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# ANTIOXIDANT VARIABILITY OF THE SEEDS IN CORE AND MARGINAL POPULATIONS OF TAURUS CEDAR (*Cedrus libani* A. Rich.)

## ANTIOKSIDACIJSKA VARIJABILNOST SJEMENA U GLAVNIM I MARGINALNIM POPULACIJAMA LIBANONOSKOG CEDRA (*Cedrus libani* A. Rich.)

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**Summary**

Genetic diversity is the basis for adaptation and survival of tree species under changing environmental conditions, representing the key issue of stability and productivity of forest ecosystems. In this study, core and marginal populations of Taurus cedar (*Cedrus libani* A. Rich.) were investigated due to their importance in gene conservation. Assessment of genetic diversity in isolated populations is of great importance for the conservation and improvement programs. Under global climate change conditions, they may possess genotypes of future adaptive potential. The aim of this study is to determine the amount of proline to understand water deficiency stress of the population, total soluble proteins, MDA, $H_2O_2$, α-amylase, the variability of antioxidant as CAT, SOD, APX and GuPX of Taurus Cedar seeds fromfive core populations (Kahramanmaraş-Andırın/Elmadağı (AND), Adana-Pozantı/Pozantı (POZ), Mersin-Anamur/Abanoz (ANA), Antalya-Finike/Aykırıçay (FIN) and Antalya-Kaş/Karaçay (KAS)) and one marginal provenance (Amasya-Tokat-Niksar/Çatalan (NIK)) in Turkey. According to the results, a significant difference was detected between populations. Significantly higher amounts of proline were detected for ANA (7,46 µmol/g) and POZ (7,22 µmol/g) populations, whereas the lowest amounts of proline were detected in KAS (3,98 µmol/g) population, which represent the optimal distribution of Taurus cedar. This finding indicates that POZ and ANA populations, in the transition zone from Mediterranean region to steppe territory, are more resistant to the frost, than the other populations. The highest α-amilase enzyme amount was detected in POZ population, growing in the optimum range for Taurus cedar. Significantly higher levels of $H_2O_2$ were detected in NIK (11,97 µmol/g) and ANA (11,60 µmol/g). This is an indication of higher levels of oxidative stress in the seed samples of these populations. With the present research it's verified that, enzymes such as SOD, CAT, GuPX and APX, controlling reactive oxygen species (ROS) levels in plant cells, are the elements of the antioxidant defence system functioning as protective mechanisms for plants against stress conditions. From the practical point of view, improvement in afforestation performance can be achieved on the steppe of Central Anatolia Region holding the potential afforestation areas of Turkey, through use of forest reproductive materials from POZ and ANA stands with their higher resistance against stress, and NIK as an isolated and marginal population.

**KEY WORDS:** Taurus cedar, abiotic stress, peripheral population, chemical components

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## INTRODUCTION
## UVOD

Taurus cedar (*Cedrus libani* A. Rich.) achieves its broadest natural distribution on Taurus Mountains. The species optimum is in altitudebetween 800 and 2100 m. However, this altitude may descend to 530 m (in groups) and 470 m (individually) in Finike province , and reach 2400 m on Bolkar Mountains-Aydos Mountain. In addition to the main distribution of this species, isolated marginal populations are locally available near Sultandağları-Dort River, Emirdağı-Çaykışla, Tokat-Erbaa-Çatalan, Tokat-Niksar-Akıncı Village and Konya-Sağlık (Günay, 1990; Boydak, 1996).

In Central Anatolian, Taurus cedar is widely used for afforestation purposes together with Anatolian black pine (*Pinus nigra* Arnold.). This region has semi-arid climate characteristics.  Fourthy percent of Turkey's lands are under this climate, and represent the main potential areas for afforestation. This increase the interest in Taurus cedar. However, differences are observed in the growth of the species depending on the local conditions (e.g. soil and climate). Adittionaly differences among populations were detected based on genetic parameters (Fady et al., 2008). Taurus cedaris assumed to be a frost- and drought-resistant species and is used in the afforestation practices in Turkey after some extreme events. As to last inventory data;, 19 populations of cedarwere selected for gene conservation and 23 populations registered as seed stands (Ayan and Yer, 2016a; Ayan et al., 2016b).

As the effects of climate change are intensely discussed, Taurus cedar is considered as a strategic, key species with its extended and variable gene pool in Turkey (approximately 500 000 ha) and its high adaptive capability. Taurus cedar is also considered as a potential species for afforestation programmes. In this regard, investigating adaptive biochemical indicators of Taurus cedarpopulations and detecting heir genetic variation hold critical importance.

Reproductive material's quality has direct impact on the success of plantation. The most important criteria for seeds are high viability and resistance to stress in addition to physical and genetic purity (McDonald, 1999; Güney et al., 2013). Seed viability and resistance to stress are highly dependent on the seed's majority level and chemical composition in addition to genetic factors. Chemical composition of seeds basically includes carbonhydrates, fats, proteins and cellulose in the membrane. Traces of compounds such as hormones, alkaloids, lectins, proteinase inhibitors, phytin and raffinose are also found in the chemical composition of seeds (Ayaz et al., 2011).

The ratio of seed chemicals in seeds also vary based on the age of the mother plant, soil characteristics, climate changes, seed harvest time, preharvest and postharvest processes and the mechanical effects arising during harvest and under storage conditions (Güney et al., 2013). Insufficiencies resulting from one of the abovementioned factors effect the chemical composition of the seed, thus impairing the quality, and resulting with up to 75% reduction in the germination capability (McDonald, 2004). From this aspect, limited studies are available on seed storage chemical content of forest trees, impairment of cellular integration (lipid peroxidation- malondialdehyte (MDA)), enzymatic activities of ascorbate peroxidase (APX), guiacol peroxidase (GuPX), catalase (CAT) and superoxide dismutase (SOD), as well as determination of α-amylase enzyme activity.

In this research; Proline, total soluble protein, MDA, Hydrogen peroxide ($H_2O_2$) amounts and activities of APX, GuPX, CAT, SOD and α-amylase enzymes were investigated for the seed samples of optimal and marginal Taurus cedar populations.

## MATERIAL AND METHODS
## MATERIJALI I METODE

### Sample populations – *Istraživane populacije*

Seeds from five core populations and from a marginal population of Taurus cedar, used in the research, were harvested in 2016, mast seed production year. For the purpose of the research, 6 provenances selected from natural stands and representing different regions were used (Tab. 1).

### Chemical Analyses – *Kemijska analiza*

Proline, protein, MDA and $H_2O_2$ in the seed samples were detected by use of the methods by Bates et al. (1973), Bradford (1976), Velikova et al. (2000). Detection of enzymatic activities in the samples was carried out by pulverization of fresh leaf sample in 0.5 g liquid nitrogen and its homogenization with 50 mM (ph 7,6) $KH_2PO_4$ (pH=7) 5 ml buffer solution including 0.1 mMNa-EDTA. The homogenized samples were centrifuged at +4 °C (15000 rpm) for a period of 15 minutes. Enzyme activities were analyzed in this supernatant. APX was spectrophotometrically determined using the method introduced by Nakano and Asada (1981) at 290 nm (E=2,8 mM $cm^{-1}$) by measuring the oxidation rate of the ascorbate; CAT activity was spectrophotometrically determined with the method introduced by Bergmeyer (1974); GuPX activity was detected with the modified method (Lee and Lin, 1995), and SOD enzyme activity was determined using the method applied by Cakmak et al. (2010). α-amylase activity of the seeds was calculated as the amount of starch hydrolyzed per 1 mg protein, using the method by which BSA is used as a standard (Morais and Takaki, 1998).

### Statistical analyzes – *Statistička analiza*

The experiments were done in three replicates. Statistical analyzes of the obtained data were performed through em-

**Table 1.** Sample seed stand populations and their properties
Tablica 1. Istraživane sjemenske populacije i njihove značajke

| **Population & Symbol** / *Populacija i oznaka* | **National Registry Number**/ *Nacionalni registarski broj* | Latitude/ Geografska širina | **Longitude**/ *Geografska dužina* | **Provenance Region** *Regija provenijencije* | Altitude/ *Nadmorska visina* **(m)** | **Exposition** *Ekspozicije* | **Age**/ *Dob* |
|---|---|---|---|---|---|---|---|
| Antalya-Finike/Aykırıçay (FIN) | 243 | 36° 27′ 01″ | 30° 10′ 46″ | 1,6 | 1300 | N | 100 |
| Kahramanmaraş-Andırın/Elmadağı (AND) | 232 | 37° 37′ 19″ | 36° 28′ 34″ | 1,1 | 1500 | E | 90 |
| Antalya-Kaş/Karaçay (KAS) | 234 | 36° 23′ 53″ | 29° 26′ 25″ | 1,6 | 1550 | N | 125 |
| Mersin-Anamur/Abanoz (ANA) | 253 | 36° 20′ 15″ | 32° 56′ 15″ | 1,4 | 1430 | N | 105 |
| Adana-Pozantı/Pozantı (POZ) | 249 | 37° 30′ 32″ | 34° 57′ 38″ | 1,2 | 1325 | W | 100 |
| Amasya-Tokat-Niksar/Çatalan (NIK) | 230 | 40° 47′ 30″ | 36° 34′ 40″ | 4,1 | 1100 | S | 100 |

ployment of the statistical program SPSS for Windows 20.0 Evaluation Version. Differences between control and treatment groups were analyzed through utilization of one-way ANOVA. After the variance analysis, Tukey multiple test was employed to determine differences in significance value of *P <0,05.* In addition, the "Correlation Analysis" was performed to determine statistical relations between seed biochemical characteristics and "Spearman Correlation Coefficient" for non-normal distribution characteristics were taken into consideration.

## RESULTS
## REZULTATI

The data related to the chemical composition and antioxidant activities of Taurus cedar seeds from different populations, have been given in table 2 and 3. According to the results of the variance analysis and multiple test results, there are significant differences between the levels of the mentioned compounds for different populations (*p<0,05*).

### Proline, total soluble protein, MDA and $H_20_2$ amounts – *Prolin, ukupni topivi protein, MDA i $H_20_2$*

Proline amounts in the sample seeds varied significantly among different populations (*p<0.001*). The highest proline value weredetected in ANA and POZ populations representing the optimum core area and the marginal-isolated NIK population from the northern distribution area. The lowest proline amount were detected in the KAS, AND and FIN population samples. As for the total soluble protein amounts, the highest values were obtained from the seed samples of FIN and KAS populations, and the lowest values were detected in ANA. High MDA concentrations were detected in NIK and AND population samples and low MDA concentrations were detected in KAS and FIN populations, two close locations. $H_2O_2$ concentrations in the seed samples varied between 4,68 and 11,97. The highest $H_2O_2$ amounts were detected in the NIK and ANA population samples (Tab. 2).

### Antioxydant activities – *Antioksidacijske aktivnosti*

In the seed samples, APX activities varied between 0,962 Enzyme Unit (EU) and 0,248 EU. The highest APX activity was detected in POZ samples, and the lowest APX activities were detected in AND, KAS and FIN samples. The highest CAT activity was detected in POZ population (0,827 EU), whereas the lowest value was detected in FIN population (0,465 EU). ANA population exhibited the highest GuPX activity; and the seed samples of AND and KAS populations exhibited the lowest activity. The highest SOD activity was detected in the seed samples of FIN, KAS and NIK, in descending order. α-amylase activity in the seeds varied between 29,26 EU and 13,42 EU. The highest α-amylase activity was detected in the seed samples of POZ, NIK and ANA, whereas the lowest values were detected in the samples of KAS and FIN (Tab. 3).

## DISCUSSION AND CONCLUSION
## RASPRAVA I ZAKLJUČAK

According to the literature, seed characteristics such as the seed morphology, physiology and biochemistry may vary depending on several factors such as genotype, variability of environmental factors, growth physiology of seeds, preharvest and postharvest processes and the interaction between these factors (McDonald, 2004).In addition to their role in the growth and development of embryo, proteins are also effective in increasing the resistance against abiotic and biotic stress factors that seedling undergoes during germination (Halliwell, 2006; Bewley et al., 2013).

In this research, the highest total soluble protein amount was detected in FIN and KAS populations, and the lowest amount was detected in ANA population (Table 2). Detection of the highest protein amount in FIN and KAS populations is attributed to low MDA concentration and high SOD activity (Foyer and Noctor, 2005; Caverzan et al., 2012). On the other hand, low protein amount in ANA samples is ascribed to high $H_2O_2$ concentration (Bailly, 2004; Halliwell, 2006). Also, detection of the highest proline

**Table 2.** Proline, total soluble protein, MDA and $H_2O_2$ amounts in the seed samples.
Tablica 2. Prolin, ukupni topivi protein, MDA i $H_2O_2$ u uzorcima sjemena.

| **Population** / *Populacija* | Proline (μmol/g) | Protein (mg/g) | MDA (μmol/g) | $H_2O_2$ (μmol/g) |
|---|---|---|---|---|
| Antalya-Finike/Aykırıçay (FIN) | 4,92 ± 0,04**c** | 66,48 ± 0,18**f** | 0,33 ± 0,001**a** | 9,22 ± 0,28**c** |
| K.Maraş-Andırın/Elmadagı (AND) | 4,37 ± 0,02**b** | 24,77 ± 0,09**c** | 0,41 ± 0,001**c** | 4,68 ± 0,11**a** |
| Antalya-Kaş/Karaçay (KAS) | 3,98 ± 0,02**a** | 43,88 ± 0,24**e** | 0,33 ± 0,001**a** | 5,84 ± 0,09**b** |
| Mersin-Anamur/Abanoz (ANA) | 7,46 ± 0,02**f** | 11,33 ± 0,15**a** | 0,38± 0,003**b** | 11,60 ± 0,14**d** |
| Adana-Pozantı/Pozantı (POZ) | 7,22 ± 0,019**e** | 23,56 ± 0,06**b** | 0,36 ± 0,001**b** | 5,34 ± 0,14**ab** |
| Amasya-Tokat-Niksar/Çatalan (NIK) | 5.30 ± 0,04**d** | 30,23 ± 0,19**d** | 0,45 ± 0,007**d** | 11,97 ± 0,22**d** |
| *F Value* | 3202,471*** | 13000,935*** | 145,517*** | 346,675*** |

Each letter shows the different homogenous groups as tomultiple test results.

amount in this population is an indication of possible water deficiency stress in this region, thus increased resistance against water stress, and production of proline and glucose required for maintaining the osmotic potential (Ashraf and Foolad, 2007; Sharma et al., 2011) through protein catabolism (Tanner, 2008). This is also supported by the fact that, ANA population is in the transition zone from Mediterranean to steppe climate.

As an effective constituent in the growth and development of plants (Tanner, 2008; Verslues and Sharma, 2010) proline has an important role in the maintenance of intracellular redox balance, thus for establishment of hemostatic balance, preservation of conformational structure and form of protein, enzyme and DNA, maintenance of membrane integrity, prevention of ROS production (Ashraf and Foolad, 2007; Bhaskara et al., 2015) improvement of membrane resistance through inclusion in the secondary membrane (Verslues and Sharp, 1999; Karlsson et al., 2005), maintenance of turgor and osmotic balance (Hong et al., 2000; Gomes et al., 2010) transfer of metabolites (Kishor et al., 2005; Lehmann et al., 2010) and in physiologic processes such as germination (Hare et al., 2003). It is also important for glucose synthesis through its catabolism, and its being C, N and ATP source (Verbruggen and Hermans, 2008; Verslues and Sharma, 2010).

In the research, the highest proline amounts were detected in ANA and POZ samples. Both populations are in the transition zone from Mediterranean to steppe climate zone. The lowest proline amounts were detected in KAS and AND population samples which represent the optimal range (Table 1). The proline amount is thought to be related to and MDA content, APX, CAT, GuPX, SOD activities in AND and in MDA, GuPX, SOD KAS population. Numerous researchers suggest that proline and enzyme activities are directly effective on MDA amount (Sung, 1996; Pukacka, 1998; Sofoa et al., 2004). Detection of high proline content in POZ samples is associated with relatively high APX, CAT, GuPX and SOD activities. Detection of high proline content in POZ and ANA samples is also indicative of high water stress (Pukacka and Ratajczak, 2005; Verslues and Sharma, 2010) or very high temperatures in these regions. Under arid conditions proline accumulates in vacuole and cytoplasm, accordingly it may have been effective in the protection of the cellular components, chemical content and water/moisture rate of the seed, as well as preservation of the morphological, physiological and biochemical structure of embryonic cells (Ueda et al., 2007; Szabados and Savoure, 2010). Moreover, higher proline and $H_2O_2$ amounts were associated with increased lignin synthesis in the seed testa or membrane, thus leading to an increased resistance against stress (Zhao et al., 2008; Yang et al. 2009; 2013). In the present research, detection of high proline and $H_2O_2$ amounts in NIK population (with an isolated and marginal distribution) and ANA population (that is in the transition zone to steppe region) is indicative of stress resistance of the seed (Table 1). In literature, proline accumulation was detected in plant tissues under stress conditions. A significant correlation between frost resistance and proline amount was also reported (Ait Barka and Audran, 1997). Proline amount significantly increased in the plants that suffer stress throughout the cold-adaptation period (Hare and Cress, 1997). Up to 3 to 6 times higher proline amounts were reported in *Citrus* sp. plants as compared to non-acclimated plants (Yelenosky, 1979).

Age of the seed, sampling time, harvest and postharvest conditions are likely to increase ROS synthesis (Bewley, 1986; Bailly, 2004; Güney et al., 2013). Oxidative stress, on the other hand, can lead to peroxidation in organelle and plasma membranes, which in turn leads to MDA accumulation (El-Maarouf-Bouteau and Bailly, 2008; Cakmak et al., 2010). In this research, the highest MDA amount was detected in NIK and AND samples, the the lowest amounts were detected in FIN and KAS samples (Table 1). High MDA content in NIK and AND seed samples was attributed to low proline amount and low activities of some of the enzymes (Bailly et al., 1996; Bhaskara et al., 2015). High $H_2O_2$ amount in NIK population can also be effective in increased MDA amount (Bailly, 2004; Corpas et al., 2015). Detection of the lowest MDA levels in KAS and FIN sam-

**Table 3.** α-amilaz, APX, CAT, GuPXand SOD activities of Taurus cedar seeds.
Tablica 3. α-amilaza, APX, CAT, GuPX i SOD aktivnosti sjemena libannskog cedra.

| Population | APX (EU/mg Protein) | CAT (EU/mg Protein) | GuPX (EU/mg Proten) | **SOD (EU/mg Pro**tein) | α -Amilaz (EU/mg Protein) |
|---|---|---|---|---|---|
| Antalya-Finike/Aykırıçay (FIN) | 0,382±0,002**c** | 0,465±0,003**a** | 0,357±0,001**c** | 63,99±0,13**f** | 13,60±0,05**a** |
| K.Maraş-Andırın/Elmadagı (AND) | 0,248±0,002**a** | 0,570±0,004**b** | 0,232±0,004**a** | 35,22±0,13**b** | 15,64±0,06**b** |
| Antalya-Kaş/Karaçay (KAS) | 0,358±0,002**b** | 0,560±0,004**b** | 0,296±0,002**b** | 54,37±0,13**e** | 13,42±0,04**a** |
| Mersin-Anamur/Abanoz (ANA) | 0,512±0,011**e** | 0,656±0,003**c** | 0,473±0,003**f** | 30,84±0,13**a** | 16,94±0,06**c** |
| Adana-Pozantı/Pozantı (POZ) | 0,962±0,005**f** | 0,827±0,001**d** | 0,395±0,003**d** | 39,36±0,16**c** | 29,26±0,06**e** |
| Amasya-Tokat-Niksar/Çatalan (NIK) | 0,409±0,003**d** | 0,480±0,006**a** | 0,413±0,002**e** | 43,71±0,16**d** | 22,25±0,01**d** |
| *F Value* | 2482,953*** | 1318,117*** | 1420,841*** | 8531,295*** | 9402,282*** |

Each letter shows the different homogenous groups as to multiple test results.

ples are indicative of very low lipid peroxidation level in these seeds (Jeng and Sung, 1994; Goel and Sheoran, 2003; Hampton et al., 2009), thus preserved membrane integrity (Demirkaya et al., 2010; Gomes et al., 2010) and protein structure (Sanders et al., 2009).

High concentrations of $H_2O_2$ result with oxidative stress, which may also lead to seed senescence (Vianello et al., 2007), loss in viability (Hampton et al., 2009) and morphological, biochemical degradations of seeds. $H_2O_2$ concentration is significantly high in ANA and NIK samples of Taurus cedar. The lowest $H_2O_2$ levels, on the other hand, were detected in AND ad KAS seed samples (Table 1). The varying $H_2O_2$ content is primarily ascribed to the differences in the growth environments (Jeng and Sung, 1994; Güney et al., 2013). Also the detection of low $H_2O_2$ content in the locations with high enzymatic activities is associated with the function of CAT, GuPX and APX activities in inhibition of ROS synthesis (Lehner et al., 2008).

Seeds contain enzymes in addition to carbonhydrates, fats, hormones, minerals, proteins and aminoacids (Hare et al., 2003; Bewley et al., 2013). These compounds protect cells, tissues and organs through preventing the damages induced by ROS and lipidperoxidation, or repairing damaged tissues, or suppressing ROS synthesis (Bailly et al., 2000).

According to the enzymatic activity values obtained from Taurus cedar population samples, the highest APX and CAT enzyme activities were detected in POZ, the highest GuPX activity was detected in ANA and NIK samples, and the highest SOD enzyme activity was detected in FIN, KAS and NIK samples in descending order (Table 3). Various researchers reported that, APX and CAT enzymes inhibit $H_2O_2$ and ROS synthesis, thus reducing the possible damages of oxidative stress (Bailly, 2004). However, low MDA and high proline and protein contents were detected in these seeds. This finding is indicative of the completion of tissue differentiation and the necessity of $H_2O_2$ inhibition for testa or other tissues' development (Corpas et al., 2015). It was verified in previous researches that hydrolytic enzymes released during seed development lead to peroxidation in cell and organelle membranes, thus resulting with increased MDA accumulation (McDonald, 2004). Low APX and GuPX activities in KAS samples led to reduced levels of $H_2O_2$ and MDA (Jeng and Sung, 1994; Caverzan et al., 2012). Protein amount was also affected by these enzymatic activities (Palma et al., 2002). The decrease in the protein content may also have stemmed from the increased proline amount. It was detected in previous researches that, proline amount triggered protein catabolism under arid and low temperature conditions (Hare et al., 2003; Sanders et al., 2009).

Varying enzyme activities in the seed samples are primarily ascribed to varying locations, thus climate and soil characteristics (Ertekin et al., 2015), seed storage conditions (Pukacka and Ratajczak, 2005; Pekşen and Palabıyık, 2013), and harvesting method. As indicated by the results of literature studies and evaluation of the obtained data, activities of the enzymes such as SOD, CAT; APX and GuPX can be used as indicators in the determination of seed quality (McDonald, 1998; Corbineau, 2012).

In addition to antioxidant enzymes, seeds also contain enzymes that control germination (Schmidt et al., 2007). It was reported in literature studies on seed germination that, seeds contain amylase (α and β) enzymes (Black et al., 1996) that breakdown starch into glucose, fructose and sucrose (Cochrane et al., 2000; Palma et al., 2002). The lowest α-amylase activities were detected in KAS and FIN samples, and the highest activities were detected in POZ and NIK samples of Taurus cedar populations (Table 2). According to numerous researchers, seed storage attributes are dependent on climate changes, soil characteristics, age and size of tissues and organs, and competitiveness (Price et al., 2003; Lehner et al., 2008).

The signal transduction and responses against stress conditions vary in roots and leaves of plants. $H_2O_2$ is effective in signal transduction and antioxidant enzyme activities. Plants are equipped with antioxidant defense system that control ROS levels; and this system comprise of defending elements such as SOD, CAT, GuPX, APX and The plants have an antioxidant defense system that will control the levels of ROS and this system; SOD, CAT, GuPX, APX, glutathione reductase (GR).

From the practical point of view, improvement in afforestation performance and possibly adaptation can be achieved in the steppe of Central Anatolia Region holding the potential afforestation areas of Turkey, through the use of reproductive material from POZ and ANA populations, that represent the main distribution of Taurus cedar in the transition zone from Mediterrenean to steppe climate, with higher resistance against water deficiency stress, and NIK as an isolated and marginal population.

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## SAŽETAK


Genetska raznolikost je osnova za prilagodbu i opstanak vrsta drveća u promjenjivim uvjetima okoline te predstavlja ključni uvjet stabilnosti i produktivnosti šumskih ekosustava. Predmet ovog istraživanja su glavne i marginalne populacije libanonskog cedra (*Cedrus libani* A. Rich.) zbog njihove važnosti u očuvanju gena. Procjena genetske varijabilnosti u izoliranim populacijama od velike je važnosti za programe očuvanja i poboljšanja. U uvjetima djelovanja globalnih klimatskih promjena populacije mogu posjedovati genotipove budućeg prilagodljivog potencijala. Cilj ove studije je utvrditi: (a) količinu prolina, za bolje razumijevanje stresa uzrokovanog nedostatkom vode u populaciji, (b) ukupnih topljivih proteina, MDA, H202, a-amilaze te (c) varijabilnosti antioksidansa kao CAT, SOD, APX i GuPX kod sjemena pet glavnih populacija (AND-Kahramanmaraş-Andırın/Elmadağı, POZ-Adana-Pozantı/Pozantı, ANA-Mersin-Anamur/Abanoz, FIN-Antalya-Finike/Aykırıçay and KAS-Antalya-Kaş/Karaçay) i jedne marginalne populacije Amasya-Tokat-Niksar/Çatalan (NIK) u Turskoj. Prema dobivenim rezultatima, značajna razlika je otkrivena među populacijama. Značajno veće količine prolina otkrivene su za populaciju ANA (7,46 μmol/g) i POZ (7,22 μmol/g), dok su najniže količine prolina otkrivene u populaciji KAS (3,98 μmol/g) koje predstavljaju optimalnu distribuciju libanonskog cedra. Ovaj rezultat pokazuje da su populacije POZ i ANA, u prijelaznoj zoni iz mediteranske regije do područja stepa, otpornije na mraz nego druge populacije. Najveća količina enzima α-amilaze detektirana je u POZ populaciji koja raste u optimalnom rasprostiranju libanonskog cedra. Značajno više razine $H_2O_2$ detektirane su u populacijama NIK (11,97μmol/g) i ANA (11,60 μmol/g), što ukazuje na veće razine oksidacijskog stresa u uzorcima sjemena iz tih populacija. Ovim istraživanjem potvrđeno je da su enzimi poput SOD, CAT, GuPXi APX koji kontroliraju razine reaktivnih vrsta kisika (ROS) u biljnim stanicama, elementi antioksidacijskog obrambenog sustava koji djeluju kao zaštitni mehanizmi biljaka protiv stresnih stanja. S praktičnog gledišta, poboljšanje pošumljavanja može se postići na stepi Srednje Anatolijske regije koja posjeduje značajane površine za pošumljavanje u Turskoj, primjenom šumskog reprodukcijskog materijala iz populacija POZ i ANA koje pokazuju veću otpornosti na stres, kao i populacije NIK koja je izolirana i marginalna.



**KLJUČNE RIJEČI**: libanonski cedar, abiotički stres, rubna populacija, kemijski sastav