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Original Article

The effect of climate on the radial growth of Oriental Beech in the Southern limit of its distribution area

Doğu Kayınının yayılışının Güney sınırında iklimin çap artımı üzerine etkisi

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ABSTRACT

This study was carried out to construct a site chronology of oriental beech in Topaktas site of the Amanos Mountains, one of the most southerly populations of oriental beech, and to investigate the relationships between tree-ring width and some climate variables such as the monthly maximum, minimum and mean temperature and monthly total precipitation. The study area was located in Topaktaş Plateau, Dörtyol, Hatay, where isolated natural populations, known as the most southerly populations of the species, exist. The average slope was 35%, the aspect was north-west, and the altitude ranged from 1300 to 1500 meter (m). 33 samples are collected by using increment borers and taken from 17 oriental beech trees in the study site, and 53-year-long treering chronology were built for the period of 1961-2013. Pearson correlation coefficients were used to investigate relationships between radial growth and climate. The radial growth of oriental beech in the site was found to be sensitive to climate with mean sensitivity value of 0.20. The results showed that high precipitation in June leads to produce wider rings ($r=0.39$, $p<0.01$), while maximum temperature in the same month has a negative significant effect on radial growth ($r=-0.32$, $p<0.05$). On the other hand, high precipitation in February and March decrease ring width of oriental beach ($r=-0.30$, $p<0.05$).

Keywords: *Fagus orientalis* Lipsky, dendroecology, tree-rings, climate

ÖZ

Bu çalışma, doğu kayınının en güneydeki popülasyonlarından biri olan Amanos Dağları'nın Topaktaş yöresinde türe ait bir yöre kronolojisi oluşturmak ve yıllık halka genişliği ile aylık maksimum, minimum, ortalama sıcaklık ve aylık toplam yağış gibi bazı iklim değişkenleri arasındaki ilişkileri ortaya koymak amacıyla yapılmıştır. Çalışma alanı, türün en güney popülasyonu olarak bilinen izole doğal popülasyonların bulunduğu Topaktaş Yaylası, Dörtyol, Hatay'da bulunmaktadır. Ortalama eğim %35, bakısı kuzey batı ve rakımı 1300 - 1500 metre (m) arasındadır. Çalışma alanındaki 17 doğu kayınından artım burgusuyla 33 örnek alınıp halka genişlikleri ölçülmüş ve 1961-2013 dönemini kapsayan 53 yıl uzunluğunda yıllık halka kronolojisi elde edilmiştir. Sahadaki doğu kayınlarının radyal büyümesinin iklime olan duyarlılığı 0.20 olarak hesaplanmıştır. Radyal büyüme ve iklim arasındaki ilişkileri araştırmak için Pearson korelasyon katsayıları kullanılmıştır. Sonuçlar, haziran ayındaki ortalamanın üzerindeki yağışların daha geniş halka oluşumuna yol açtığını gösterirken ($r=0,39$, $p<0,01$), aynı aydaki yüksek maksimum sıcaklığın çap artımı üzerinde olumsuz bir etkisi olduğu belirlenmiştir ($r=-0,32$, $p<0,05$). Diğer yandan, şubat ve mart aylarındaki yüksek yağışların, Amanos Dağları'nın Topaktaş mevkiinde, doğu kayınının halka genişliğini azalttığı görülmüştür ($r=-0,30$, $p<0,05$).

Anahtar Kelimeler: *Fagus orientalis* Lipsky, dendroekoloji, ağaç halkası, iklim

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INTRODUCTION

Fagus orientalis Lipsky (oriental beech) belongs to the family *Fagaceae*. The genus *Fagus* L. includes 12-different species distributed in temperate areas of the northern hemisphere (Catalogue of Life, 2019). Two of them, oriental beech and European beech (*Fagus sylvatica* L.) occur in Turkish flora, and compared to the other species, first one has a common distribution in Turkey (Yılmaz, 2018). Oriental beech is natively distributed from the Balkans in the west, through Anatolia, to the Caucasus, Crimea, and northern Iran (Kandemir and Kaya, 2009). In its distribution in

Turkey, this species is common in Northern Turkey and scattered in Western and Southern Anatolia (Yaltırık, 1982; Yılmaz, 2018). The isolated relict populations of the species occur on the Amanos Mountains in the Eastern Mediterranean Region (Figure 1). These populations are known as the most southerly populations of oriental beech (Kandemir and Kaya, 2009). The altitudinal distribution of the species changes from 30 m up to 2100 m, however its optimal altitudinal range is between 700 m and 1300 m (Kandemir and Kaya, 2009; Yaltırık, 1982; Yılmaz, 2018). Oriental beech forms both pure stands and mixed forests with conifers such as *Abies nordmanniana* (Steven) Spach, *Pinus nigra* J.F.Arnold, *Pinus sylvestris* L. and *Picea orientalis* (L.) Peterm. and other deciduous broadleaf species such as *Quercus* L. sp., *Castanea sativa* Mill., *Carpinus betulus* L. and *Carpinus orientalis* Mill.. The broadleaved species covers almost 2 million ha of forest area, making it the fourth most abundant forest tree species in Turkey (OGM, 2015).

In Turkey, many researches have been carried out on climate-tree ring relationships. However, these studies generally focused on the Gymnospermae species such as *Pinus nigra* Arnold (Touchan et al., 2003, 2005a; Akkemik & Aras, 2005; Sevgi & Akkemik, 2007; Akkemik et al., 2008; Köse et al., 2011, 2012, 2013, 2017; Janssen et al., 2018), *Pinus pinea* L. (Akkemik, 2000a; Martin-Benitto et al., 2016), *Pinus sylvestris* (Touchan et al., 2005a; Akkemik et al., 2008; Martin-Benitto et al., 2016), *Pinus brutia* Ten. (Touchan et al., 2003, 2005a), *Abies nordmanniana* (Köse, 2012; Touchan et al., 2005a; Martin-Benitto et al., 2018), *Abies cilicica* (Antoine & Kotschy) Carrière (Akkemik, 2000b), *Cedrus libani* A. Rich. (Akkemik, 2003; Touchan et al., 2003, 2005a), *Picea orientalis* (Özkan, 1999; Martin-Benitto et al., 2016, 2018) and *Juniperus* L. sp. (Touchan et al., 2003, 2005a, b, 2007; Kahveci et al., 2018). The dendroclimatological studies using the Angiospermae species are relatively few in Turkey, and the studies mostly focused on *Quercus petraea* (Matt.) Liebl. (Akkemik et al., 2005; Wazny et al., 2014; Martin-Benitto et al., 2016), *Quercus frainetto* Ten. (Wazny et al., 2014), *Quercus cerris* L. (Wazny et al., 2014) and *Fagus orientalis* (Akkemik & Demir, 2003; Köse & Güner, 2012; Martin-Benitto et al., 2018) in different ecological sites.

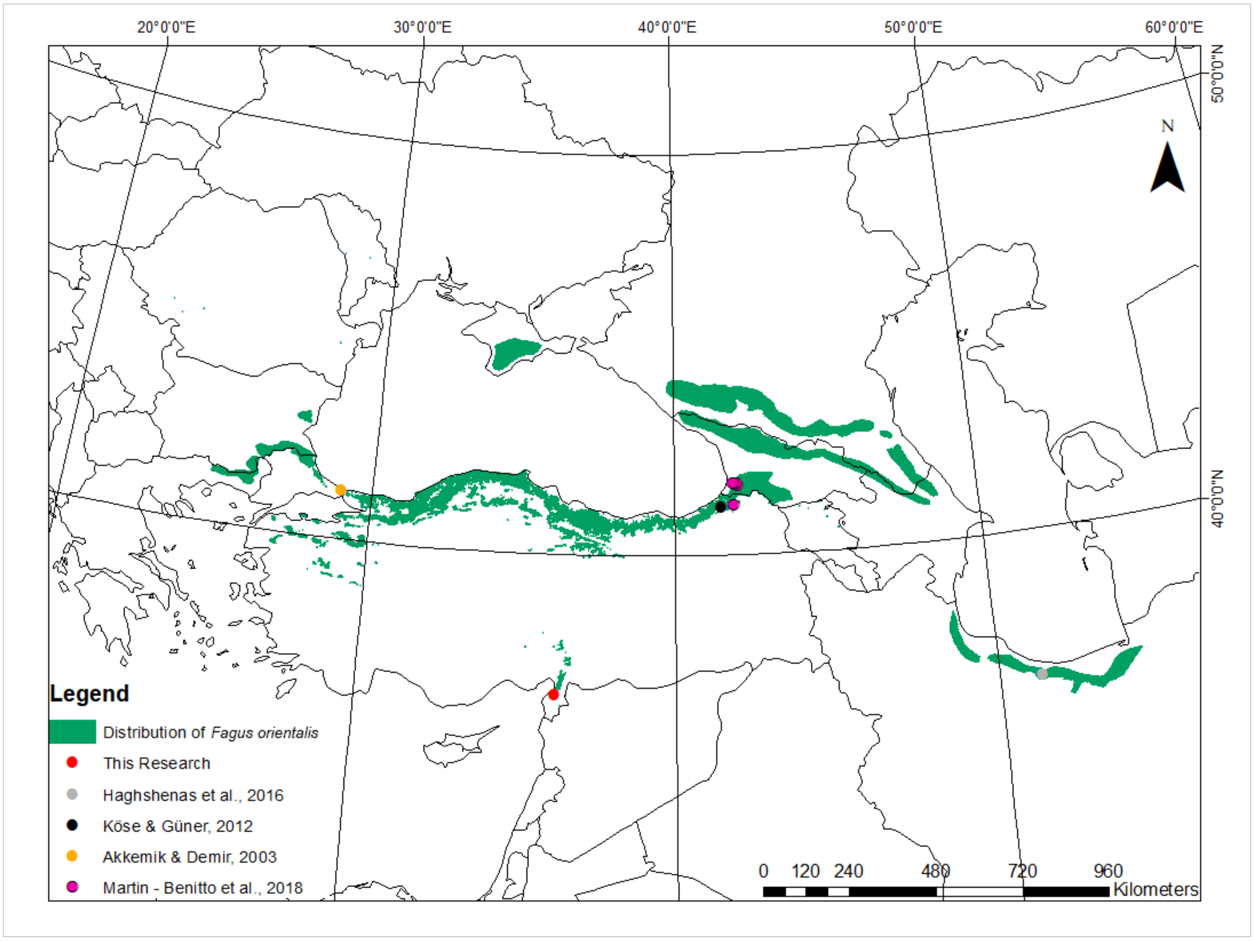

Figure 1. Site information. Green area represents natural distribution of *F. orientalis*, which obtained by merging the distribution data obtained from European Forest Genetic Resources Program (EUFORGEN, 2017) and from forest management plans of General Directorate of Forestry. Red dot represents the sampled site of this research; pink, black, yellow and purple dots show *F. orientalis* sites sampled by previous researches (by Martin-Benitto et al., 2018; Köse & Güner, 2012; Akkemik & Demir, 2003; Haghshenas et al., 2016 respectively)

The effects of climatic factors on oriental beech was studied in different ecological sites in its natural distribution area, which are Belgrad Forest in the northwestern part of Turkey (Akkemik and Demir, 2003), the temperate forests of the Caucasus region including northeastern Part of Turkey and Georgia (Köse and Güner, 2012; Martin Benitto et al., 2018) and Caspian forests of northern Iran (Haghshenas et al., 2016) (Figure 1). However, there is a gap on the information of the most southerly populations of oriental beech in Turkey. More chronologies from different habitats are needed to understand the relationship between radial growth and climate, therefore, a 53-year long (1961-2013) chronology was built by using 33 increment cores from 17 trees in the most southerly population of oriental beech in Turkey. In addition, we identified the most important climate factors affecting the radial growth of oriental beech growing in Southern Turkey, and compare our results with the previous oriental beech chronologies. The aim of the study is to build a site chronology for oriental beech in its southern limit and to understand climate-growth relationship.

Table 1. Some characteristics of the study area

Site Code	TRAMFAOR
Latitude	36°49'16"N
Longitude	36°20'11"E
Altitude (m)	1350-1500
Aspect	North-west
Slope (%)	35
Canopy (%)	70-80
Climate Type	Humid according to Emberger's bioclimatic diagram (Akman, 2011).
Geological Age	Lower to Upper Paleozoic (Kehl, 2018)
Bedrock	Quartzite, sandstones and siltstones (Kehl, 2018)
Soil Type	Haplic alisols (Kehl, 2018). Alisols have been found on slopes that are exposed to frequent rain bearing winds and wetter climate conditions in Mediterranean areas (FAO, 2019).
Main Tree Species	*Fagus orientalis, Pinus nigra, Quercus cerris*

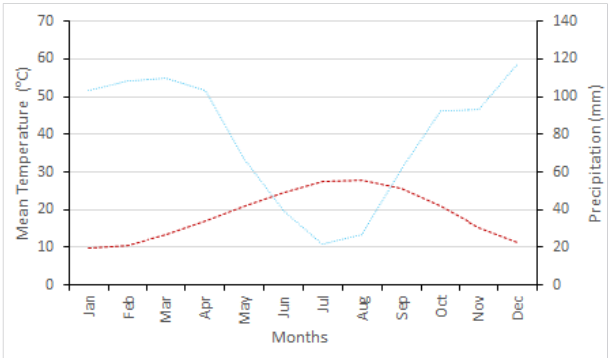

Figure 2. Ombrothermic diagram of Dörtyol Meteorological Station, Hatay. Blue dashed line represents monthly total precipitation and red dashed line represents mean monthly temperature values (1960-2010)

MATERIALS AND METHODS

Study Area

The study area was located in Topaktaş Plateau, Dörtyol, Hatay (36°49'16" N, 36°20'11"E) (Figure 1). Here, the average slope was 35%, the aspect was north-west, and the altitude ranged from 1300 to 1500 m. Oriental beech was dominant tree species in the study area; however, black pine (*Pinus nigra*) and Turkish oak (*Quercus cerris*) were also present in the stand composition (Table 1). The total annual precipitation and mean temperature (1960-2010) from the Dörtyol meteorological station (36° 51' 21" N, 36° 13' 20" E), which was the closest to the study area, was 944.3 millimetre (mm) and 18.8 °C, respectively. However, the study area was higher in elevation than the Dörtyol meteorological station (28 m), and was under the influence of cloudbank formations damming up due to the north-south stretching Amanos mountain range, and of the moist rich winds on especially the westerly exposed slopes (Kehl, 2018). Thus, higher precipitation and lower temperature were expected in the study area. The lowest precipitation value was in July (21.9 mm) and in August (26.8 mm) during the year. Additionally, the highest mean temperature observed in the same months with 31.1°C and 32°C, respectively. Ombrothermic diagram of Dörtyol was shown in Figure 2.

Chronology Development

Thirty-three increment cores were taken from 17 living oriental beech trees using Haglöf Sweden increment borer with 300 mm in length, 5.15 mm in core diameter. To make the core surface clear, transverse sections were sanded using progressively finer grit sandpaper (Orvis and Grissino-Mayer, 2002). The mean age of the sampled beech stand is 60, however, the first 10-tree rings after the pith is removed from analysis due to their juvenile properties in terms of ontogenetic ageing. Therefore, we avoided to measure juvenile wood rings near the pith because of the differences in their characteristics from adult wood. Samples were cross-dated by standard dendrochronological techniques (Swetnam, 1985; Stokes and Smiley, 1996). The measurements of the tree-ring width were completed by using PAST4LT measurement system with 0.01 mm accuracy. COFECHA software was used to evaluate the quality of cross-dating (Holmes, 1983; Grissino-Mayer, 2001). Cross-dating verification was performed by COFECHA software (Holmes, 1983; Grissino-Mayer, 2001). Linear or negative exponential regression equations were applied for standardization of the measurement series. To build the mean chronology, bi-weight robust mean values were used. For the standardization and building mean chronology, ARSTAN software was used. (Cook, 1985; Grissino-Mayer et al., 1996). This process removes the non-climatic trends such as the age-size related trends, and the stand dynamic disturbances (Fritts, 1976; Cook et al., 1990). To explore climate-radial growth relationships, residual chronologies were used, which remove autocorrelation and keep a robust climate signal.

Growth-climate relationship analysis

The monthly mean, maximum, and minimum temperature and monthly total precipitation values of Dörtyol Meteorological Station, the closest meteorological station to the study field, were taken for the chronology time span 1961 to 2013. However, due to lack of some values belonging to the last three years, the climate data belonging to the period of 1961-2010 were used. To assess climate-radial growth relationships for the duration of the biological year (from October of the previous year to September of the current year), we used Pearson correlation coefficients based on the outputs of DENDROCLIM 2002 (Biondi and Waikul, 2004).

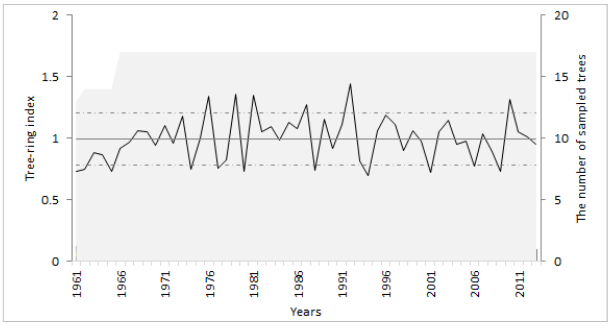

Figure 3. Residual chronology of oriental beech

RESULTS

Chronology characteristics

In this study, we could build 53-year-long (1961-2013) chronology for oriental beech trees in Amanos Mountain, because the trees were quite young in the area (Figure 3).

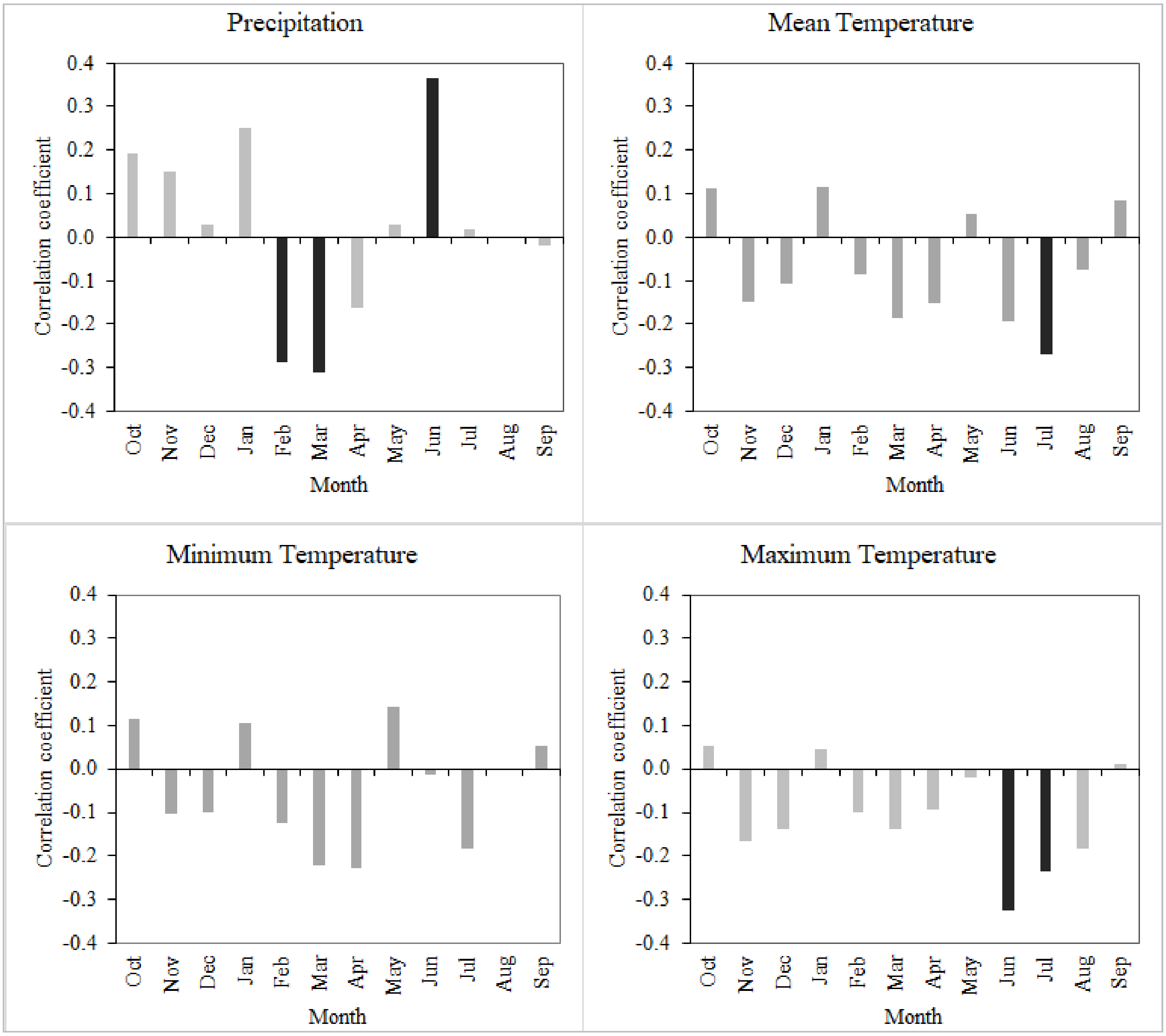

Figure 4. Correlation coefficients between the residual chronology and monthly total precipitation and monthly mean, minimum and maximum temperatures respectively. Black bars represent significant coefficients (p<0.05) with the related month

Mean sensitivity value of the chronology was 0.20. Common interval analysis showed the following mean correlations respectively: 0.39 among all radii, 0.38 between trees, 0.65 within trees and 0.62 for radii vs mean. Signal-to-noise ratio was 9.79 and the variance explained by the first eigenvector of the chronology was 41.9%.

Growth-climate relationship

Correlation coefficients between the chronology (ring widths) and climate variables (monthly mean, maximum and minimum temperature and monthly total precipitation) are shown in Figure 4. In terms of the effect of precipitation on the radial growth, correlation coefficient was significantly positive in June of the current year ($p<0.05$), however it was significantly negative in February and March of the current year ($p<0.05$). The effect of precipitation was very weak for all of the other months. With regard to the temperatures, in addition to the negative effect of mean temperature in July of the current year ($p<0.05$), maximum temperatures also showed significant negative effect on the radial growth in both June and July of current year ($p<0.05$). However, any significant correlation did not appear on the effect of minimum temperatures to the radial growth (Figure 4).

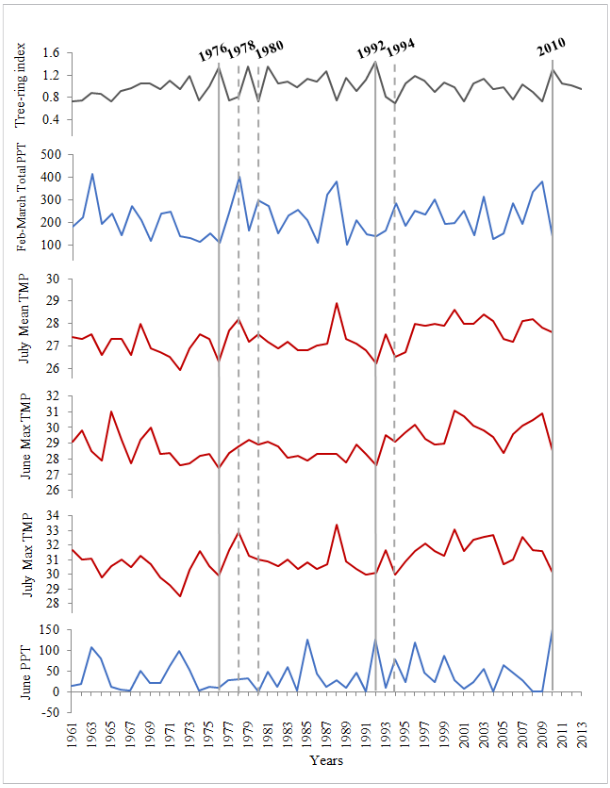

Figure 5. Residual chronology against to the limiting factors on radial growth of oriental beach, which are February-March total precipitation, July mean temperature, June and July maximum temperatures, and June precipitation, respectively. Vertical dashed lines show extreme negative years, and solid lines show extreme positive years

In summary, high precipitation in June leads to produce larger ring, while high precipitation in February-March, and high mean temperature in July and high maximum temperature in June-July causes narrow ring formation. For better understanding the collective effect of temperature and precipitation on radial growth, we illustrated residual chronology against to the months which has significant correlations, for the period of 1961-2010 (Figure 5).

For instance, in 1992 and 2010, a large annual ring formation was observed due to the positive effect of high June and low February- March precipitation and low temperatures in June and July. On the contrary, in 1976, another large ring formation year, June precipitation having positive effect on radial growth was very low. In this year, the reason for large ring formation was low temperatures during June and July, which reduce drought effects besides low precipitation during the February and March. One of the years observed narrow rings was 1980 in which the effect of very low June precipitation was dominant.

DISCUSSION and CONCLUSION

In the present study, we formed 53-year-long oriental beech chronology for the Eastern Mediterranean Region of Turkey. Even though it is quite short chronology (1961-2013), it gives valuable and comparable information for the most important climate factors affecting the radial growth of oriental beech in its Southern distribution. The most comprehensive sampling of oriental beach was performed in the Caucasus by Martin-Benitto et al. (2018). They emphasize a distinct climate response between the trees from higher and lower elevations. The effect of May, June or July temperatures at the sites just below the current tree-line was positive, while warmer springs cause drought in sites located in lower elevation. Köse and Güner (2012), who collected their samples from the northeastern distribution and upper vertical limit (1830 to 2118 m above sea level (a.s.l)) of oriental beech in Turkey, showed that precipitation was a limiting factor on tree growth, but only in June. Moreover, high temperatures had a positive effect during the period of March to July and did not cause a drought problem. The positive effect of precipitation in June was evident in our study too. On the contrary to high elevation sites in the Caucasus, our research showed that summer temperatures caused drought in the southern distribution limit of the species.

Akkemik and Demir (2003) showed that the effect of precipitation on the radial growth of oriental beech from Northwestern Turkey was generally positive, and the coefficient was significant in February. In their study, it was observed that the high temperatures occurring in May and June caused the soil drought and also the decrease in ring width, and on the other hand, especially the high temperatures in March at the beginning of the vegetation period caused an increase. In their study, increment cores were collected from lower elevational areas of the species (110 m). Therefore, drought effects, which were represented by positive coefficient associated with precipitation during almost the whole biological year and negative coefficient associated with temperature in May-June, were distinctive on the radial growth of the trees at this site. Temperatures during all seasons had significantly positive effect in Caspian forests (Haghshenas et al., 2016).

Compared with the previously built oriental beech chronologies, the radial growth of the species in Southern Turkey showed a different response to climate. This is because the oriental beech trees are under different climate conditions on the Amanos Mountains. In this site, while June precipitation has positive effect on the radial growth of oriental beech, February-March precipitation and June-July maximum temperature has negative effect. Based on ombrothermic diagram of the closest meteorological station (Dörtyol) to the site, it can be seen that there is a dry period continuing from the beginning of June to the beginning of September (Figure 2). However, in the western slopes of the Amanos Mountains above Dörtyol, there are typical humid altitudinal belts because of frequent cloudbank formations blocked by the north-south stretching mountain range (Kehl, 2018). Kehl (2018) measured the following yearly precipitations in different altitudes above Dörtyol during his project period: 1300 mm in 500 m a.s.l, 2300 mm in 950 m a.s.l., 1800 mm in 1600 m a.s.l, and 1300 mm 2100 m a.s.l. Here, very high precipitation value in 950 m a.s.l and altitudinal trend of precipitation is quite remarkable for the eastern Mediterranean Region of Turkey. These precipitation values can help elucidate why oriental beech and many other Euro-Siberian species are native to these belts of Amanos Mountains. In the present study, we collected the samples from the altitudinal range between 1300 and 1500 m above Dörtyol. It can be explained that high February-March precipitation in the site causes a delay of the beginning of growth period and therefore a result of narrower tree-rings of oriental beech. In these months, high snow pack may delay beginning of vegetation period, because of decreasing soil temperatures (Thomsen, 2001). In addition, June-July maximum temperature also causes narrower tree-rings due to droughts in the two months, but in the years having high June precipitation, they are wider. Haghshenas et al. (2016) reported that air temperature is a key parameter affecting the growth of oriental beech trees in the Caspian forest region having temperate climate. In their study, while precipitation had no significant effect on ring-width of beech trees except for the month of March, temperature in the month of August was highly positive correlated with ring-width. In our study, the negative influence of February-March precipitation and June-July maximum temperature indicated that different climate dynamics in Amanos Mountains have been functioned on the growth of oriental beech unlike the Western and Eastern Black Sea Region of Turkey and the Caspian forest region of Iran (Akkemik and Demir, 2003; Köse and Güner, 2012; Martin-Benitto et al., 2018; Haghshenas et al., 2016). More studies are needed to understand the response of oriental beech growth to the climate within its full ecological range in the Amanos Mountains. To achieve this, local temperature and precipitation measurements are needed in the oriental beech habitats of Amanos Mountains having first increasing then decreasing precipitation trend from 500 to 2100 m a.s.l (Kehl, 2018). It is crucial to understand the particular local climate of vulnerable oriental beech habitats in the Eastern Mediterranean Region due to global warming and climate change.

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REFERENCES

- Akkemik, Ü., 2000a. Dendroclimatology of umbrella pine (*Pinus pinea* L.) in Istanbul, Turkey. *Tree-Ring Bulletin* 56: 17-20.
- Akkemik, Ü., 2000b. Tree-ring chronology of *Abies cilicica* Carr. in the Western Mediterranean Region of Turkey and its response to climate. *Dendrochronologia* 18: 73-81.
- Akkemik, Ü., Demir D., 2003. Tree ring analysis on eastern beech (*Fagus orientalis* Lipsky.) in the Belgrad Forest. *Forestist* 53: 33-36.
- Akkemik, Ü., Aras A., 2005. Reconstruction (1689-1994) of April–August precipitation in southwestern part of central Turkey. *International Journal of Climatology* 25: 537-548. **[CrossRef]**
- Akkemik, Ü., Dağdeviren, N., Aras, A., 2005. A preliminary reconstruction (A.D. 1635–2000) of spring precipitation using oak tree rings in the west. *International Journal of Biometeorology* 49(5): 297-302. **[CrossRef]**
- Akkemik, Ü, D'Arrigo, R, Cherubini, P, Köse, N, Jacoby, G., 2008. Tree-ring reconstructions of precipitation and streamflow for north-western Turkey. *International Journal of Climatology* 28: 173-183. **[CrossRef]**
- Akman, Y. 2011. İklim ve Biyoiklim. Palme Yayıncılık, Ankara.
- Biondi, F, Waikul K., 2004. DENDROCLIM2002: A C++ program for statistical calibration of climate signals in tree-ring chronologies. *Computers & Geosciences* 30(3): 303-311. **[CrossRef]**
- Catalogue of Life. (2019). Retrieved 27 December 2019, from https://www.catalogueoflife.org/
- Cook, E., 1985. A time series analysis approach to tree-ring standardization. PhD Thesis. University of Arizona, Tucson, AZ, USA.
- Cook, E., Briffa, K., Shiyatov, S., Mazepa V,. 1990. Tree-ring standardization and growth-trend estimation. In: Methods of Dendrochronology: Applications in the Environmental Sciences; Cook E, Kairiukstis LA (Eds), Kluwer Academic Publishers, Boston. pp. 104-122.
- EUFORGEN., 2017. European Forest Genetic Resources Program, http://www.euforgen.org/species /fagus-orientalis/. [11 October 2017].
- FAO, 2019. Lecture Notes on the Major Soils of the World. Edited by: Paul Driessen, Wageningen Agricultural University, International Institute for Aerospace Survey and Earth Sciences (ITC), Jozef Deckers, Catholic University of Leuven Otto Spaargaren, International Soil Ref-

erence and Information Centre Freddy Nachtergaele, http://www.fao.org/3/y1899e/y1899e08a.htm [26 December 2019].

- Fritts, H. C., 1976. Tree Rings and Climate. Academic Press, New York.
- Grissino-Mayer, H.D., Holmes, R.L., Fritts H. C., 1996. The International Tree-Ring Data Bank Program Library Version 2.0 User's Manual, Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona.
- Grissino-Mayer, H. D., 2001. Evaluating crossdating accuracy: a manual and tutorial for the computer program COFECHA. *Tree-Ring Research* 57: 205-221.
- Haghshenas, M., Mohadjer, M.R.M., Attarod, P., Pourtahmasi, K., Feldhaus, J., Sadeghi, S. M.M., 2016. Climate effect on tree-ring widths of *Fagus orientalis* in the Caspian forest northern Iran. *Forest Science and Technology* 12(4): 176-182. **[CrossRef]**
- Holmes, R. L., 1983. Computer-assisted quality control in tree-ring data and measurement. *Tree-ring Bulletin* 43: 69-78.
- Janssen, E., Kint, V., Bontemps, J.D., Özkan, K., Mert, A., Köse, N., İçel, B., Muys, B., 2018. Recent growth trends of black pine (*Pinus nigra* J.F. Arnold) in the eastern Mediterranean. *Forest Ecology and Management* 412: 21-28. **[CrossRef]**
- Kandemir. G., Kaya, Z., 2009. EUFORGEN Technical Guidelines for genetic conservation and use of oriental beech (*Fagus orientalis*). Biodiversity International, Rome, Italy.
- Kehl, H., 2018. A multi-disciplinary Project on Causes and Diversity of Extrazonal Temperate Flora & Vegetation in the Amanos Mountains. (SE-Turkey). http://lv-twk.oekosys.tu-berlin.de/project/loekat-/e-loekat.htm
- Köse, N., Akkemik, Ü., Dalfes, H. N., Özeren, M. S., 2011. Tree-ring reconstructions of May–June precipitation of western Anatolia. *Quaternary Research* 75(3): 438-450. **[CrossRef]**
- Köse, N., 2012. Climatic Factors Affecting Tree-Ring Growth of *Abies nordmanniana* (Stev.) Spach. subsp. *bornmuelleriana* (Mattf.) Coode&Cullen from Kastamonu, Turkey. *Forestist* 62(1): 71-83.
- Köse, N., Akkemik, Ü., Dalfes, H. N., Özeren, M. S., Tolunay, D., 2012. Tree-ring growth of *Pinus nigra* Arn. subsp. *pallasiana* under different climate conditions throughout western Anatolia. *Dendrochronologia* 30(4): 295-301. **[CrossRef]**
- Köse, N., Güner, H. T., 2012. The effect of temperature and precipitation on the intra-annual radial growth of *Fagus orientalis* Lipsky in Artvin, Turkey. *Turkish Journal of Agriculture and Forestry* 36(4): 501-509.
- Köse, N., Akkemik, U., Guner, H. T., Dalfes, H. N., Grissino-Mayer, H. D., Ozeren, M. S., Kindap, T., 2013. An improved reconstruction of May-June precipitation using tree-ring data from western Turkey and its links to volcanic eruptions. *International Journal of Biometeorology* 57(5): 691-701. **[CrossRef]**
- Köse, N., Güner, H.T., Harley, G. L., Guiot, J., 2017. Spring temperature variability over Turkey since 1800CE reconstructed from a broad network of tree-ring data. *Climate of the Past* 13: 1-15. **[CrossRef]**
- Martin-Benitto, D., Ummenhofer, C. C., Köse, N., Güner, H. T., Pederson, N., 2016. Tree-ring reconstructed May–June precipitation in the Caucasus since 1752 CE. *Climate Dynamics* 47: 3011-3027. **[CrossRef]**
- Martin-Benitto, D., Pederson, N., Köse, N., Doğan, M., Bugmann, H., Mosulishvili, M., Bigler, C., 2018. Pervasive effects of drought on tree growth across a wide climatic gradient in the temperate forests of the Caucasus. *Global Ecology and Biogeography* 27: 1314-1325. **[CrossRef]**
- OGM, 2015. Türkiye Orman Varlığı. T.C. Orman ve Su İşleri Bakanlığı Orman Genel Müdürlüğü, Bulten.
- Orvis, K. H., Grissino-Mayer, H. D., 2002. Standardizing the reporting of abrasive papers used to surface tree-ring samples. *Tree-Ring Research* 58(1/2): 47-50.
- Özkan, Z. C., 1999. Türkiye'deki Doğu Ladini (*Picea orientalis* (L.) Link.)'nin Dendrokronolojisi. *Turkish Journal of Agriculture and Forestry* 23(2): 263-267.
- Sevgi, O., Akkemik, Ü., 2007. A dendroecological study on *Pinus nigra* Arn. at different altitudes of northern slopes of Kazdaglari, Turkey. *Journal of Environmental Biology* 28(1): 73-75.
- Stokes, M. A., Smiley, T. L., 1996. An Introduction to Tree-ring Dating. University of Arizona Press, Tucson.
- Swetnam, T. W., 1985. Using dendrochronology to measure radial growth of defoliated trees. USDA Forest Service, Cooperative State Research Service, Agriculture Hand Book.
- Thomsen, G., 2001. Response to winter precipitation in ring-width chronologies of *Pinus sylvestris* L. from northwestern Siberian Plain, Russia. *Tree-ring Research* 57(1): 15-29.
- Touchan, R., Garfin, G. M., Meko, D. M., Funkhouser, G., Erkan, N., Hughes, M. K., Wallin, B. S., 2003. Preliminary reconstructions of spring precipitation in southwestern Turkey from tree-ring width. *International Journal of Climatology* 23: 157-171. **[CrossRef]**
- Touchan, R., Xoplaki, E., Funchouser, G., Luterbacher, J., Hughes, M. K., Erkan, N., Akkemik, Ü., Stephan, J., 2005a. Reconstruction of spring/summer precipitation for the Eastern Mediterranean from tree-ring widths and its connection to large-scale atmospheric circulation. *Climate Dynamics* 25: 75-98. **[CrossRef]**
- Touchan, R., Funkhouser, G., Hughes, M.K., Erkan, N., 2005b. Standardized Precipitation Index reconstructed from Turkish ring widths. *Climatic Change* 72: 339-353. **[CrossRef]**
- Touchan, R., Akkemik, Ü., Huges, M.H., Erkan, N., 2007. May-June precipitation reconstruction of southwestern Anatolia, Turkey during the last 900 years from tree rings. *Quaternary Research* 68(2): 196-202. **[CrossRef]**
- Yaltırık, F., 1982. *Fagus* L. In: Davis P. H. (ed.) Flora of Turkey, vol. 7. University Press, Edinburgh, pp. 657-658.
- Yılmaz, H., 2018. *Fagus* L. In: Türkiye'nin Doğal-Egzotik Ağaç ve Çalıları; Akkemik Ü (Eds). Pp: 337-338 Orman Genel Müdürlüğü Yayınları, Ankara.