# Comparison of Water Consumption by Needle and Broad-Leaved Tree Species in the First Month of Growing Season

***Mehmet S. ÖZÇELİK[1], Kamil ŞENGÖNÜL[1], Ferhat GÖKBULAK[1]**
[1]Istanbul University, Faculty of Forestry, Istanbul/TURKEY
*Corresponding Author: msaid.ozcelik@istanbul.edu.tr

**Abstract**

Water consumption by trees is one of the important components in water budget. The objective of this research was to compare water consumption of needle and broad-leaved tree species growing on the same site. Tree species and their wood physiologies are important factors influencing amount of water plants transpire. *Pinus nigra* Arn. subsp. *pallasiana* (Lamb.) Holmboe and *Quercus petraea* (Matt.) Liebl were selected as representatives of needle and braod-leaved tree species in the Atatürk Arboretum-Belgrad Forest. The study period was the first month of growing season. Two experimental plots next to each other were established and 6 trees from each plot were selected based on the quantiles of total method. Trunks of the sample trees were equipped with sap flow sensors measuring according to trunk heat balance method for estimating water uptake by each tree and stand. Oak trees had no foliage whereas pine trees had needle leaves at the beginning of the study. During the study period, total amount of precipitation was 18.7 mm and mean daily temperature was 13.8˚C. Despite low amount of precipitation during the study period, moisture was high in the soil as a result of soil moisture discharge with sufficient winter precipitations and mean soil water potential was -0.20 bar. Results showed that daily water uptake by individual trees varied from 0.08 kg to 57.83 kg for pine trees while it changed between 0.05 and 52.55 kg for oak trees. Average daily uptakes were 1.43 mm m-2 and 1.31 mm m-2 for oak and pine stands, respectively. When whole study period was considered, water consumptions were 35.51 mm m-2 for pine and 38.75 mm m-2 for oak stands. Based on preliminary results of this study, it seems that higher transpiration rates will be observed from both study plots as vegetation period progresses and leaf area index increases.

**Keywords:** Sap flow, Trunk heat balance, Transpiration, Water uptake, Water consumption

## İbreli ve Geniş Yapraklı Ağaç Türlerinin Vejetasyon Periyodunun İlk Ayındaki Su Tüketimlerinin Karşılaştırılması

**Özet**

Ağaçların su tüketimi havzalarda su bütçesinin ortaya konmasında önemli bileşenlerinden biridir. Bu çalışmanın amacı, ibreli ve yapraklı türlerin aynı yetişme koşullarındaki su tüketimlerini karşılaştırmaktır. Ağaçların türleri ve odun yapıları transpirasyonla meydana getirdikleri su kaybını etkileyen önemli faktörlerdir. İbreli ve yapraklı türleri temsilen Belgrad Ormanı-Atatürk Arboretumu'nda bulunan Anadolu karaçamı (*Pinus nigra* Arn. subsp. *pallasiana* (Lamb.) Holmboe) ve sapsız meşe (*Quercus petraea* (Matt.) Liebl) türleri seçilmiştir. Araştırmanın süresi vejetasyon periyodunun ilk ayını kapsmaktadır. Karşılıklı iki deneme parseli alınmış ve toplamın dağılımı yöntemine göre 6' şar ağaç seçilmiştir. Seçilen ağaçların gövdelerine birey ve meşcere bazında su tüketimlerini hesaplamak için gövde ısı dengesi yöntemine göre çalışan bitki özsuyu akış ölçüm sensörleri yerleştirilmiştir. Çalışmanın başlangıcında çam ağaçlarında gelişmiş yapraklar bulunurken, meşe ağaçlarında tomurcuklar patlamış ve yapraklanma yeni başlamıştır. Çalışma süresi boyunca 18.7 mm yağış gerçekleşmiş, günlük ortalama sıcaklık ise 13.8˚C olarak kaydedilmiştir. Araştırmanın yürütüldüğü süre içinde yağış miktarı az olsa da; kışın gelen yağışların da etkisiyle toprak nemi yüksek seyretmiş ve toprak su potansiyeli -0.20 bar düzeyini aşmamıştır. Sonuçlar çam ağaçlarında günlük su tüketiminin 0.08 - 57.83 kg; meşe ağaçlarında ise 0.05-52.55 kg arasında değiştiğini göstermiştir. Çalışma periyodu boyunca su tüketimi çam meşceresinden 35.51 mm m-2; meşe meşceresinden ise 38.75 mm m-2 olarak gerçekleşmiştir. Devam etmekte olan bu çalışma vejetasyon periyodu ilerledikçe ve yaprak yüzey alanı arttıkça her iki meşcereden de daha yüksek su tüketimi miktarlarının ölçüleceğini göstermektedir.

**Anahtar Kelimeler:** Bitki özsuyu akışı, Gövde ısı dengesi, Su tüketimi, Transpirasyon

**Introduction**

Water is one of the main component for all kinds of living organisms and it has an important role on the quality of life. Countries which have less water than 1000 m-3/per year/per capita classified as “water poor country”. Turkey has 1519 m-3 water per year per capita today (URL1, 2016). According to population grow projections by Turkish Statistical Institute, (URL2, 2016) water scarcity will be an important issue in 2030.

If a watershed considered as a factory, precipitation can be accepted as an input, and water flow as an output. Since the amount of precipitation cannot be increased by humans continuously, vegetation management practises are conducted to gain more water from watersheds. Hence, it is important to know consumption rates of tree species for vegetation management and plantations in these watersheds.

Variety of methods have been developed to measure transpiration of plants such as, transpirometer, lysimeter, tent, watershed water balance and sap flow methods (Özhan, 1982). Sap flow method has been developed after the pioneer work of Huber in 1932 and several methods have been announced based on different principals (thermodynamic, electric, magnetic resonance) ever since (Cermak, 2004). The primary of them are, trunk segment heat balance method (Cermak vd., 1973, 1982; Kucera vd., 1977), stem heat balance method (Sakuratani 1981,1984), heat dissipation method (Grainer, 1987) and heat field deformation method (Nadezdhina, 2012). The advantages of the sap flow method can be summerized as being time and cost effectiveness, measurement directly in the pure nature without any restriction, mobility, simple setting and reliability of the results beside measuring without any damage to the trees.

The main goal of this study was to compare water consumption of needle and broad-leaved tree species in the same site in order to understand which one is more water efficient or which one consumes more water than the other.

**Material and Methods**

The study was carried out in Atatürk Arboretum - Belgrad Forest (41° 09' 48" - 41° 10' 55" N, 28° 57' 27" -28° 59' 27" E) on two experimental plots next to each other. Mean annual precipitation is around 1090.4 mm and mean annual temperature is 12.8 ˚C in the site. The warmest month is July and the coldest is February (Serengil et al; 2007).

*Pinus nigra* Arn. subsp. *pallasiana* (Lamb.) Holmboe and *Quercus petraea* (Matt.) Liebl were selected as representatives of needle and braod-leaved tree species, respectively (Figure 1). The oak stand was natural while pine stand was plantation. The study period covered the first month of the growing season (01.04.2016-30.04.2016). Six trees in both plots were selected as sample trees according to the quantil of total method (Cermak et al, 2004). Leaf area index (LAI) of the plots were 0.58 for pine and 0.54 for oak. The area of the pine plot was 800 m-2 while the oak plot was 1300 m-2.

Figure 1: The oak plot on the left and the pine plot on the right in Atatürk Arboretum-Belgrad Forest

The equipment used for this study were 12 EMS 81 sap flow sensors (six sensors per plot from Environmental Measuring Systems, Brno, Czech Republic) working according to the trunk heat balance method (Cermak vd., 1973, 1982; Kucera vd., 1977); 12 electronic dendrometers, one mini automatic weather station including pluviometer, solar radiation sensor, air humidity and air temperature sensor (EMS

Minikin RTHI and rain gauge) just next to the experimental plots, triple soil water potential sensors for each plot (EMS Microlog SP3) and one automatic meteorological station (Campbell Scientific GRWS 1000) 5 km far away from the study area. Leaf area index (LAI) was estimated by CL-110 plant canopy imager (Bio-science.inc).

In the trunk heat balance method, a section of a large tree trunk was heated from the inside by an electric current (with electrodes), which passes through the the tissues. There were four electrodes and thermosensors in the system, all of them were placed into the tree trunk (Figure 2). Three of the electrodes were heated and positioned up to 10 cm above from one central electrode (Cermak et al., 2004).

The central electrode was not heated. The temperature difference (dT) between upper heated electrodes and reference end was measured by needle type thermosensors. Method was calculated the heat balance of a defined heated space according to the equation below (Cermak et al., 2004):

$$P = QdTc_w + dT\lambda$$

Where P is input power (W), Q is the sap flow rate (kg s-1), dT is the temperature difference in the measuring point (K), cw is the specific heat of water (J kg-1 K-1) and λ is the coefficient of heat losses from the measuring point (W K-1).

After installation of the sensors, tree trunks were packed with polyuretan foams against direct heat of the sun and heat isolation. The data were evaluated by EMS Mini32 and Microsoft EXCEL softwares.

Figure 2: EMS 81 Sap flow system with electrodes and thermosensors on a tree trunk

**Results**

During the study period, total amount of precipitation was 18.7 mm and mean daily temperature was 13.8˚C. Even though low amount of precipitation during the study time, moisture was high in the soil as a result of soil moisture discharge with sufficient winter precipitations and mean soil water potential was -0.20 bar.

Results showed that daily water uptake by individual trees varied from 0.08 kg to 57.83 kg for pine trees while it changed between 0.05 and 52.55 kg for oak trees per day. Maximum daily uptakes were 3.93 mm m-2 and 1.91 mm m-2, average daily uptakes were 1.43 mm m-2 and 1.31 mm m-2 for oak and pine stands, respectively. When whole study period was considered water consumptions were 35.51 mm m-2 for pine and 38.75 mm m-2 for oak stands. At the beginning of the study period, oaks had no foliage while pines had already grown up leaves, but interestingly, water uptake of oak increased dramatically, only 8 days after the beginning of vegetation period, and never fell behind of the the pine (Figure 3).

**Discussion and Conclusion**

There are not many research on transpiration and water uptakes of pine and oaks in our country. On the other hand, Anatolian black pine is a native tree species to Turkey. So results of this study were compared with the results of similar studies from all over the world. Results of this study was inconsistent with those carried out in different regions. For instance, Poyatos et al (2005) found that Scots pine (*P. sylvestris* L.) transpired almost twice more water than pubescent oak (*Q. pubescens* Willd.) with 3.7 mm and 1.4 mm maximum transpirations respectively for whole growing season. Other researchers reported also lower transpiration rates for pine, as 88 mm total in Austria (Weiser et al, 2014) and 25 kg daily maximum in Sweden (Cienciala et al, 2002), which are quite lower compared to ours, but mean annual temperature and precipitation was also lower (7.3˚C and 718 mm) in the study carried out in Austria. Maximum stand transpiration for Scots pine reported 3.9 mm (Moore et al, 2004). The water uptake of our pine plot did not reach this value at the beginning of the vegetation period, but it may reach as vegetation period progresses.

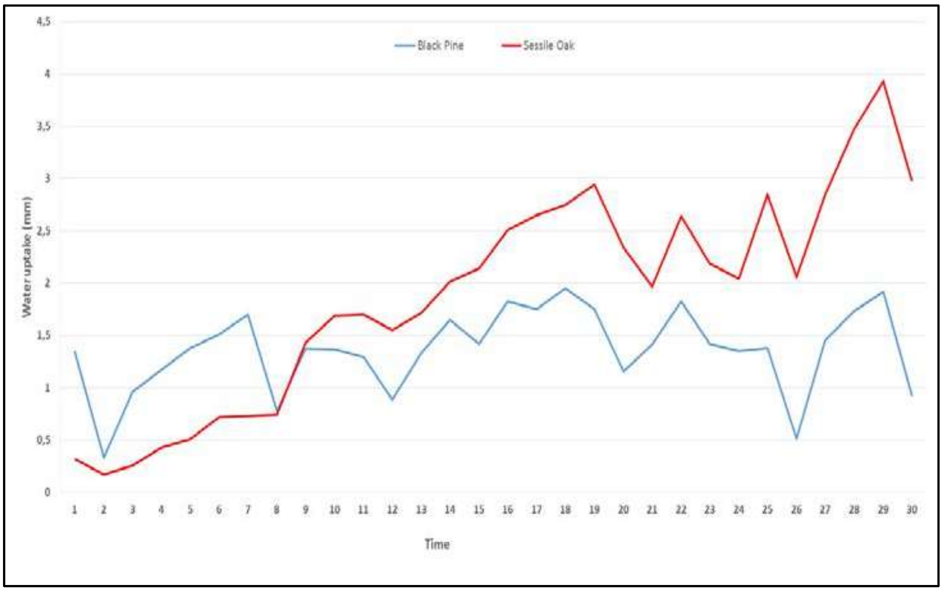


Figure 3. The water uptake comparison of black pine and sessile oak in the first month of vegetation period

Moreover; daily maximum transpiration rates reported as 71 kg for *Q. alba* L. and 46 kg for *Q. rubra* L. (Wulschlegger et al, 2001). One of the highest transpiration rate reported with 100 ears old *Q. robur* L. as 400 kg daily maximum and 39000 kg total for growing season per tree, in a floodplain forest, Czech Republic (Cermak et al, 1982). Compared our results, we have already seen or we were very close to these values in the beginning of the vegetation period except the one in floodplain forest, so it is obvious that we will see much higher amounts of transpiration rates in the sessile oak. These differences can be attributed to differences in both meteorological-geographical conditions and the difference of the species.

With considering the preliminary results of this study, higher amounts of water uptake can be expected for both species as air temperature raises, leaf are index increases and vegetation period progresses. It can also be expected that oak stand will transpire 2-3 times more water than pine stand for the whole vegetation period in the sub-humid region. It is also apparent that more researches should be done in Turkey about water consumption of trees in order to practise water efficient vegetation management studies for next years.

**References**

Cermak, J., Deml, M., Penka, M. 1973. A new method of sap flow rate determination in trees. Biologia Plantarum, 15 (3), 171-178.

Cermak, J., Ukehla, J., Kucera, J., Penka, M. 1982. Sap flow rate and transpiration dynamics in the full-grown oak (Quercus robur L.) in the floodplain forest exposed to seasonal floods as related to potential evapotranspiration and tree dimensions. Ecologia Plantarum, 24 (6), 446-460.

Cermak, J., Kucera, J., Nadezhdina, N. 2004. Sap flow measurements with some thermodynamic methods, flow integration within trees and scaling up from sample trees to entire forest stands. Trees, 18, 529-546.

Cienciala, E., Mellander, P.E., Kucera, J., Oplustilova, M., Ottoson-Löfvenius, M., Bishop, K. 2002. The effect of a north-facing forest edge on tree water use in a boreal Scots pine stand. Canadian Journal for Forest Research, 32, 693-702.

Granier, A. 1987. Evaluation of transpiration in a Douglas-fir stand by means of sap flow measurements. Tree Physiology, 3, 309-320.

Kucera J., Cermak, J., Penka, M. 1977. Improved thermal method of continual recording the transpiration flow rate Dynamics. Biologia Plantarum, 19, 413-420.

Moore,G.W., Bond, B.J., Jones, J.A., Phillips, N., Meinzer, F.C. 2004. Structral and compositional controls on transpiration in 40 and 450 year-old riparian forests in western Oregon, USA. Tree Phsyology, 24, 481-491.

Nadezhdina, N. 2012. Sap flux density measurements based on the heat field deformation method.Trees, 26, 1439-1448.

Özhan, S., 2004. Havza Amenajmanı. İstanbul Üniversitesi Orman Fakültesi Yayınları, Yayın No: 481, İstanbul.

Poyatos, R., Llorens, P., Gallart, F. 2005. Transpiration of montane Pinus sylvestris L. And

Quercus pubescens Willd. Forest stands measured with sap flow sensors in NE Spain. Hydrology and Earth System Sciences, 9, 493-505.

Sakuratani, T. 1981. A heat balance method for measuring water flux in the stem of intact plants. Journal of Agricultural Meteorology, 37 (1), 9-17.

Sakuratani, T. 1984. Improvement of the probe for measuring water flow rate in intact plants with the stem heat balance method. Journal of Agricultural Meteorology, 40, 273-277.

Serengil,Y., Gökbulak, F., Özhan, S., Hızal, A., Şengönül, K. 2007. Alteration of stream nutrient discharge with increased sedimentation due to thinning of a deciduous forest in Istanbul. Forest Ecology and Management, 246, 264-272.

URL1, 2016. Devlet Su İşleri. Toprak ve SuKaynakları. http://www.dsi.gov.tr/toprak-ve-su-kaynaklari Son erişim tarihi: 24.06.2016

URL2, 2016. Türkiye İstatistik Kurumu. Nüfus Projeksiyonları.2013-2075. Son erişim tarihi: 24.06.2016.http://www.tuik.gov.tr/PreHaberBultenleri.do?id=15844.

Weiser, G., Leo, M., Oberhuber, W. 2014. Transpiration and canopy conductance in an inner alpine Scots pine (Pinus sylvestrisL.) forest. Flora, 209, 491-498.

Wullschleger, S.D, Hanson, P.J., Todd, D.E., 2001. Transpiration from a multi-species forest estimated by xylem sap flow techniques. Forest Ecology and Management, 143,205-21