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RESEARCH ARTICLE

# SPATIAL PATTERN IN ORIENTAL BEECH (*FAGUS ORIENTALIS* LIPSKY.) AND ULUDAĞ FIR (*ABIES NORDMANNIANA SSP. BORNMUELLERIANA* MATTF.) MIXED FORESTS

*Tuğrul VAROL, Fahri Ersoy DEMİR and Halil Bariş ÖZEL

Department of Forest Engineering, Faculty of Forestry, University of Bartın, Bartın-Turkey

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ABSTRACT

Both of two sample plots have been chosen within the mixed forests of Hasankadı Forest Sub-District Directorate for analysis of natural regeneration of Oriental beech (Fagus orientalis Lipsky.) and Uludağ fir (*Abies nordmanniana ssp. bornmuelleriana*). The locations of all saplings (height ≤ 0.8 m), seedlings (height > 0.8 m) and trees (height > 1.8 m) have been determined, and the measurements have been performed. Spatial pattern analysis and statistical assessments have been carried out by Ripley's K function in R software. Although grouping has been observed in all growth stages of Uludağ fir and oriental beech, there is a positive relationship between juvenilities of fir and older beech trees. These results indicate the stable growth in first stages of development. It is understood that the suitable growth locations are under the canopy of beeches for abies and under the older beeches for beech trees.



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## INTRODUCTION

In recent years, the new ecological approaches (e.g. hierarchy theory) together with development in information technologies (Geographical Information System, spatial statistics, and etc.) guide the forestry studies (Bradshaw, 1998). In ecologic studies and forestry activities, it is required to add the spatial data to ecosystem analyses in forestry activities and evaluating those data. While satellite images and GIS data provide the visual appearance of forests to a large scale, most of ecological information needs to be obtained in smaller scales. That's why; it is very important to understand how to integrate the large-scale information with smaller-scale information. While the small-scaled data in forestry implementations show the spatial configurations (such as diameter distribution) and mixtures of trees, the large scaled ones indicate the functional data such as canopy and biomass. While the canopy of forest cover provides the micro-habitats for plants and animals, it affects the processes above (e.g. forest floor) and below (e.g. soil respiration) the ground (Lowman and Nadkarni, 1995). Because such processes are related with composition of species (Nielsen and Ejlersen, 1977) it is a complex problem how the interaction of trees can change the individual properties, while individual development of trees can be well understood. Despite of significant decrease of fir in European forests (Jaworski *et al.,* 2002), due to the derogation of ecologic stability of beech (Kn) stands in study region in time, it transforms into KnG (oriental beech-Uludağ fir), GKn (Uludağ fir-oriental beech) or KnDy (oriental beech-other broadleaved tree species) and KnGDy (oriental beech-Uludağ fir-other broadleaved tree species) stands (Figure 1). In order to eliminate the natural regeneration problems of these mixed stands, it is required to understand the natural regeneration as good as possible. It can only be possible by collecting and assessing all the practical information about mixed stands (especially the maintenance efforts together with regeneration efforts) (Korpel and Saniga, 1995). The protection of beech existence in stands is possible with protection of its ecologic stability. The actual status can be explained with beech's distancing from places where its struggling power is low, or with the wrong implementations before. When evaluating the dynamics of natural or almost-natural forests by considering the growth stages, it can be seen that it consists of continuous regeneration of species in large or small spaces (Hladik *et al.,* 1993). The juvenilities of beech and fir accumulate in small spaces under the stand cover, the big gaps are occupied by other species. Despite that regeneration dynamics of each of species in mixed stands are well known, the mutual interactions have not been clarified yet (Michal, 1983). It is

***Corresponding author: Tuğrul VAROL***
Department of Forest Engineering, Faculty of Forestry, University of Bartın, Bartın-Turkey.

stated that fir constitutes the fundamental stand in beech-fir mixed stands in western Black Sea region, and that beech enters into mixture as single tree or the cluster of trees (Çalışkan, 1992). Up to the present, significant efforts have been made in order to define the structure of forests having various variables such as age, height, growth, and biomass (Oliver and Larson, 1990). But in recent years, those studies have focused on characteristics of components and the mutual interaction and relationships between them. The authors such as (Mou and Fahey, 1993) and (Reed and Burkhart, 1985) have utilized models considering the distribution of trees and their mutual interactions while determining the ecological issues such as regeneration, growth, and development of layers. The regeneration relationships in abies and beech's adult stands are explained through spatial pattern analysis. For this purpose, the spatial properties of beech-abies stands containing both old and young members have been determined by spatial statistic (e.g. Ripley's K function by Moeur (1993)), GIS and other land measurements. How the tree species are distributed among the stand in this period (e.g. randomly or in clusters) and whether the models are in accord with functions of species in terms of interaction between stand and species are some of the interested problems.

## MATERIALS AND METHODS

### Study Area

The study area was the Hasankadı Forest Sub-District Directorate located within Ulus Forest District in the Western Black Sea Region in Turkey. In Büyükdüz Meteorology Station at 1550m of altitude, which is the closest one to study area, the highest temperature over long years has been determined to be 31.5°C in August, while the minimum temperature has been determined to be -16°C in January. Mean monthly temperature is 6.08°C, while mean precipitation is 3.92 mm. The region has acid-reaction forest soil, where the limestone, clay, marn, schist, sandstone, conglomerate and flysh formations are seen (URL1, 2015). The research area has same properties with other mixed oriental beech (Kn)–Fir (G) stands located in Black Sea region. The range of oriental beech is located in east of common beech's range, and starts from Balkan Peninsula in south-east. This very large range continues to Western Anatolia through northern (Istranca Mountains) and southern (Tekirdağ) mountains of Trakya and Istanbul, then reaches to Caucasia and Crimea along with northern edge mountains. Oriental beech forms pure forests having large connections, as well as it mixes with fir, black pine, Scotch pine and various oak species in all Black Sea mountains. The oriental beech-fir mixed stands are located as "Moisture Forests" in Black Sea Mountains' slopes facing with sea. The mixed oriental beech-Uludağ fir stands show vertical distribution between altitudes of 500 and 2000m; they are generally located at higher points of Hasankadı Forest Sub-District Directorate at 700 -1400 m altitudes. Considering 3 planning periods ($1^{st}$ period: 1986-2000, $2^{nd}$ period: 2001-2010, $3^{rd}$ period: 2013-2022), an area increase has been observed in stands consisting of beech, Uludağ fir and mixture of other species (18.68%, 31.73%, 44.19%, respectively), while a decrease has been observed in pure beech stands (43.31%, 40.91%, 27.28%, respectively), and pure Uludağ fir stands which haven't existed in first 2 periods have arose in final one.

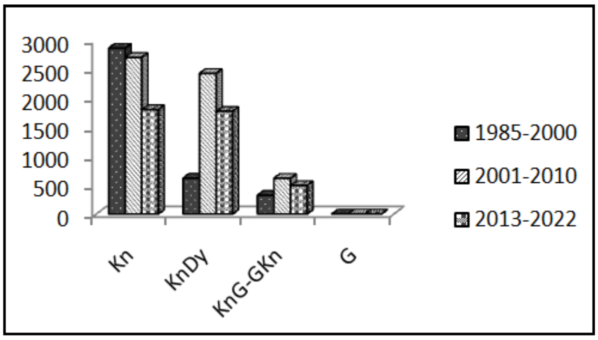



**Figure 1. The status of Kn, G and Kn-Gn, G-Kn stands during 3 plan periods**

### Sampling and Analysis

We have inspired from studies of (Dixon, 2002) and (Hofmaister *et al.,* 2008) for this study. In year 2013, two sample plots (SP) have been chosen for investigating the statuses of stand and its regeneration. Both of two sample plots have been chosen in the way they can represent the status of region's forests (50 x 50m). In collection of the data, the Pro mark 700 having cm-level sensitivity has been used during finding the spatial coordinates of trees. The measurements have been carried out for every tree having height higher than 0.1 m. Of the trees in sample plots, heights have been measured by hypsometer in 10 cm-sensitivity, diameters have been measured with digital compass in 1 mm sensitivity, and the top width have been measured by radial projection in 50 cm sensitivity. The samples have been grouped into 3 categories as seedling (height ≤ 0.8 m), sapling (height > 0.8) and trees (height > 1.8). In two sample plots, total of 794 seedlings, 62 saplings, and 534 trees have been measured (Table 1). The mean body diameter, mean stand height, dominant stand height (described as the mean height of the highest 100 trees per ha), stand density, volume and stand basal area (SBA) have been calculated with dendrometric methods by using volume and biomass tables. The top projection has been calculated by averaging the buffer zones via top width value. Ripley's K analysis with 1 and 2 variables have been utilized in order to test the individuals' spatial statuses in both of inter se and intra-category. Because Ripley's K analysis takes the distances between all body couples into account, it provides information in various scales (Diggle, 1983; Ripley, 1977). With Ripley K analysis, the matrix $\delta_{ij}$ of distances between all tree couples in sample plots is created and the deviations from randomization are calculated. K(d) is calculated with the formula written below;

$$K(d) = A \sum_{i=1}^{n} \sum_{i=1}^{n} \frac{\delta_{ij}(d)}{n^2} \quad \text{for } i \neq j \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Where; A indicates the area of sample plot having n trees, $\delta_{ij}$ indicates the distance between $i^{th}$ and $j^{th}$ trees (Diggle, 1993). Because K($d$) tends to decrease, by utilizing the corrections to linearize it, square root change L($d$) has been made(Ripley, 1977).

$$L(d) = \sqrt{\frac{K(d)}{n}} - d \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

**Table 1. Density of seedlings, saplings and trees in the SP's (N/ha)**

| Sample plot | Seedlings | | Saplings | | Trees | |
|---|---|---|---|---|---|---|
| | beech | fir | beech | fir | beech | fir |
| 1 | 174 | 348 | 5 | 14 | 54 | 128 |
| 2 | 86 | 186 | 26 | 17 | 330 | 52 |

**Table 2. Characteristics of the stand**

| Sample plot | Percentage in V | | | N (ha) | p | BA ($m^2$/ha) | V ($m^3$/ha) | *h* mean (m) | $h_{100}$ (m) | $d_{1.3}$ mean (cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | beech (%) | fir (%) | others (%) | | | | | | | |
| 1 | 69.1 | 24.7 | 6.2 | 1101 | 1.0 | 29.9 | 299.5 | 10.7 | 27.7 | 12.5 |
| 2 | 72.5 | 25.3 | 3.2 | 1287 | 1.1 | 37.8 | 312.0 | 14.7 | 26.1 | 20.1 |

N- number of trees ($d_{1.3}$ above 3.0 cm), BA- basal area, V-volume, $d_{1.3}$- diameter at breast height, *h*- height, $h_{100}$- height of the 100 highest trees per ha, p- stand density

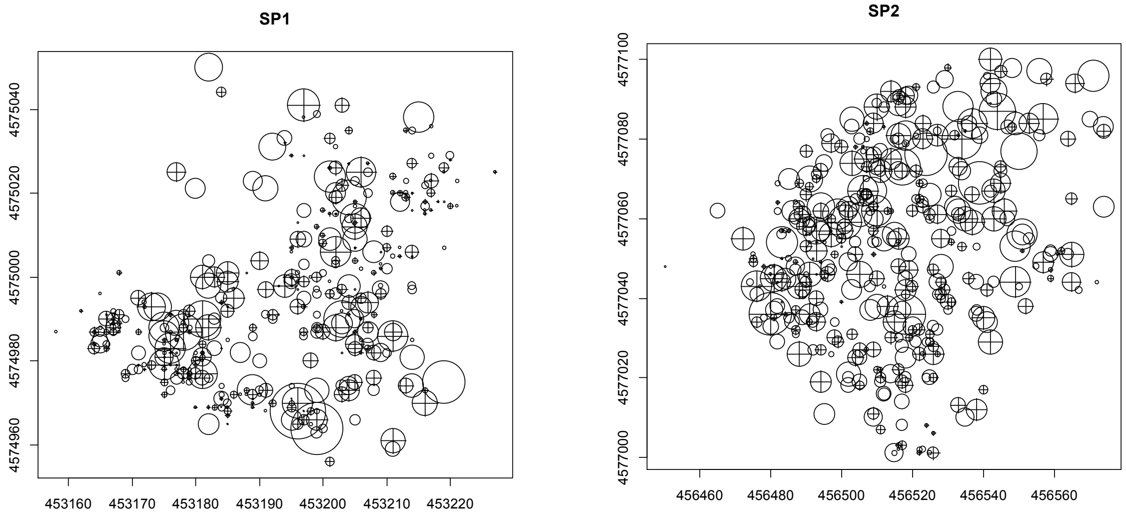



**Figure 2. The spatial distribution of oriental beech and Uludağ fir trees in sample plot 1 and 2 based on the tree diameters (in a and b regions, respectively)**

L(*d*) linearizing K(*d*) and balancing its variance is expected to be near to zero in Poisson assumption. Monte Carlo methods simulates the K(*d*) function values expected from randomly distributed point groups in desired significance level (P<0.05) in order to compare them with randomly created points in similar sizes (Hançerlioğulları, 2006). If the calculated K(*d*) function value is higher, equal or less than 95% of confidence level, the spatial pattern can be described as regular, random or generic (in single-variable models) in any d distance, respectively (Grassi *et al.,* 2004). In complete randomness position, the derived L(*d*) function equals to zero (Horak, 2002). In multi-variable models, the independent variables hypothesis has been taken into account in calculations based on similar relationships. If L(*d*)=0 applies to components, the components are spatially independent from each other in multi-variable models. If the L(*d*) is positive or negative, then there is a positive or negative relationship in *d* distance (Simulauer, 2007). The maximum distance and minimum space have been accepted to be 25m and 0.5m, respectively. K-function have been utilized in spatial analysis of plant communities by many authors such as (Hofmaister *et al.,* 2008; Klimas *et al.,* 2007; Nagel *et al.,* 2006; Wolf 2005).

$$\delta_{ij}(d) \quad \begin{matrix} 1 & \text{if } d_{ij} \leq \text{d} \\ 0 & \text{if } d_{ij} > \text{d} \end{matrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The distributions of all of the trees have been assessed by using single-variable method. The species showing poor distribution in sample plot have not been included in analysis. The regeneration of stand has been individually analyzed based on the species. Besides the individual effects of both of two species on regeneration, the double-variable model has also been utilized in analysis of together-effect of oriental beech and Uludağ fir trees on regeneration. For all conditions, the regenerations have been provided based on species individually. In a stand containing all of the grown trees, we can determine whether the natural regeneration is related with spatial pattern (Hofmaister *et al.,* 2008). So it can be possible to determine whether the regeneration occurs around the canopy of trees or in stand gaps. The segregation based on species can reveal the distribution of juvenilities in those species. The distribution of beeches and firs in SP1 and SP2 involved in analyses is given in Table 1 as seedling, sapling and tree.

## RESULTS AND DISCUSSION

In Table 2, there are the calculated dendrometric data. High stand density, volume and stand basal area are seen in SP2. Although the stand height characteristic of SP2 is also higher than SP1, it is lower when considering the 100 highest trees.

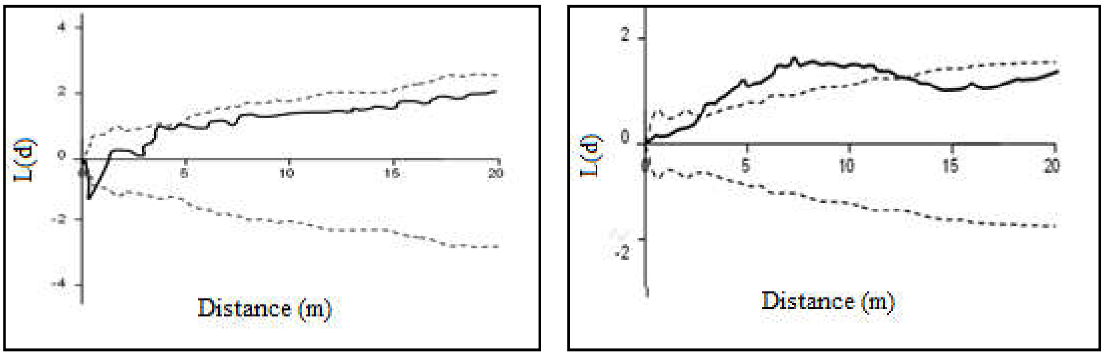
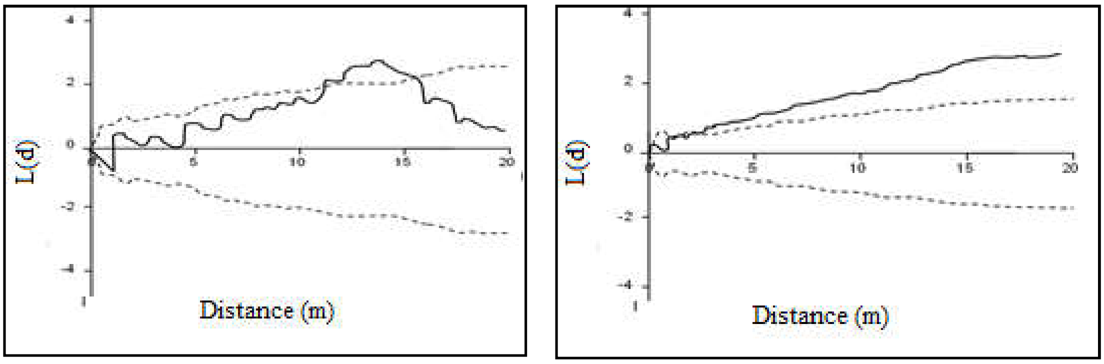
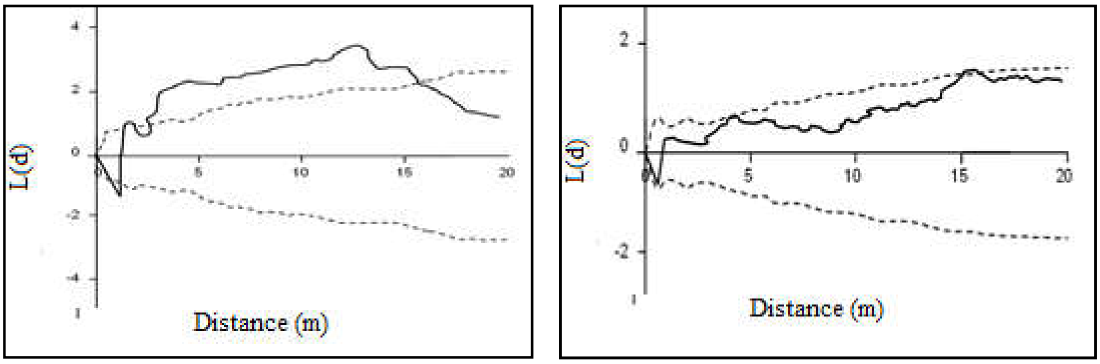



**Figure 3. L(d) function of all of the trees in SP1 (a) and SP2'de**




**(a)**




**(a)**

**Figure 4. L(d) functions of oriental beech (a) and Uludağ fir (b) trees in SP1 and oriental beech (c) and Uludağ fir (d) trees in SPE2**

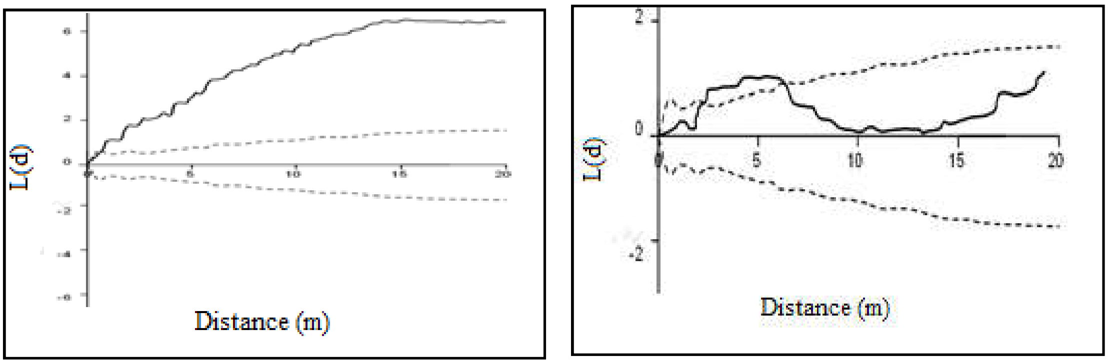
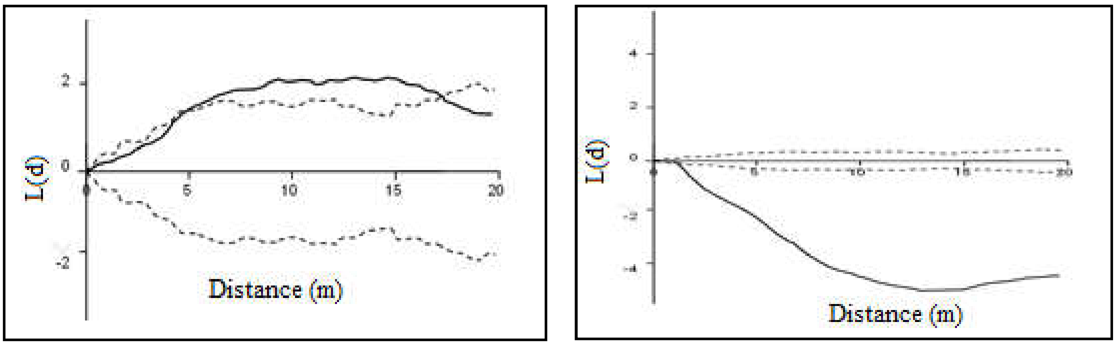



**Figure 5. L(d) function of oriental beech and Uludağ fir seedlings in SP1**

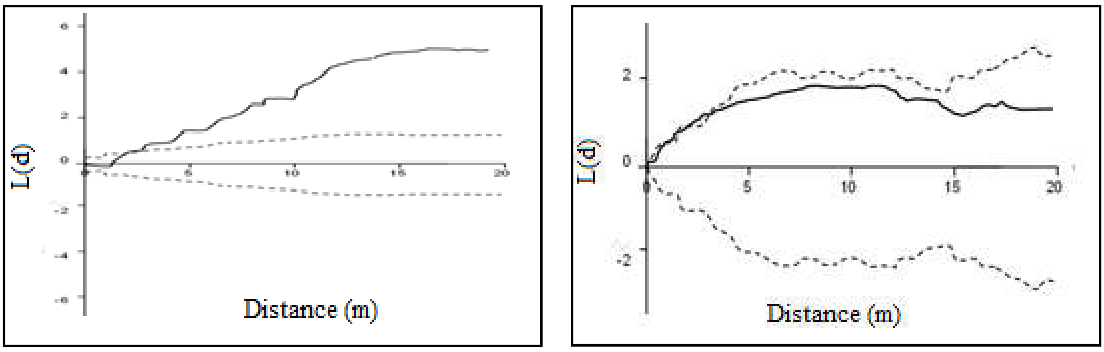
Both of two stands have reached the optimal position in terms of closure, they will be able to produce large diameters in future. While the numeral superiorities of abies trees and abies seedlings in SP1, the number of abies seedlings in SP2 is higher despite of numeral superiority of beech trees.

In Figure 2, there is the top view of the trees in relation with their diameters. In Figure 3, the assessment of all of the trees in both of two sample plots in 95% confidence level is given with Monte Carlo simulation. All of the trees up to 1m in SP1 are pushing each other and tend to show regular distribution

(Figure 3a). But in SP2, all of the trees between 2 and 12 m are in tendency of strong grouping; the maximum value has been obtained at 7 m. Oriental beech trees show the grouping tendency in both of SP1 and SP2 (Figure 4a, c). While grouping is between 11 and 16 m in SP1 (maximum is at 14 m), it is between 3 and 16 m in SP2 (maximum is at 12. m). In SP1, the Uludağ fir trees show strong grouping tendency from 3 m to 20 m at 95% statistical confidence level, while the maximum point is at 17 m (Fig. 4b). In SP2, Uludağ fir trees show grouping tendency not as strong as in SP1 (Fig. 4c). Grassi (2004) and Paluch (2006) have mentioned about that fir can regenerate in groups. and that the grouping occurs in SP2 from short distances. Also, when considering the grown trees, it is seen that the number of adult Uludağ fir trees in SP1 and the number of adult oriental beech trees in SP2 are dominant. It is known that the Uludağ fir specie is regenerated first in mixtures (Szymura, 2005) and they can survive even under strong shadow (Paluch, 2005). Therefore, the low-light areas which do not provide a satisfactory growth performance for common beech are ideal places for fir (Stancioiu and O'hara, 2005). Although it has been stated by Hunziker and Brang (2005) that the fir regeneration occurs in gaps, the oriental beech regeneration has been observed in gaps in this study.




**(a)**




**(b)**

**Figure 6. The L(d) function of oriental beech trees and Uludağ fir seedlings (a), Uludağ fir trees and oriental beech seedlings (b), oriental beech trees and seedlings (c), and Uludağ fir trees and seedlings (d) in SP1**

While the beech seedlings in SP1 have strong conglomeration structure in 0-20 m range at 95% confidence level, the maximum distance is 15 m (Figure 5a). But the abies seedlings in SP1 show conglomeration between 2 and 6 meters, while the maximum value is reached at 5$^{th}$ meter (Figure 5b). While the numbers of beech and abies saplings in both of two sample plots are low, they show random distribution. The oriental beech trees between 5 and 17.5 m having the maximum at 9 m have positive relationship with Uludağ fir seedlings. The Uludağ fir trees and oriental beech seedlings have negative relationship at 0-25 m distance (Fig.6b). While the oriental beech trees positively group with oriental beech seedlings at 2.5-20 m distance, the maximum value is at 17$^{th}$ m (Figure 6c). While Uludağ fir trees and Uludağ fir seedlings show grouping tendency between 2$^{nd}$ and 4$^{th}$ m, they show regular distribution p to 20 m (Figure 6d). Considering the growth of individuals, which have successfully germinated, in first years, it is understood that the success of regeneration is closely related wit grown trees. It is thought that the previous interventions in study area are related with that trees in SP1 push each other

Kadlus (1969) states that especially the closure has influence on regeneration of spruce, fir and common beech. The regeneration of the species under adult trees of the same species, so the push of tree species each other is expected. While this natural regeneration applies to fir in short and long distances, it is observed that the juvenilities of oriental beech trees is under grown oriental beech trees between 0 and 2 meters and Uludağ fir juvenilities is more dominant in longer distances. As well as Uludağ fir could place to better regenerate under oriental beech, it has been explained in some studies (Hladik *et al.,* 1993) that specie may find a place to better grow under other species. Kuuluvaienen *et al.* (1996) have stated that the mixture of trees smaller than 15 m has heterogeneous structure, while longer trees constitute more regular groups. It has been stated by Hofmaister *et al.* (2008) that this relationship is related with soil and mold structure rather than light. Although beech has advantage against fir in mediums facing with light (Stancioiu and O'hara, 2005) the higher regeneration density of Uludağ fir under grown oriental beeches can be explained with that Uludağ fir find there a better place to grow. The protection of Uludağ fir from winds and frost in those regions is one of the possible reasons. Similar with impossibility of survival of oriental beech in extremely shadowed regions, the regeneration of beech has negative relationship with abies trees in 1.5-20 m distances. It has been explained by Akhavan *et al*. (2012) that positional dependency in adult beech stands varies between 14 and 24 m. In both of experiment fields, the trees are covered by open areas in different densities. In Black Sea and Marmara regions, which are suitable for such stands, mentioned situation can be observed especially when there are frost drought damages (URL2, 2015). As expected, abies seedlings can exist under adult abies trees allowing the certain level of distributed light (Hunziker and Brang, 2005) as well as they exist under adult oriental beech trees, but the juvenilities of oriental beech under only grown beech trees. The next problem is whether the oriental beeches requiring a certain minimal light level in further growth will be able to sustain their growth under closed Uludağ fir stand.

**Conclusion**

In order to ensure the continuity of mixture of oriental beech and Uludağ fir species in forests of the region, it is required to have knowledge about the dynamics of oriental beech and Uludağ fir population as much as possible. Despite of the effects of oriental beech trees on spatial regeneration of Uludağ fir, it is seen that the regeneration of oriental beech is related with Uludağ fir trees. Considering the progress in 3 periods, it can be seen that the importance of future regeneration of oriental beech in sustaining the continuity of mixed stands has increased.

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