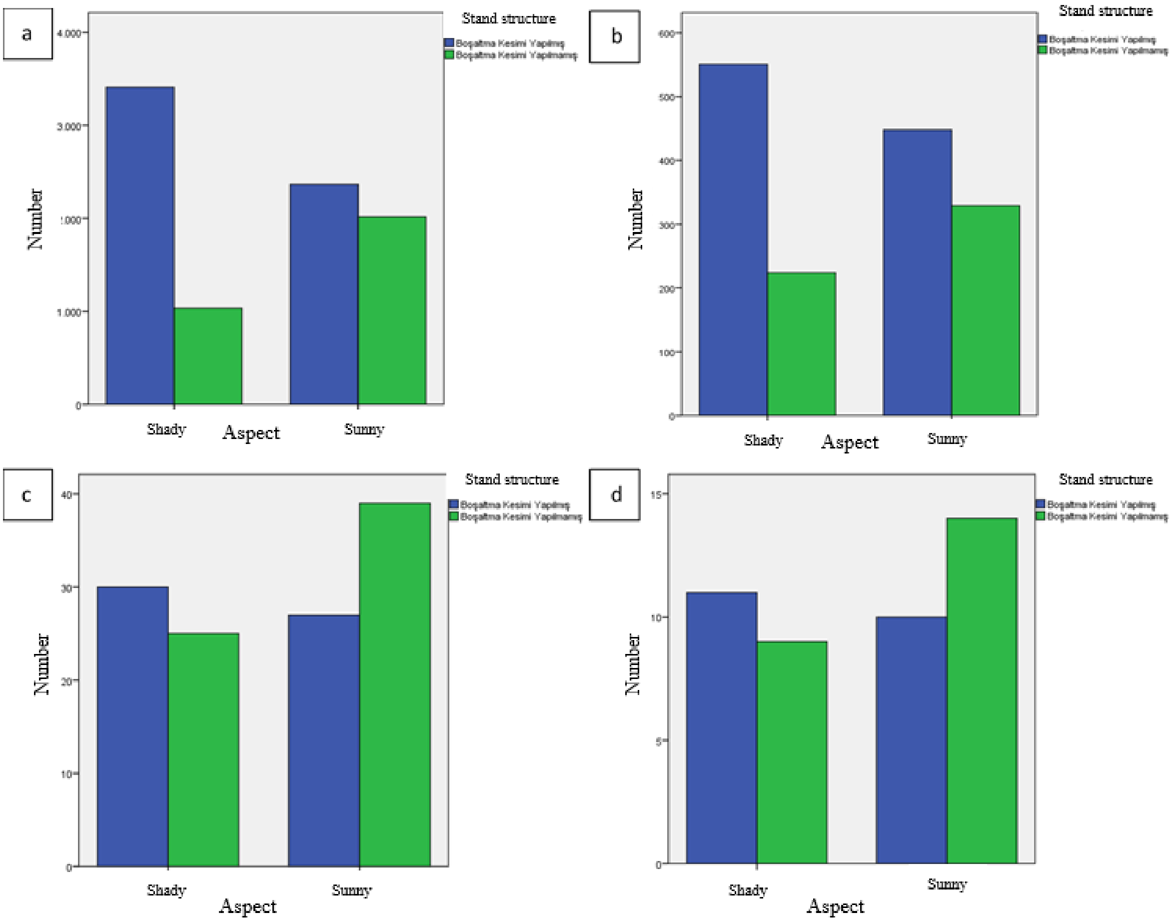

Figure 5. Aspect distribution of sapling with well (a), under the good (b), not good (c), very low (d) growth potential according to stand structure.

When Figure 5 is examined, different relationships emerged in the comparisons made according to the stand structure and aspect factor on the growth potentials of saplings in four sample areas. The development of saplings with "well" growth potential in shady and sunny aspects where final cutting was performed was compared (Figure 5a). In final cutting areas, the growth potential, number of individuals per hectare, diameter and height developments of most saplings in shady aspects were found to be better than in sunny aspects. In final cutting areas, shady aspects created more humid growth environments and positively affected the development of the sapling. Ertuğrul and Bilir (2020) reported that the height development of Anatolian black pine seedling changed depending on the altitude and aspect and that development was better in the northern aspect. Yılmaz and Kalkan (2019) observed that there were more seedlings coming from living seeds in shady aspect in the natural regeneration method of seed trees. Ata (1995) stated that in areas where shelter is insufficient, the seedlings are affected by summer drought. In sunny aspects, the soil moisture rate decreases with the increase in temperature. Therefore, although sufficient light conditions are provided for the growth and development of Anatolian black pine seedlings, factors affecting growth and development such as soil moisture should also be evaluated. In this context, it can be said that in areas where the young trees are completely exposed, in southern exposures or in sunny exposures, more moderate silvicultural interventions can yield better results. Again, saplings with "well" growth potential were compared as shaded and sunny aspects where no final cutting was made (Figure 5a). However, the growth potential of saplings in sunny aspects where final cutting was not made was found to be better than in shaded aspects. However, the number of sapling with not good and very low growth potential is higher in this area than in all other areas. In sunny areas where no final cutting is done, there is intense competition for resources such as light, water and nutrients between trees in the overstory and saplings in the understory. However, limited resources can create an environment in the understory where some sapling can better exhibit their growth potential. Sunny aspect provides good light intake, but this light may only be sufficient for some saplings. Therefore, while some saplings grow well, others grow poorly due to lack of resources. This situation can cause saplings with both well and very low growth potential to exist in the lower layer at the same time.

In similar growing environments, reducing the intensity of canopy closure at the tree level increases the growth potential.

In the study, in areas where final cutting was done, the growth potential of saplings in shady aspect was found to be higher than in sunny aspect. In addition, in areas where final cutting was not done and the canopy is at relatively high values, sunny aspect is more effective in having good growth potential than in shady aspect. In this case, it shows that Anatolian black pine needs a shady aspect along with its light requirement in its first years. It is an indication that Anatolian black pine is a semi-light tree. Therefore, it shows that the degree of cutting should be adjusted very well in silvicultural interventions to be made in Anatolian black pine. At the same time, it is revealed that the aspect factor should also be taken into consideration in the correct management of the process of gaining seedling biological independence. All these situations show that the temporal and technical processes of silvicultural processes applied in regeneration studies should not be subject to synthesis in general terms. The fact that Anatolian black pine can stay under shelter for a long time without losing its growth energy in good growing environments on the north does not indicate that it needs shelter at the seedling age. Its resistance to shade decreases in arid and poor growing environments (Yılmaz & Kalkan, 2019). Therefore, shade tolerance may be affected by site quality. Therefore, the response of species to different light levels needs to be investigated in more detail.

Since the numbers of saplings with "well" growth potential in the sample areas with and without final cutting in the sunny aspect were very close to each other, no significant difference was observed. In the shaded aspect, the number of saplings with well growth potential in the final cutting area was considerably higher than the number of saplings with "well" growth potential in the sample area without final cutting, a significant difference was observed (Figure 5a). In final cutting, more light reaches the lower layer and provides better development of the seedling in the lower layer. In the shaded aspect, the development of seedlings is limited by other sources due to low light conditions. In light and semi-light tree species, the amount of light entering the stand generally positively affects the number of seedling and growth potential (Noemie et al., 2011). Köseoğlu and Kara (2019) stated that the amount of light entering the stand is the most important determinant of the root collar diameter and height values of seedling in Anatolian black pine stands. Similarly, some previous studies have shown that the light entering the stand is considered the most effective factor affecting the growth of Anatolian black pine seedling (Tíscar & Linares, 2014). In the area where no final cutting is done, the number of individuals with well growth potential is the least, and it can be said that the competition of all individuals above and below the soil in terms of light, water, nutrients and growing environment reveals this relationship. In a natural environment, the seedling habitat is shared with other subsoil vegetation, and this situation can delay seedling development. Augusto et al. (2003) stated that the understory directly and indirectly affects the forest structure by competing with new youth or saplings during the establishment phase, changing the microclimate conditions in which the saplings grow and affecting the nutrient cycle. Nilsson and Wardle (2005) showed that the understory influences the overstory in various ways. They stated that the understory shrub layer's competition for nutrients and light may determine the regeneration potential and the eventual dominance of overstory trees. Comparisons made for individuals with "under the good" growth potential revealed a similar distribution to those defined as "well" growth potential (Figure 5b).

As a result of the comparisons made on saplings defined as "not good" and "very low" growth potential, a single assessment was made for these two classifications because the distributions of saplings with both growth potentials (not good and very low) overlapped with each other (Figure 5c and Figure 5d). In the sample areas with sunny aspect without final cutting, the number of individuals with not good and very low growth potential was higher than the number of sapling with not good and very low growth potential in the sample areas with shady aspect. On the other hand, in the sample area with shady aspect with final cutting, the number of sapling with not good and very low growth potential was higher than in the sunny aspect. However, since the numbers of not good and very low sapling were very close to each other in these sample areas, no statistically significant difference was observed. Again, since the numbers of sapling with not good and very low growth potential were very close to each other in the sample areas with shady aspect with and without final cutting, no statistically significant difference was observed. Since the number of sapling with not good and very low growth potential in the sunny aspect without final cutting was considerably higher than the number of saplings with not good and very low growth potential in the sample areas in the sunny aspect with final cutting, a statistically significant difference was observed. In the closed stand, the competition for resources increases and the growth and survival of the seedling in the lower layer becomes difficult (Çoban, 2007).

The total number of sapling measured in the shaded and sunny areas where no final cutting was done was 3692, while 6853 individuals were measured in the sample areas where final cutting was done, which is approximately twice as many. At the same time, the number of sapling with "well" growth potential (5776) in the final cutting areas is approximately twice as much as the sapling ones in the sample areas where final cutting was not done (3052). In natural regeneration studies in areas with similar growing environments, it is understood that the two most important factors in terms of the growth potential and vitality (living power) of the sapling are light and canopy closure. Therefore, it has been determined that the growth potential of the sapling is clearly related to the stand characteristics. It is possible to say that the competition of all individuals above and below the soil in terms of light, water, nutrients and growing environment (Çoban, 2007) reveals this relationship.

4. Conclusion

In natural regeneration studies, understanding the effects of the light factor on the development and survival of the seedling provides important data for sustainable forest management. The healthy development of forests requires the most suitable light conditions for the species. Therefore, it has been revealed in many studies and applications that the light demand of Anatolian black pine should be evaluated very well due to its biology. This study reveals that using the Honowski Light Factor values to determine the light needs of the saplings can be useful in numerically presenting the evaluations. According to the results obtained in this study, it can be said that if the canopy closure is 0.2-0.3 in the first light cutting stage in the natural regeneration studies of Anatolian black pine, the diameter-height development rates of the saplings can be better. At the same time, in addition to meeting the light needs in advance in the first years, it can also shorten the natural regeneration period. Therefore, revealing the light needs of saplings with numerical values such as the Honowski Light Factor can be beneficial in planning time and developing the stand in natural regeneration studies. Improving natural regeneration processes provides significant benefits for sustainable forestry studies by supporting the long-term protection and maintenance of forest ecosystems. It is revealed that the aspect factor should also be taken into account for the correct management of the process of gaining biological independence of the saplings. Similar studies using Honowski Light Factor values can be carried out on Anatolian black pine and other species with similar requirements, and the degrees of canopy density can be re-established, especially in the seed cutting and post-seed cutting stages.

Acknowledgment

This study was produced from the master's thesis titled "Analysis of Growth - Development of Natural Saplings of Anatolian Black Pine (*Pinus nigra* J.F. Arnold subsp. *pallasiana*) by the Honowski Light Factor in Region of Simav-Kütahya" prepared by Yasin Çağrı Doğmuş under the supervision of Assoc. Prof. Dr. Ercan OKTAN at Karadeniz Technical University, Institute of Science.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

Ádám, R., Odor, P., & Janos, B. (2013). The effects of stand characteristics on the understory vegetation in *Quercus petraea* and *Q. cerris* dominated forests. *Community Ecology*, *14*(1), 101-109. https://doi.org/10.1556/ComEc.14.2013.1.11

Ata, C. (1995). *Silvikültür tekniği*. Zonguldak Karaelmas Üniversitesi Bartın Orman Fakültesi Yayını. (In Turkish)

Augusto, L., Dupoueyb, J. C., & Rangerb, J. (2003). Effects of tree species on understory vegetation and environmental conditions in temperate forests. *Annals of Forest Science*, *60*(8), 823-831. https://doi.org/10.1051/forest:2003077

Ayan, S., Yücedag, C., Simovski, B. (2021). A major tool for afforestation of semi-arid and anthropogenic steppe areas in Turkey: *Pinus nigra* J.F. Arnold subsp. *pallasiana* (Lamb.) Holmboe, Journal of Forest Science, 67 (10): 449–46367. https://doi.org/10.17221/74/2021-JFS

Balandier, P., Marquier, A., Dumas, Y., Gaudio, N., Philippe, G., Da Silva, D., Adam, A., Ginisty, C., & Sinoquet, H. (2009). *Light sharing among different forest strata for sustainable management of vegetation and regeneration*. Proceedings of the International Scientific Conference "Forestry in Achieving Millennium Goals". Serbie.

Balcı, N. (2008). *Kocadüz-Hendek yöresindeki Doğu kayını (Fagus orientalis* Lipsky*) doğal gençliklerinde vitalite ve büyüme formları üzerine araştırmalar* (Master's thesis, İstanbul University). (In Turkish)

Barbier, S., Gosselin, F., & Balandier, P. (2008). Influence of tree species on understory vegetation diversity and mechanisms involved – a critical review for temperate and boreal forests. *Forest Ecology and Management*, *254*(1), 1-15. https://doi.org/10.1016/j.foreco.2007.09.038

Barnes, B. V., Zak, D. R., Denton, S. R., & Spurr, S. H. (1998). *Forest ecology*. John Wiley and Sons, Inc.

Bayar, E. & Deligöz, A. (2019). Burdur yöresi doğal Anadolu karaçamı meşceresinde sıklık bakımının üç yıllık sonuçları. *Artvin Çoruh Üniversitesi Orman Fakültesi Dergisi*, *20*(1), 18-27. https://doi.org/10.17474/artvinofd.476662 (In Turkish)

Bharathi, S., & Prasad, A. G. D. (2017). Diversity, population structure and regeneration status of arboreal species in the four sacred groves of Kushalnagar, Karnataka. *Journal of Forestry Research*, *28*, 357-370. https://doi.org/10.1007/s11676-016-0328-9

Çalışkan, A., Güney, H. S., & Çalışkan, S. (2014). Effects of different soil preparation techniques on the Anatolian Black Pine (*Pinus nigra* Arnold subsp. pallasiana (Lamb.) Holmboe) regeneration. *Journal of the Faculty of Forestry Istanbul University*, *64*(2), 56-68. https://doi.org/10.17099/jffiu.74421

Carus, S., & Çatal, Y. (2010). Growth response of Lebanon Cedar (*Cedrus libani*) plantations to thinning intensity in Western Turkey. *Journal of Environmental Biology*, *31*(5), 609-614.

Chai, Z. Z., & Wang, D. X. (2016). Environmental influences on the successful regeneration of pine-oak mixed forests in the Qinling Mountains, China. *Scandinavian Journal of Forest Research*, 31(4), 368-381. https://doi.org/10.1080/02827581.2015.1062912

Chazdon, R. L., & Guariguata, M. R. (2016). Natural regeneration as a tool for large-scale forest restoration in the tropics: prospects and challenges. *Biotropica*, *48*(6), 716-730. https://doi.org/10.1111/btp.12381

Çoban, S. (2007). *Bolu-Aladağ'daki Sarıçam (Pinus sylvestris L.) meşcerelerinde doğal gençleşme örnekleri üzerine araştırmalar* (Master's thesis, İstanbul University). (In Turkish)

Cui, R., Qi, S., Wu, B., Zhang, D., Zhang, L., Zhou, P., Ma, N., & Huang, X. (2022). The Influence of stand structure on understory herbaceous plants species diversity of *Platycladus orientalis* plantations in Beijing, China. *Forests*, *13*(11), 1921. https://doi.org/10.3390/f13111921

Ertuğrul, G. S., & Bilir, N. (2020). Kütahya-Simav yöresi Anadolu karaçamı doğal gençleştirme sahasında bazı değerlendirmeler. *Artvin Çoruh Üniversitesi Orman Fakültesi Dergisi*, *21*(1), 75-81. https://doi.org/10.17474/artvinofd.615569 (In Turkish)

Eruz, E. (1984). *Balıkesir Orman Başmüdürlüğü bölgesindeki saf karaçam meşcerelerinin boy gelişimi ile bazı edafik ve fizyografik özellikler arasındaki ilişkiler*. İstanbul Üniversitesi Orman Fakültesi Yayınları. (In Turkish)

Fabijanowski, J., Jaworski, A., & Musiel, W. (1974). The use of certain morphological features of the fir (*Abies alba* Mill.) and spruce (*Picea excelsa* Link.) in the evaluation of the light requirements and quality of their up-growths. *Acta Agriria et Silvestria – Series Silvestris*, *14*, 3-29 (In Polish).

Gaudio, N., Balandier, P., Perret, S., & Ginisty, C. (2011). Growth of understorey Scots pine (*Pinus sylvestris* L.) saplings in response to light in mixed temperate forest. *Forestry: An International Journal of Forest Research*, *84*(2), 187-195. https://doi.org/10.1093/forestry/cpr005

Grant, R. H. (1997). Partitioning of biologically active radiation in plant canopies. *International Journal of Biometeorology*, *40*, 26-40. https://doi.org/10.1007/BF02439408

Güner, Ş. T. (2001). Afyon Orman İşletme Müdürlüğü Anadolu karaçamı meşcerelerindeki doğal gençleştirme çalışmalarının değerlendirilmesi. *Süleyman Demirel Üniversitesi Orman Fakültesi Dergisi*, *Seri A*(2), 61-74. (In Turkish)

Kalıpsız, A. (1963). *Türkiye'de karaçam (Pinus nigra Arnold) meşcerelerinin tabii bünyesi ve verim kudreti üzerine araştırmalar*. Yenilik Basımevi. (In Turkish)

Kerr, G. (2000). Natural regeneration of Corsican pine (*Pinus nigra* subsp. *laricio*) in Great Britain. *Forestry: An International Journal of Forest Research*, *73*(5), 479-488. https://doi.org/10.1093/forestry/73.5.479

Köseoğlu, E., & Kara, F. (2019). Bazı meşcere değişkenlerinin karaçam gençlik sayısı ve büyümesi üzerine etkilerinin karşılaştırılması. *Turkish Journal of Forestry*, *20*(4), 305-311. https://doi.org/10.18182/tjf.621550 (In Turkish)

Lv, K., ZHou., M., Ding, Y., Zang, R., Yao, J., Luo, Y., & Yan, D. (2023). Regeneration characteristics and influencing factors of woody plant on natural evergreen secondary broad-leaved forests in the subtropical, China. *Global Ecology and Conservation*, *42*, e02394. https://doi.org/10.1016/j.gecco.2023.e02394

Madsen, P., & Larsen, J. B. (1997). Natural regeneration of beech (*Fagus sylvatica* L.) with respect to canopy density, soil moisture and soil carbon content. *Forest Ecology and Management*, *97*(2), 95-105. https://doi.org/10.1016/S0378-1127(97)00091-1

Nguyen, Q. V., Pham, M. P., Meng, L., Bui, H. M., Pham, H. T., Nguyen, H. V., Nguyen, T. T., & Kang, Y. X. (2022). Spatial structure of the dominant tree species in an evergreen broadleaved forest stand in south Vietnam. *Biology Bulletin*, *49*, S69-S82. https://doi.org/10.1134/s1062359022130131

Nilsson, M. C., & Wardle, D. A. (2005). Understory vegetation as a forest ecosystem driver: Evidence from the northern Swedish boreal forest. *Frontiers in Ecology and the Environment*, *3*(8), 421-428. https://doi.org/10.1890/1540-9295(2005)003[0421:UVAAFE]2.0.CO;2

Noemie, G., Philippe, B., Sandrine, P., & Christian, G. (2011). Growth of under storey Scots pine (*Pinus sylvestris* L.) saplings in response to light in mixed temperate forest. *Forestry: An International Journal of Forest Research*, *84*(2), 187-195. https://doi.org/10.1093/forestry/cpr005

Odabaşı, T., Calışkan, A., & Bozkuş, H. F. (2004). *Silvikültür tekniği.* İstanbul Üniversitesi Yayınları. (In Turkish)

Oktan, E. (2015). *Torul Orman İşletme Müdürlüğü doğal yaşlı orman alanlarında meşcere kuruluşları ve silvikültürel analizler* (Doctoral dissertation, Karadeniz Technical University). (In Turkish)

Polat, S., Polat, O., Kantarcı, M. D., Tüfekçi, S., & Aksay, Y. (2014). Mersin-Kadıncık Havzası'ndaki sedir (*Cedrus libani* A. Rich.) ve karaçam (*Pinus nigra* Arnold.) ağaçlandırmalarının boy gelişimi ile bazı yetişme ortamı özellikleri arasındaki ilişkiler. *Ormancılık Araştırma Dergisi*, *1*(1 A), 22-37. https://doi.org/10.17568/oad.86449 (In Turkish)

Redmond, M. D., & Kelsey, K. C. (2018). Topography and overstory mortality interact to control tree regeneration in spruce-fir forests of the southern Rocky Mountains. *Forest Ecology and Management*, *427*, 106-113. https://doi.org/10.1016/j.foreco.2018.05.057

Saatçioğlu, F. (1979). *Silvikültür tekniği*. İstanbul Üniversitesi Yayınları. (In Turkish)

Schütz, J. (2001). *Die Technik der Waldverjüngung von Wäldern mit Ablösung der Generationen: Skript zur Vorlesung Waldbau II*. ETH Zentrum Zürich. (In German)

Sıvacıoğlu, A., Özdemir, E., & Ayan, S. (2008). Karadere (Kastamonu) Orman İşletme Müdürlüğü doğal gençleştirme alanlarında "Sıfır Alan Yöntemi" İle başarı kontrolü. *Kastamonu Üniversitesi Orman Fakültesi Dergisi*, *8*(2), 157-164. (In Turkish)

Smith, D. M., Larson, B. C., Kelty, M. J., & Ashton, P. M. S. (1997). *The practice of silviculture: Applied Forest ecology*. Wiley.

Tíscar, P., & Linares, J. (2014). Large-scale regeneration patterns of *Pinus nigra* subsp. *salzmannii*: Poor evidence of increasing facilitation across a drought gradient. *Forests*, *5*(1), 1-20. https://doi.org/10.3390/f5010001

Wright, E. F., Coates, K. D., Canham, C. D., & Bartemucci, P. (1998). Species variability in growth response to light across climatic regions in northwestern British Columbia. *Canadian Journal of Forest Research*, *28*(6), 871-886. https://doi.org/10.1139/x98-055

Yılmaz, M., & Kalkan, M. (2019). Tohum ağacı doğal gençleştirme yönteminin karaçam (*Pinus nigra* subsp. *pallasiana*)'da uygulanması, Eskişehir- Tandır örneği. *Turkish Journal of Forest Science*, *3*(1), 24-36. https://doi.org/10.32328/turkjforsci.544130 (In Turkish)

Zhang, Y. H., Dian, Y. Y., Huang, G. T., Liu, X. Y., Han, Z. M., Jian, Y. F., Li, Y., & Wang, X. (2021). Effects of spatial structure on species diversity in *Pinus massoniana* plantation of different succession stages. *Chinese Journal of Ecology*, *40*(8), 2357-2365. https://doi.org/10.13292/j.1000-4890.202108.015