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Some physiological and biochemical changes In oak trees after fire

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FOREST ECOLOGY

ABSTRACT

Background: Forest fires are considered integral parts of many forest ecosystems despite being a disaster influencing the forest ecosystem dynamics significantly. A fire that occurred within the borders of Düzce-Konuralp State Forest Enterprise affected 16 ha of oak forest. The present study aimed to investigate the physiological and biochemical changes in two oak species (*Quercus pubescens* and *Q. cerris*) at post-fire period. For this purpose, seasonal shoot and leaf samples were collected from 15 trees (5 trees from high and low fire intensity and control groups) for each oak species. The samples were subjected to xylem, water potential, and stomatal conductivity analysis in the field and carbohydrate concentration and proline analyses in the laboratory.

Results: It was found that leaf surface area decreased, and the root-leaf water connection was broken depending on the intensity of the fire. As the fire severity increased, water potential and stomatal conductivity of trees increased; proline and carbohydrate concentration amounts decreased. *Q. pubescens* had lower water potential and stomatal conductivity than *Q. cerris* but higher proline and carbohydrate concentration amounts.

Conclusion: *Q. pubescens* was more resistant to drought stress during the post-fire season than *Q. cerris* from the aspect of physiological and biochemical characteristics.

Key words: Carbohydrate concentration; Forest fire; Proline; Stoma conductivity, Water potential

HIGHLIGHTS

The physiological and biochemical changes were investigated in two oak species during post-fire period.
Midday xylem water potential, stomatal conductivity, proline, and carbohydrate concentration amounts were performed.
The water potential, stomatal conductivity, carbohydrate concentration, and proline content in leaves differed significantly among tree species and fire intensity.

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INTRODUCTION

Forest fires are large-scale natural disasters affecting terrestrial ecosystems as a changing and renewing force (Attiwil, 1994). Through a process lasting millions of years, the mutual relationship and interaction between fires and vegetation (Trabaud, 1994) caused them to be accepted as an inevitable and inseparable part of ecosystems (Bond and Van Wilgen, 1996). Fires release the energy, which has been stored in combustible materials, by combusting at different intensities and spreading at different levels (Johnson and Miyanishi, 2001). Fire intensity refers to the energy released as a result of the combustible material combusted in a unit of time and area (Byram, 1959). Fire intensity is an important parameter for fire behavior (Alexander, 1982) since it caused plants to die by having aboveground plant tissues being subjected to lethal temperatures or directly subjected to the flames (Michaletz and Johnson, 2007). Different intensity levels and combustible material amounts observed in fires can create many positive and negative effects on vegetation (Keeley, 2009). Investigating and understanding these effects of fires are of significant importance for the management and sustainability of natural sources (Hirsch et al., 2001; Hutto, 2008).

Almost 55% of the forest areas in Türkiye consist of first and second-degree sensitive forest fires (GDF, 2020). Most of these forest stands are constituted by Turkish pine (*Pinus brutia* Ten.), black pine (*Pinus nigra* J. F. Arnold), and shrub plants (maquis). The fires, which occur in coniferous and shrub forest areas generally in the summer season, can negatively affect the forests and the forestation works.

Fires pose an important danger for broad-leaved forest areas in addition to coniferous forests. Approximately 30% of the forest area of Türkiye consists of broad-leaved forest tree species. Considering the tree species diversity and area covered in Türkiye broad-leaved forest areas, oaks come to the forefront (GDF, 2020). Oak species have certain characteristics allowing them to survive frequent and low-intensity fires (Catry et al., 2012; Oliveira and Fernandes, 2009; Pausas et al., 2004). Mature and old oak individuals have a thicker stem bark when compared to many other broad-leaved tree species (Nicolai, 1988). Fires encourage the development of oak species through root stool and trunk shoots (Hutchinson, et al 2005).

Quercus species are widely distributed in the northern hemisphere (Lemouissi et al., 2014) and many *Quercus* species are fire-tolerant (Johnson et al., 2002). In Türkiye, *Quercus cerris* L. and *Q. pubescens* Willd. are the two remarkable oak species having a wide distribution area(GDF, 2015). Both species have a high ability to shoot forth after a fire (Millios et al., 2017; Simeone et al., 2019). Their intense interactions with fires make oaks important species to study among the broad-leaved forest tree species in Türkiye. Especially in recent years, the investigation of physiological changes caused by biotic and abiotic factors on trees has gained importance (Teshome et al., 2020). The soluble sugars (nonstructural carbohydrates) stored in plants have a strong effect on the plant's tolerance to stress conditions (Barbaroux et al., 2003; Ma et al., 2020; Wang et al., 2023). These conditions have detrimental effects on the growth, productivity, physiological, and biochemical processes of plants (Mareri et al., 2022; Zhang et al., 2021). The effects of fire on nonstructural carbohydrate concentration changes in some Quercus species were studied. (Flecjk at al., 1996; Kruger and Reich, 1997; Lemouissi at al., 2014). There has only been one study (Berber et al., 2015) that examined the changes in physiological and biochemical parameters of *Q. cerris* and *Q. pubescens* species caused by forest fires in Türkiye. The present study aims to examine seasonal changes in stomatal conductivity, water potentials, proline and total carbohydrate concentration (TCC) amounts in leaves of *Q. cerris* and *Q. pubescens* species, which were affected by a fire at different intensity levels, during the first vegetation period after the fire.

MATERIAL AND METHODS

Study area

The study area is Konuralp Forest Sub-district Directorate located within the borders of Düzce Forest Management Directorate affiliated with the Bolu Regional Directorate of Forestry (40° 54′ 51″ N, 31° 15′ 35″ E). In this field, a fire started on 2nd September 2015, was taken under control at the beginning of 3rd September, and completely extinguished in the morning of 9th September. Different fire types and combustible material consumptions were observed at fire affected compartments. The size of the compartments was approx. 32 ha (Baysal, 2017), and almost half of this area affected by fire consisted of productive young oak forest and degraded shrub cover. The study area is located in the south aspects and the altitude ranged between 240 and 400 m. Based on the long years of meteorological measurements (1959-2020), the annual total precipitation was 829.8 mm, and the mean temperature was 13.1 °C. In 2016, the measurement was performed and listed in Table 1. The precipitation during the vegetation season was measured with the nearest meteorological station as 486 mm. The mean temperature and relative humidity data were collected with a data logger.

Table 1. Meteorological data of measurement area for year 2016.

Meteorological measurements	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Agu.	Sep.	Oct.	Nov.	Dec.	General
Mean Temperature (°C)	3.0	8.9	10.2	14.6	16.2	22.1	23.3	24.2	19.1	13.9	8.5	1.1	13.8
Mean precipitation (mm)	179.8	96.6	66.6	48.0	133.6	62.6	19.0	59.5	65.4	30.8	67.2	139.4	968.5
Mean Relative humidity (%)	85.8	79.4	70.2	67.9	77.8	70.5	72.1	75.1	73.5	82.8	82.5	93.0	77.6

Sample tree selection

The present study was carried out on two oak species (*Q. cerris* and *Q. pubescens*) affected by low and high fire intensity levels and a control group (Figure 1). The trees with completely affected living crown structure and having living cambium tissue were considered as high fire intensity, whereas the trees with none-affected crown structure but having a trunk that has been affected to a certain level were considered as low fire intensity. The trees outside the fire area and having a 50 m distance to the fire area were used as a control group. Within this context, 5 trees were selected from each species and each group (30 trees in total).

Selected trees were numbered using spray paint and information notes were hung on the trunks. The locations of trees were determined using a GPS device. Moreover, the characteristics of trees such as diameter at breast height ($d_{1.30}$), tree height, live crown base height, crown width, living crown height, and bark thickness (Table 2).

Measurement

The measurements on oak species were performed between June and November of 2016. During the measurement period, midday xylem water potential, stomatal conductivity, TCC amounts, and proline measurements were performed every month. Sampling was performed between 12.00 and 15.00 from the branches at the top 1/3 of the canopy. The leaved branches were taken from the south direction of the canopy by using long pruning shears. The xylem water potential of samples was measured using a Scholander pressure chamber and stomatal conductivity measurements were performed with a Delta T porometer in the field. Moreover, for TCC amounts and proline measurements, sufficient leaves was wrapped using aluminum foil. The sample numbers were labeled on them and they were taken to the laboratory. Leaf samples were kept at -86 °C in a deep freezer until analyses. Then, the proline concentration of leaves was determined using the method of Bates et al. (1973), and the TCC amounts were performed using the method of Dubois et al. (1956).

Statistical analysis

Two-way variance analysis (Two-Way ANOVA) was used to determine the effects of fire intensity on the physiological and biochemical properties of the oak species examined. If the variance analysis results were found to be statistically significant ($P < 0.05$), then the mean values were compared using the Duncan test. The relationships between measured physiological and biochemical properties were examined using Pearson's correlation. Before the analyses, it was tested if the data of variables were distributed normally and if the variances were homogeneous. Normality test was performed using the "Shapiro-Wilk" test and the homogeneity of variances was tested using "Levene's test". Statistical analyses were conducted using IBM SPSS Statistica 24.0 package software.

RESULTS

Water potential

The statistical analysis results showed that the effects of tree species and fire intensity on the water potential were significant ($P<0.05$), whereas the interaction between tree species and fire intensity was not significant ($P=0.691$; Table 3). Based on the average of the measurement period, the water potential of *Q. pubescens* was 28% less than that of *Q. cerris* (1.8±0.7 MPa). The water potential of trees exposed to low intensity of fire was 12% and trees exposed to high intensity fire was 25% higher water potential than that of control trees subjected to no fire (2.3±0.8 MPa) (Figure 2).

Figure 1: Selection and measurement of low intensity (a) and high intensity (b) affected *Q. cerris* and *Q. pubescens* trees after the one month later in buned area, collecting samples from low intensity (c), high intensity (d) affected *Q. cerris* and *Q. pubescens* trees and control groups (e).

Table 2. Allometric measured values of sampled trees.

Tree species Groups	Quercus cerris			Quercus pubescens		
	Control	Low intensity	High intensity	Control	Low intensity	High intensity
Min. age (year)	34.0	38.0	32.0	32.0	39.0	27.0
Max. age (year)	59.0	54.0	56.0	45.0	51.0	43.0
Maen age (year)	43.0	45.0	45.6	37.0	44.0	33.0
Min. $d_{1.30}$ (cm)	12.3	13.4	13.0	14.8	13.6	12.5
Max. $d_{1.30}$ (cm)	18.5	17.6	19.3	17.8	18.1	18.5
Maen $d_{1.30}$ (cm)	15.0	14.9	17.4	15.9	16.2	16.0
Min. height (m)	8.8	8.0	10.3	13.8	12.0	10.0
Max. height (m)	12.8	12.0	13.0	15.0	13.0	13.0
Maen height (m)	10.8	10.2	11.2	14.5	12.6	11.3
Min. crown widht (m)	3.1	3.4	2.5	3.0	3.0	2.7
Max. crown widht (m)	6.1	5.1	5.1	4.6	4.3	3.2
Maen crown widht (m)	4.0	4.1	4.1	3.8	3.7	2.9
Min. crown base height (m)	1.9	3.0	1.3	2.5	1.9	1.8
Max. crown base height (m)	4.1	5.4	5.1	3.8	4.5	2.7
Maen crown base height (m)	2.9	3.9	3.2	2.9	2.5	2.1
Min. bark thickness (mm)	0.6	0.8	1.3	0.8	0.9	1.2
Max. bark thickness (mm)	2.4	1.6	2.5	2.0	2.1	2.0
Maen bark thickness (mm)	1.6	1.4	2.0	1.5	1.5	1.7

Table 3. Variance analysis results regarding the effect of fire intensity on tree species' water potential, stomatal conductivity, proline content, and TCC amounts by the measurement time.

Measurement time	Factor	Water potential		Stoma conductivity		Prolin amount		TCC amounts	
		F	P	F	P	F	P	F	P
June	Tree species (TS)	26,13	0,000	108,52	0,000	86,02	0,000	0,09	0,765
	Fire intesity (FI)	41,68	0,000	185,83	0,000	174,91	0,000	43,04	0,000
	TSxFI	4,10	0,020	39,66	0,000	13,97	0,000	3,25	0,040
July	Tree species (TS)	35,49	0,000	12,76	0,000	24,80	0,000	5,52	0,020
	Fire intesity (FI)	9,55	0,000	52,60	0,000	89,87	0,000	3,50	0,031
	TSxFI	37,35	0,000	1,95	0,146	3,94	0,023	7,66	0,001
August	Tree species (TS)	249,40	0,000	0,90	0,344	9,71	0,003	194,17	0,000
	Fire intesity (FI)	58,22	0,000	29,31	0,000	90,85	0,000	82,97	0,000
	TSxFI	7,39	0,001	0,58	0,560	0,35	0,703	10,53	0,000
September	Tree species (TS)	163,22	0,000	5,34	0,022	188,80	0,000	130,56	0,000
	Fire intesity (FI)	52,47	0,000	11,77	0,000	587,32	0,000	127,43	0,000
	TSxFI	11,36	0,000	5,08	0,007	3,12	0,049	10,29	0,000
October	Tree species (TS)	18,14	0,000	13,91	0,000	7,51	0,007	6,22	0,013
	Fire intesity (FI)	105,11	0,000	15,21	0,000	10,97	0,000	59,01	0,000
	TSxFI	4,12	0,020	6,75	0,002	0,78	0,463	8,01	0,000
November	Tree species (TS)	153,84	0,000	71,90	0,000	2,84	0,096	2,60	0,108
	Fire intesity (FI)	44,90	0,000	2,23	0,111	14,80	0,000	15,33	0,000
	TSxFI	6,30	0,003	9,93	0,000	1,67	0,194	9,58	0,000
Mean	Tree species (TS)	64,12	0,000	21,78	0,000	44,67	0,000	64,43	0,000
	Fire intesity (FI)	28,65	0,000	38,46	0,000	140,09	0,000	52,44	0,000
	TSxFI	0,37	0,691	3,87	0,021	0,72	0,487	9,25	0,000

F: Two-way analysis of variance results F test value, P: Significance level ($P < 0.05$).

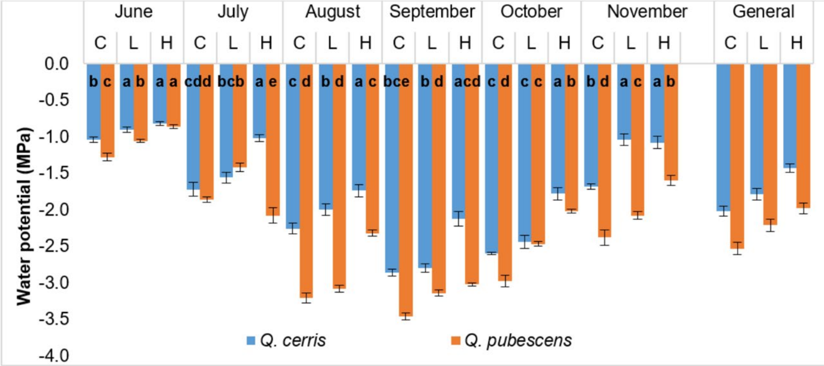

Figure 2: Change of tree species' water potential by the measurement period. Bars refer to standard error. According to the Duncan test, the mean values labeled with the same letter in the same month are statistically similar (P>0.05), whereas the interaction is insignificant for non-labeled months.

According to monthly measurements, the highest water potential was found in *Q. cerris* exposed to high fire intensity, whereas the lowest water potential (except for July) was found in *Q. pubescens* in the control group (Figure 2). The trees in the control group exposed to no fire had lower water potentials than those in the parcels exposed to fire for both species. It means that the water potentials of oak trees increased with increasing fire intensity (Figure 2). In both species, the highest water potential was found in June, and the lowest water potential was found in September in the control parcel. In general, *Q. pubescens* had lower water potential than *Q. cerris* in all months.

Stoma conductivity

According to the results, the effect of tree species, fire intensity, and interaction between tree species and fire intensity on the stomatal conductivity was found to be significant (P<0.05; Table 3). Although the stomatal conductivity increased in trees exposed to high intensity fire, the stomatal conductivity of *Q. cerris* in fire areas was higher than *Q. pubescens* by 48% and 24%, respectively (Figure 3).

In June, stomatal conductivity values of *Q. cerris* trees exposed to low and high fire intensity were found to be higher than those in the control parcel by 97% and 116%, respectively. *Q. cerris* yielded the highest value in the high fire intensity parcel, whereas the lowest value was found in the control parcel. In both species, the highest value was found in June and the lowest one in September. In general, *Q. cerris* showed higher stomatal conductivity than *Q. pubescens* in all months.

Proline content

The results showed that the tree species and fire intensity had a significant effect on the proline content in leaves, whereas the effect of interaction between tree species and fire intensity was not significant (Table 3). *Q. pubescens* contains 14% more proline in comparison to *Q. cerris*. When compared to the control, trees exposed to a low intensity of fire have 12% less proline and those exposed to high intensity of fire have 33% less proline. Considering the measurement months, tree species had a significant effect on proline content in all months (except for November) but fire intensity had a significant effect in all months, whereas the interaction between *tree species and fire intensity* had a significant effect only in June, July, and September (Table 3). The proline content of trees exposed to intensityfire was found to be lower than those exposed to low fire intensity and those in control parcels (Figure 4).

During June, July, and September, when the interaction was significant, *Q. pubescens* trees in control parcels were found to have the highest proline content, whereas the *Q. cerris* trees exposed to high-intensity fire were found to have the lowest proline content (Figure 5).

In August, October, and November, proline content decreased with increasing fire damage, and proline content of *Q. pubescens* was found to be higher than *Q. cerris* in all the procedures (Figure 5).

Carbohydrate concentration

Effects of tree species, fire intensity, and interaction between tree species and fire intensity on TCC were significant (P<0.05; Table 3). *Q. pubescens* trees have TCC 3.4% more than *Q. cerris*. When compared to the control, the trees exposed to the low intensity of fire have 6% less TCC, and those exposed to high intensity of fire have 24% less TCC. Considering the interaction between *tree species and fire intensity,* the highest TCC content was found in *Q. pubescens* trees exposed to no fire, whereas the lowest TCC content was found in *Q. cerris* exposed to high intensity of fire (Figure 6).

Considering the measurement months, the effect of tree species on TCC was significant except in June and November, whereas the effects of fire intensity and interaction between tree species and fire intensity on TCC were found to be statistically significant in all months (P<0.05; Table 3). During the measurement months, the oak trees exposed to high intensity of fire were found to have the lowest TCC, whereas those exposed to no or low intensity of fire were found to have similar TCC content (Figure 6). The highest TCC level was found in control parcel in October, whereas the lowest values were found in high fire intensity parcels for *Q. cerris* in June and for *Q. pubescens* in September.

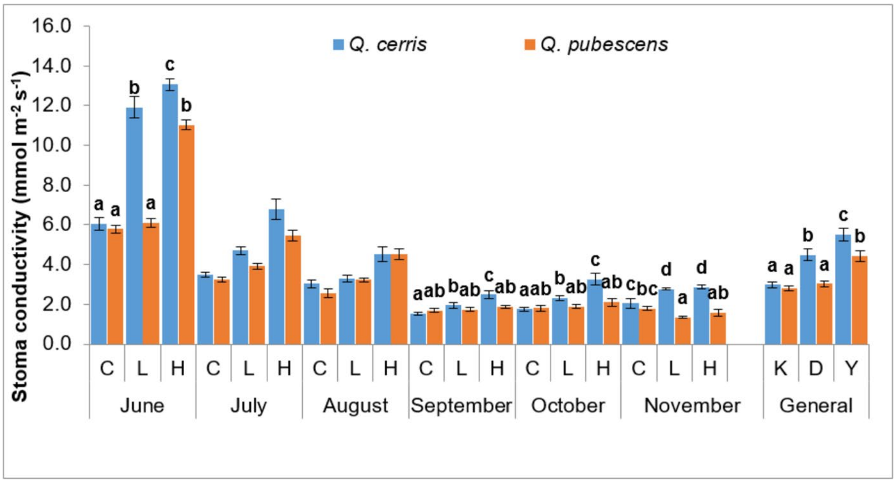

Figure 3. Change of tree species' stomatal conductivity by fire intensity during the measurement period. Bars refer to standard error. According to the Duncan test, the mean values labeled with the same letter in the same month are statistically similar (P>0.05), whereas the interaction is insignificant for non-labeled months.

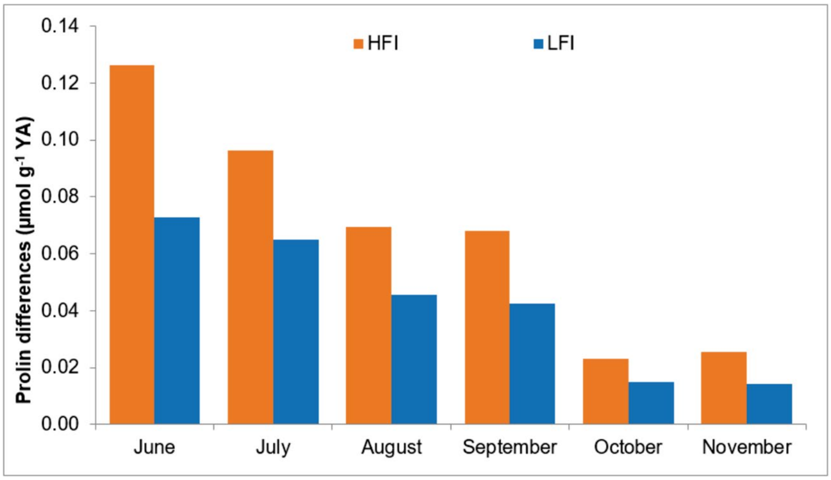

Figure 4. Difference of proline content of trees in fire parcels from the control.

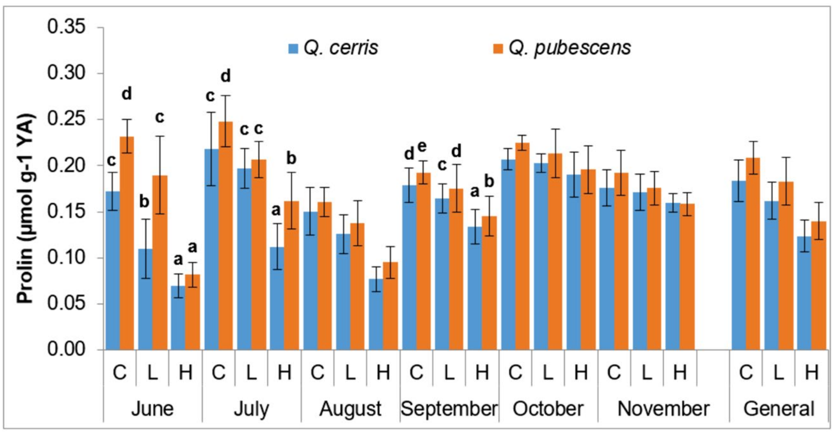

Figure 5. Effect of the interaction between tree species and fire intensity on the proline content in measurement months. Bars refer to standard error. The mean values labeled with the same letter in the same month are statistically similar (P>0.05), whereas the interaction is insignificant for non-labeled months.

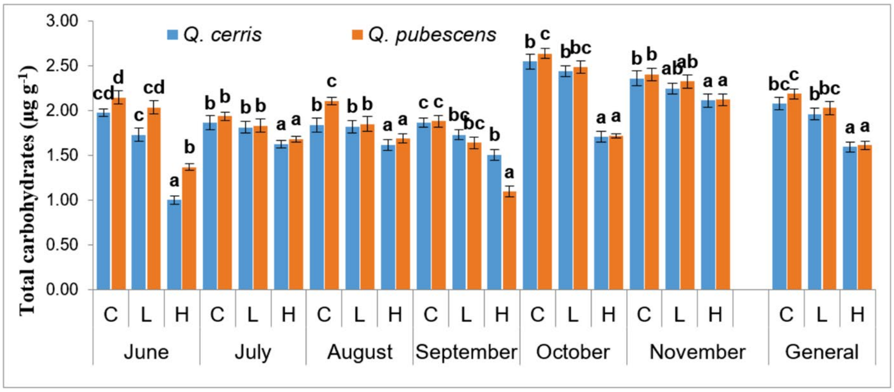

Figure 6. Effect of the interaction between tree species and fire intensity on the total carbohydrate concentration in measurement months. Bars refer to standard error. The mean values labeled with the same letter in the same month are statistically similar (P>0.0.5), whereas the interaction is insignificant for non-labeled months.

Regardless of species, a negative and strong relationship was found between water potential and stomatal conductivity (r=-0.68). There was a negative relationship between stomatal conductivity and TCC (r=-0.56; r=-0.51). A positive relationship was found between proline content and TCC (r=0.63). Considering the tree species, the negative relationship between stomatal conductivity and proline and TCC contents was stronger in *Q. cerris*, no such relationship was found in *Q. pubescens*.

DISCUSSION

Oak species have certain fire-related properties that allow them to survive forest fires (Catry et al., 2012; Oliveira and Fernandes, 2009; Pausas et al., 2004). When compared to coniferous species, oaks have advantages such as their strong capacity to shoot forth (Silva and Catry, 2006) and to resist the drought conditions developing after the fire (Pausas et al., 2004). Post-fire shoot development and heals generally occur in the summer season, when water scarcity develops in soil and atmosphere. It was reported that summer drought or water stress plays an effective role in many properties of plants such as morphological, physiological, and biochemical characteristics (Kulaç, 2010; Levitt, 1972; Salisburry and Ross, 1994). (Chehab et al. 2009) reported a direct relationship between plant growth and water availability in soil. In this study, similarly, the lowest midday water potentials were achieved in August-September, when the summer drought is observed, but it started increasing in the next months. The water potentials of oak trees damaged by fire were found to be higher than non-damaged oaks and water potential increased with increasing fire intensity. This could be due to a deterioration of the root-leaf relationship in favor of the root and a decrease in transpiration due to a decrease in leaf surface area due to fire damage. Hence, (Gricar et al. 2020) reported that the midday water potential of fire-damaged *Q. pubescens* trees was higher than non-damaged ones. During the measurement period, the midday water potential of *Q. pubescens* was found to be lower than that of *Q. cerris*. This might be related to *Q. pubescens*'s ability to increase the concentration of matter dissolved in intracellular fluids (Ragazzi et al., 1999). However, *Q. pubescens* was reported to have a higher drought tolerance when compared to *Q. cerris* (Dreyer et al., 1992).

Stoma conductivity values of two oak trees exposed to no fire were found to be similar but stomatal conductivity increased with increasing levels of fire-related damage. Similarly, the stomatal conductivity of fire-damaged *Q. pubescens* and *Q. ilex* individuals was reported to be higher than that of individuals exposed to no fire (Fleck et al., 1998; Gricar et al., 2020). Because of the increase in the root-trunk index after the fire, the amount of water reaching the leaves didn't decrease. Moreover, since fire removed the grass and bush cover competing with oaks in fire areas, it positively contributed to the water availability in the soil. Thus, they might not have narrowed the stomatal gaps as much as the trees in the control parcel since there was no water scarcity in the lands of the fire areas. This result is also corroborated by the finding that there was a strong negative correlation between water potential and stomatal conductivity (r=-0.68).

In general, the stomatal conductivity of *Q. cerris* individuals exposed to high intensity of fire was higher than control individuals and *Q. pubescens* individuals exposed to high intensity of fire. Besides that, it can also be related to the fact that *Q. cerris* responded to drought and stress conditions by reducing the stomatal gap less in comparison to *Q. pubescens* (Cotrozzi et al., 2016). However, it is emphasized that this is not a good characteristic regarding drought tolerance. Contrary to the water potential, stomatal conductivity gradually decreased from June to September and continued at low levels until November. It can be explained by trees reducing their stomatal gap in response to the reduced water availability in soil depending on increasing summer temperature and decreasing precipitation. Hence, (Osakabe et al. 2014) stated that the initial balancing process in plants having water stress was to narrow or close the stomas to prevent water loss.

In both oak species, the proline and TCC contents in leaves decrease with increasing levels of fire damage. It can be explained by decreasing leaf surface area and plant-water relationship after the fire, rather than a direct effect of fire. It is known that there is a negative relationship between proline and TCC content, and water potential in plants (Kandemir, 2002). In the present study, a strong positive relationship was found between stomatal conductivity and proline and TCC contents. High proline and TCC contents in oak trees in control parcels can be explained with their higher water stress. Similarly, *Q. pubescens'* higher proline and TCC content than *Q. cerris* can be related to *Q. pubescens'* lower water potential. Cotrozzi et al. (2016) reported that *Q. pubescens* subjected to drought and ozone stress had a higher increase in proline content when compared to *Q. cerris*. Moreover, *Q. pubescens* might have a higher proline and TCC accumulation since it has a higher drought tolerance when compared to *Q. cerris* (Cotrozzi et al., 2016; Dreyer et al., 1992). Plants partially protect themselves against stress by accumulating proline under conditions such as water scarcity, salinity, heavy metal, and low temperature (Hayat et al., 2012). It was reported that, as the drought stress increased, the proline and TCC content of *Q. cerris* (Deligöz and Bayar, 2018) and *Q. pubescens* (Holland et al., 2016) also increased. Moreover, in many studies, it was emphasized that proline and TCC contents increased because of increasing stress (Akça and Yazıcı, 1999; Ghanbary et al., 2018; Guehl et al., 1993; Kulaç, 2010; Lansac et al., 1994; Munns and Weir, 1981; Rhizopoulou, 1991; Thomas, 1990).

When compared to the control trees, the proline content of fire-damaged trees gradually decreases towards the end of the vegetation season (Figure 3). The decrease in difference from control arises from the increase in the proline content of fire-damaged trees (especially in October and November) rather than the decrease in the proline content of control trees. Similarly, in their study on Scotch pine, Kulaç (2010) reported that, while proline content was at a high level at the beginning of the vegetation period, it decreased in mid-summer and then increased again at the end of the vegetation period. Moreover, while there was no remarkable change in TCC values between June and September, an increase was observed in October and November. Similarly, it is known that *Acer saccharum* Marshall increases TCC by decreasing starch concentration in cold months and, thus, this process helps with protecting the tissues against cold (Wong et al., 2003).

CONCLUSIONS

The frequency of forest fires gradually increases in Türkiye. Fires, which are frequently seen in Turkish pine stands in southern and western Türkiye, started to be seen more frequently in broad-leaved forests in the Black Sea region (Coşkuner, 2021; Küçük et al., 2008). The scenarios projecting that temperature and summer drought will increase in the future due to climate change suggest that prevalence of fire might further increase. It is important to understand several physiological and biochemical changes in trees due to summer drought after fire damage. However, the influence of fire on trees' physiology might induce several hard-to-understand complex post-fire mechanisms (Bär et al., 2019). Oak species sustain their lives through new shoots after a fire. However, if the leaf surface area decreases due to fire damage and is unable to produce the carbohydrate that the tree requires, growth may slow and tree resistance to insects may decrease.It may result in secondary pests such as insects and fungi invading the tree. In the present study, despite the deterioration of the root-trunk equilibrium that was caused by the increase in tree canopy height in parallel with the fire intensity, the trees were able to survive. Since *Q. cerris* had a higher level of transpiration, it seems to be more dependent on soil water from the aspect of physiological characteristics after the fire. For this reason, it can be stated that *Q. pubescens* has a higher capacity in struggling with post-fire summer drought from the aspect of physiological and biochemical characteristics when compared to *Q. cerris*. However, further studies on this subject are needed in order to reveal the more complex physiological mechanisms developing after a fire.

AUTHORSHIP CONTRIBUTION

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