https://doi.org/10.31298/sl.148.1-2.5

Izvorni znanstveni članci – Original scientific papers
Šumarski list, 1–2 (2024): 49–58

THE EFFECT OF STORAGE TIME ON GERMINATION OF TURKISH PINE (*Pinus brutia* Ten.) SEEDS

UTJECAJ VREMENA SKLADIŠTENJA NA KLIJAVOST SJEMENA BRUCIJSKOG BORA (*Pinus brutia* Ten.)

Bilal ÇETIN[1]*

SUMMARY

In this study, seeds of the Turkish pine (*Pinus brutia* Ten.) species, which is most widely distributed in Turkey, were collected from the Anamur and Mersin regions in 2005 from four elevations: 0-400, 400-800, 800-1200 and above 1200 meters (m). These seeds were stored at +2-4 °C and germinated at temperatures of 15, 20 and 25 °C in 2005, 2010, 2012, 2014, 2016, 2018 and 2020, and the effect of storage time on germination percentage (GP) was investigated. According to the general average, there was no significant change in the GP of the seeds as the storage period increased. However, the effect of storage time on GP varied according to region, elevation and germination temperature. Especially in germination at 20 °C at lower elevations, the GP did not change much at the end of 15 years or largely maintained the 2005 germination rates. In the other zones, 80% of the initial germinations were obtained in most of the zones, although there was a slight decrease at the end of the storage period. At 15 °C, the declines in germination were very insignificant in the first years in both sections, but became significant in the following years. At 25 °C, the decline in germination was generally higher than at other germination temperatures, and the declines started from the 5th year onwards, and at the end of 15 years, germination declined between 38.0-61.0%. As a result, after 15 years of storage of Turkish pine seeds, it was observed that at 20 °C the GP was significantly maintained, while at other germination temperatures, the decline in germination increased as the storage period increased. In the storage of the seeds of the species, the storage period should be determined by considering the region and elevation where the seeds were collected.

KEY WORDS: Turkish pine, storage time, elevation, germination temperature

INTRODUCTION
UVOD

Turkish pine (*Pinus brutia* Ten.) is also found in Palestine, Jordan, Syria, Iraq, Lebanon, Cyprus, Iran, Azerbaijan, Crimea, Greece and Italy, but it is most widely distributed in Turkey, covering an area of 5.2 million hectares (Anonymous 2020). In addition, it ranks first among the species with natural distribution in Turkey and constitutes 23% of the country's forest area (Yaltırık 1993; Anonymous 2020). The species, which is a typical tree of the Mediterranean climate, has an important place in the national economy with its rapid growth, resistance to long summer droughts, high genetic diversity, and wide range of wood and non-wood utilization areas (Boydak et al. 2006).

Mediterranean ecosystems where Turkish pine is distributed are often negatively affected by fires. For example, approximately 15000 ha of forest area was burned in 2020 and more than 124000 ha was burned in 2021 in the regi-

[1] Asst. Prof. Dr. Bilal Çetin, Düzce University, Faculty of Forestry, 81620-Düzce, Türkiye, e-mail: bilalcetin@duzce.edu.tr

ons where the Mediterranean climate prevails in Turkey (Anonymous 2021). Most of the burned areas are Turkish pine forests. One of the most important duties of the General Directory of Forestry (OGM) is to afforest the burned Turkish pine areas by seeding or planting as soon as possible. In order to obtain enough seedlings for artificial regeneration (afforestation) and to reforest these areas in a short time after unexpected large fires, it is necessary to keep enough seeds in stock. These stored seeds are also important for maintaining genetic integrity (Pradhan and Badola 2012).

Although Turkish pine produces a certain amount of seeds every year, the abundant seed year varies according to elevation, age and year, and the species does not produce abundant seeds every year (Saatçıoğlu 1971; Ürgenç 1977; Ürgenç et al. 1989). Since fewer seeds are formed in poor seed years compared to abundant seed years, it is necessary to collect seeds from large areas and more individuals in order to obtain enough seeds, which increases the cost (Ürgenç and Odabaşı 1971; Göktürk et al. 2019). Storage conditions and tree species are very effective in storing the collected seeds under suitable conditions without damaging seed viability. The main principle in seed storage is to keep the vital activities of the seed at the lowest level (Atay et al. 1970). The storage period of seeds may vary according to the tree species, health and maturity (harvest time), harvesting technique and storage method (Yahyaoğlu and Ölmez 2003). Seeds are stored in two ways: orthodox (dry) and recalcitrant (moist). Orthodox seeds have low moisture content and long storage time (Bonner 2008). Turkish pine is one of the species stored after the seed moisture becomes air-dry. In order for the seeds of this species to be stored for a certain period of time without losing their viability, the seeds must be kept at low temperature and in a dry state (Saatçıoğlu 1971). In general, most pine seeds are orthodox and can be safely dried to 6-7% moisture content. At these moisture contents, at storage temperatures of 3 to 5 °C, most orthodox (dry) tree seeds show little deterioration over 5-15 years of storage (Gosling 2007). Bonner (2008) also reported that orthodox seeds can be dried to a moisture content of 10% or less and stored at this moisture content.

Long-term storage of pine species affects the viability of the seed, and viability losses may also be observed depending on the storage conditions and duration. *Pinus ponderosa* seeds were stored at 0 °C for 7 years and no loss of viability was observed (Allen 1957). No loss of viability was observed in *Pinus elliottii*, *Pinus patula*, *Pinus radiata* and *Pinus taeda* stored at -16 °C for 6 years (Donald and Jacobs 1990). However, in some pine species, storage time and storage conditions may affect seed viability to a certain extent. Ürgenç and Odabaşı (1971) observed a slight decrease in germination after 7 years of storage at room temperature without opening the cone. Again, the viability of *Pinus gerardiana* seeds decreased after 12 months of short-term storage at room temperature (Malik and Shamet 2009). It has been revealed that in seeds stored at room temperature, that is, seeds that are not stored at low temperatures, deterioration, loss of viability and consequently low germination rates occur (Nasreen et al. 2004).

In *Pinus nigra*, 99% germination occurred in newly collected seeds, while a 91% germination percentage was obtained after 10 years of storage at 4-7 °C (Ürgenç 1973). In another study on *Pinus nigra*, it was determined that the GP of seeds stored for 10 years decreased from 96% to 58% and that storage humidity directly affected the viability of seeds (Temel et al. 2011). Atay et al. (1970) found that after 8 years of storage of larch and Scots pine seeds at +4 - +5 °C and about 8% moisture content, the initial GP did not change much in larch, but germination in Scots pine was halved at the end of storage. In another study, after 10 years of storage at 2 °C and -18 °C, the germination rate decreased by 20% at 2 °C and 15% at -18 °C (Hilli et al. 2003). *Pinus echinata* seeds were germinated after 10 years of storage at 6% moisture content and germination decreased by 32% (Barnett 1969). In *Pinus elliottii*, *Pinus patula*, *Pinus radiata* and *Pinus taeda*, both germination decreased and abnormal germination occurred after 15 years of storage (Donald and Jacobs 1990). *Pinus ponderosa* seeds collected from 20 different regions were stored at +5 °C and -16 °C for 22 years and it was found that both storage temperature and origin had no effect on germination percentage (Van Haverbeke and Peterson 1989).

Like storage time, germination temperature can also affect the germination behavior of seeds (Bewley and Black 1994; Schmidt 2000). The optimum germination temperature of seeds varies according to species, origin of collection and ecological characteristics. In general, the optimum germination temperature of plant seeds varies between 15 and 30 °C (Copeland and McDonald 1999). Although Turkish pine seeds germinate between 5-25 °C, the optimum germination temperature is between 15-20 °C (Şefik 1964; Thanos and Skordilis 1987; Thanos 2000). The germination percentage of Turkish pine seeds may vary according to factors such as elevation, aspect and pre-treatment (cold stratification, etc.) (Ürgenç 1977; Ürgenç et al. 1989; Skordilis and Thanos 1995; Çetin 2010; Çetin 2023). Çetin (2010) obtained the highest germination at 20 °C on average in seeds obtained from different regions and elevations, and also obtained very high germination at 15 °C in lower elevation zones. Skordilis and Thanos (1995) germinated Turkish pine seeds collected from three different latitudes at different temperatures, and while low germination was observed in seeds of northern origin, differences were observed in germination rates between origins at different germination temperatures.

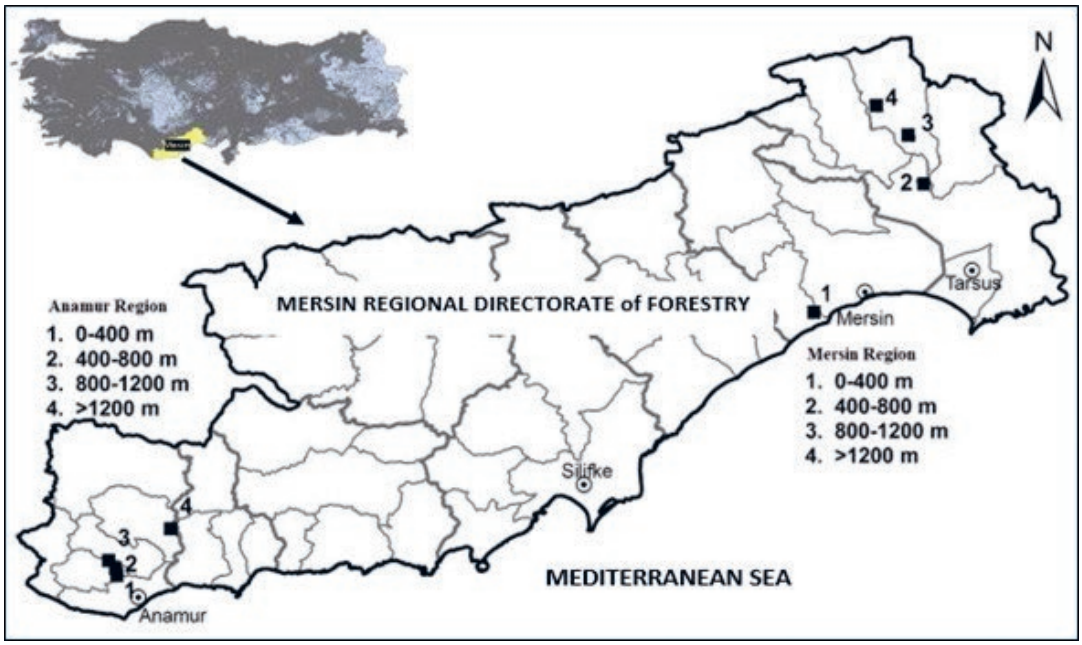

Figure 1. Seed collection regions
Slika 1. Regije sakupljanja sjemena

In summary, Turkish pine does not produce abundant seeds every year, and although it varies according to ecological regions, a rich seed year is observed every 2-3 years. For this reason, it is an important requirement to collect and store the seeds under appropriate conditions during abundant seed years and to meet the seed requirement from these stored seeds when necessary. In this respect, it is important to collect enough seeds in the abundant seed year and to collect and store, under appropriate conditions, the seeds required for sapling production in other years, for annual afforestation work, and for afforestation of burnt areas in a short while. In this study, Turkish pine seeds collected and stored from different regions and elevations were germinated at different germination temperatures and the effects of storage time and germination temperature on GP were investigated.

MATERIAL AND METHODS
MATERIJALI I METODE

Seed supply – *Opskrba sjemenom*

The seeds used in the study were obtained from four elevations: 0-400 m (Z1), 400-800 m (Z2), 800-1200 m (Z3) and >1200 m (Z4) in the Anamur and Mersin regions. The distance between these two regions is approximately 150 km and extends from the seaside to the inland (Figure 1).

The seed material used in the study was obtained from mature brown cones collected in July 2005 from natural red pine stands in the southern aspect. The trees from which the seed material was collected were 25-30 years old and older, from good sites, straight trunks, healthy and abundant cones (Table 1).

Table 1. Some topographical characteristics of the sites where the Turkish pine seeds used in the study were collected
Tablica 1. Neke topografske karakteristike lokacija na kojima je prikupljeno sjeme brucijskog bora korišteno u istraživanju

Regions Regije	Elevation zone (m) Visinska zona (m)	Height at which cones were collected (m) Visina na kojoj su sakupljeni češeri (m)	Aspect Aspekt	Latitude Zemljopisna širina	Longitude Zemljopisna dužina
Anamur	Z1	150±50	South	N:36° 07′ 26″	E:32° 47′ 06″
	Z2	500±50	South	N:36° 08′ 29″	E:32° 46′ 54″
	Z3	900±50	South	N:36° 09′ 36″	E:32° 45′ 53
	Z4	1300±50	South	N:36° 14′ 12″	E:32° 55′ 04″
Mersin	Z1	150±50	South	N:36° 42′ 34″	E:34° 20′ 14″
	Z2	500±50	South	N:37° 07′ 36″	E:34° 48′ 22″
	Z3	900±50	South	N:37° 13′ 48″	E:34° 47′ 16″
	Z4	1300±50	South	N:37° 13′ 13″	E:34° 39′ 10″

The collected cones were laid out on a flat surface and the cones were opened using the sun method. Water was sprinkled and stirred frequently to accelerate the opening of the cones. The seeds emerging from the cones were separated from the scales manually and by using simple tools, and after cleaning, the seeds were laid out again and allowed to air-dry.

While seed moisture content percentages were 8.31, 8.53, 8.48, 8.19 respectively at the elevation levels of Anamur origin, they were 8.03, 8.28, 8.20, 8.01 at Mersin origin. Seeds were placed in closed glass jars and stored in the refrigerator (2-4 °C) until germination tests were performed. Seed moisture was checked periodically during the storage period.

Germination of seeds – *Klijanje sjemena*

Germination tests were carried out in glass Petri dishes with a diameter of 9 cm by placing them on filter paper in such a way that they did not touch each other. Seeds were germinated at 15, 20 and 25 °C ambient temperature and germination period was 28 days. The study was conducted with 2 sections x 3 germination temperatures x 4 elevations x 7 different years x 4 replications x 50 seeds = 33,600 seeds. Seeds with radicles as long as the seed length were considered germinated (Kamra and Simak 1968).

The first germination was carried out in 2005 when the seeds were collected and subsequent germination tests were carried out in 2010, 2012, 2014, 2016, 2018 and 2020. After the first germination in 2005, the second germination was carried out 5 years later in 2010 because Turkish pine seeds are generally considered to be medium-lived seeds which maintain their viability in the first 5 years and can be stored (Ürgenç and Odabaşı 1971: Saatçioğlu 1971). After 2010, germination was carried out every 2 years in order to reveal the changes that may occur in the GP during the storage process in more detail.

GP was calculated for the germinated seeds using the following formula:

$$GP\ (\%) = \frac{\sum ni}{N} x100$$

GP (%): Germination percentage
ni: The number of germinated seeds on day i
N: The total number of tested seeds

Statistical analyses – *Statističke analize*

The germination rate in each zone in both Anamur and Mersin region was compared for the 15, 20 and 25 °C temperatures. The SAS software was used in the statistical analysis of the data and the results were accepted as different at a significance level of α = 0.05 (Sas Inst. 1996). For variables whose ANOVA results differed, the Tukey mean separation test was performed at a significance level of α = 0.05.

RESULTS
REZULTATI

Considering the average of all regions and zones, the effect of storage periods on germination percentage (GP) according to germination temperatures was found to be statistically insignificant (Figure 2). When germination percentages were evaluated according to germination temperatures, GP of seeds germinated at 15 °C in all zones decreased from 46.9% to 33.9%, from 69.2% to 61.3% at 20 °C and from 46.1% to 22.9% at 25 °C in 2020 compared to 2005. Considering these results, the highest decrease was at 25 °C with

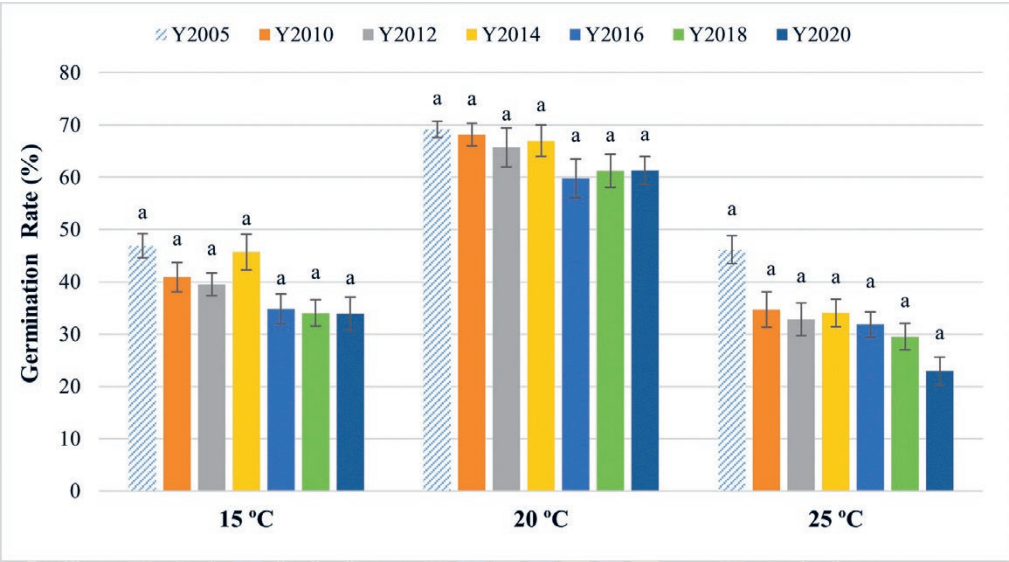

Figure 2. Effect of storage periods on GP according to germination temperatures
Slika 2. Utjecaj razdoblja skladištenja na GP prema temperaturama klijanja

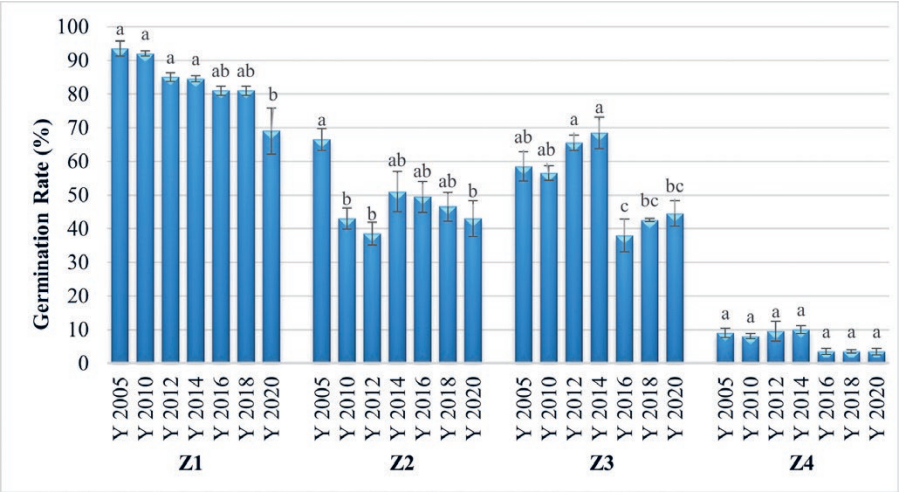

Figure 3. Germination percentages of seeds collected from different elevations in the Anamur region and germinated at 15 °C. (In each zone, means followed by the same lowercase letter are not significantly different at $\alpha = 0.05$ (bars are standard errors))

Slika 3. Postoci klijavosti sjemena prikupljenog s različitih nadmorskih visina u regiji Anamur i klijalog na 15 °C. (U svakoj zoni srednje vrijednosti iza kojih slijedi isto malo slovo ne razlikuju se značajno pri $\alpha = 0,05$ (stupci su standardne pogreške))

50.4%, while the lowest decrease was 27.7% at 15 °C. According to the average of all the sites and zones, the highest GP was obtained at the germination temperature of 20 °C and the lowest decrease in GP during the storage period was also obtained at this temperature (Figure 2).

When the effect of storage time on GP of the seeds collected according to region, germination temperature and elevation zone is examined, the effect of storage time varies according to region, germination temperature and elevation zone.

In Anamur Z1 seeds germinated at 15 °C, an average of 83% germination was obtained as a result of 15 years of storage and in general, the seeds in this zone maintained the germination values of the first year (2005) during the storage period. In Z2, the GP decreased from the fifth year of storage and continued at the same rate in the following storage periods. In Z3, 11 years of storage did not significantly change the initial GP, while a decrease was observed after 11 years. In Z4, the germination rate during the storage period did not change compared to the initial germinations (Figure 3).

At 15 °C germination temperature, the germination percentages were maintained throughout the storage period in Z1, Z2 and Z4 of the Mersin region. However, after 11 years of storage in Z3, the germination rate decreased by more than half to about 10% (Figure 4).

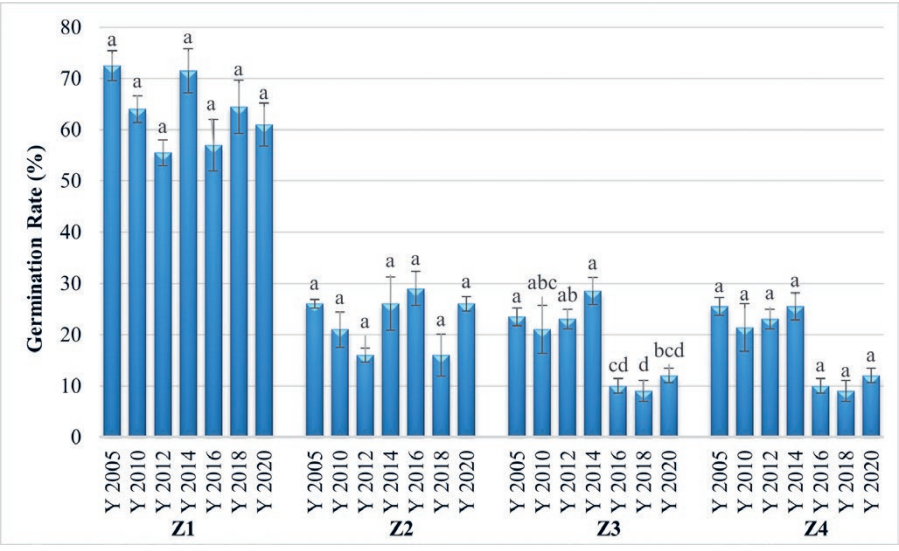

Figure 4. Germination percentages of seeds collected from different elevations in the Mersin region and germinated at 15 °C. (In each zone, means followed by the same lowercase letter are not significantly different at $\alpha = 0.05$ (bars are standard errors))

Slika 4. Postoci klijavosti sjemena prikupljenog s različitih nadmorskih visina u regiji Mersin i klijalog na 15 °C. (U svakoj zoni srednje vrijednosti iza kojih slijedi isto malo slovo ne razlikuju se značajno pri $\alpha = 0,05$ (stupci su standardne pogreške))

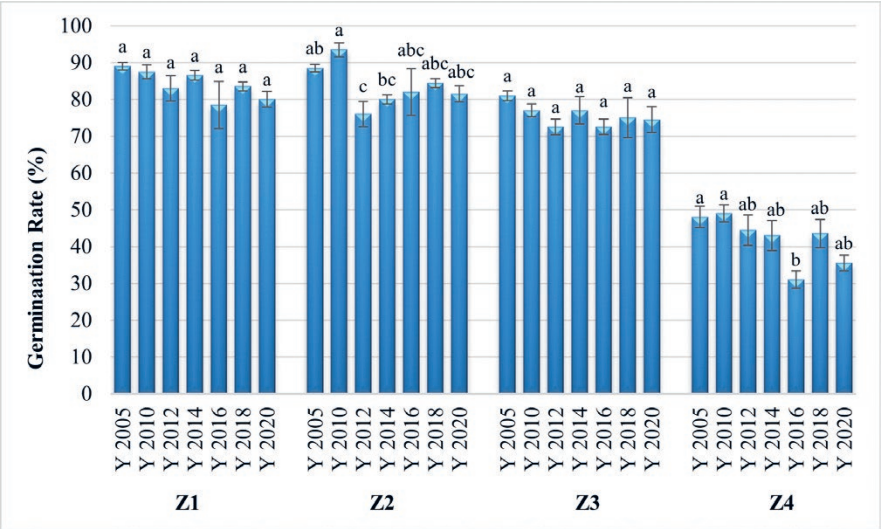

Figure 5. Germination percentages of seeds collected from different elevations in the Anamur region and germinated at 20 °C. (In each zone, means followed by the same lowercase letter are not significantly different at $\alpha = 0.05$ (bars are standard errors))

Slika 5. Postoci klijavosti sjemena sakupljenog s različitih nadmorskih visina u regiji Anamur i klijalog na 20 °C. (U svakoj zoni srednje vrijednosti iza kojih slijedi isto malo slovo ne razlikuju se značajno pri $\alpha = 0,05$ (stupci su standardne pogreške))

Seeds collected in the Anamur region and germinated at 20 °C maintained their initial germination rates throughout the storage period in Z1 and Z3. Although there was a slight decrease in germination in Z2 and Z4, germination percentages did not change much in general. The course of germination in these zones showed some fluctuations over the years (Figure 5).

Seeds collected in the Mersin region and germinated at 20 °C preserved the germination percentages in Z1 and Z4 to a great extent. However, Z2 showed a decrease in GP as the storage period was prolonged, while Z3 seeds showed increases and decreases in germination according to the first year germination percentages throughout the storage period (Figure 6).

Seeds collected in the Anamur region and germinated at 25 °C showed a 50% decrease in germination compared to the initial germination at the end of 15 years of storage in all zones (Figure 7). In Z1, Z2 and Z3, there was a significant decrease in GP in the 5th year of storage, while in Z3, there was a decrease in GP after 11 years of storage.

Seeds collected in the Mersin region and germinated at 25 °C showed significant decreases in germination percentages after the first 5 years (2010) in all zones. After 2010, the decline continued but decreased after this year (Figure 8).

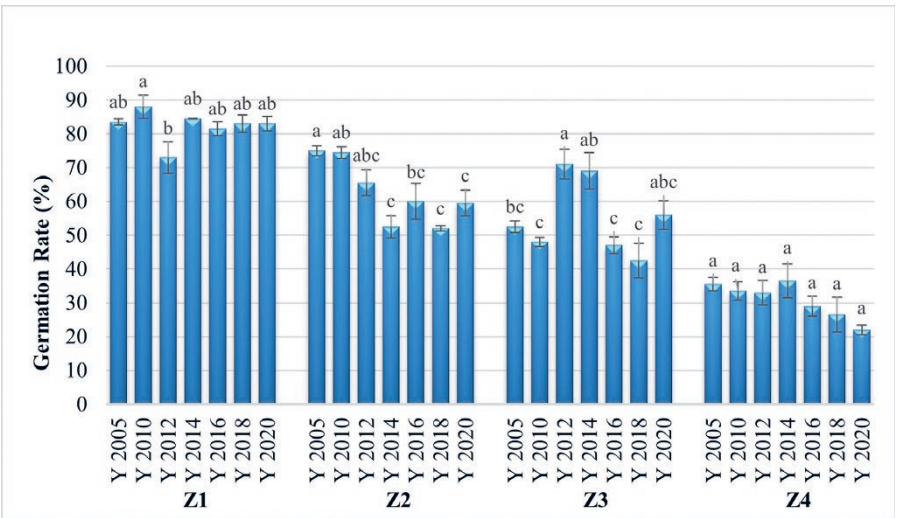

Figure 6. Germination percentages of seeds collected from different elevations in the Mersin region and germinated at 20 °C. (In each zone, means followed by the same lowercase letter are not significantly different at $\alpha = 0.05$ (bars are standard errors))

Slika 6. Postoci klijavosti sjemena prikupljenog s različitih nadmorskih visina u regiji Mersin i klijalog na 20 °C. (U svakoj zoni srednje vrijednosti iza kojih slijedi isto malo slovo ne razlikuju se značajno pri $\alpha = 0,05$ (stupci su standardne pogreške))

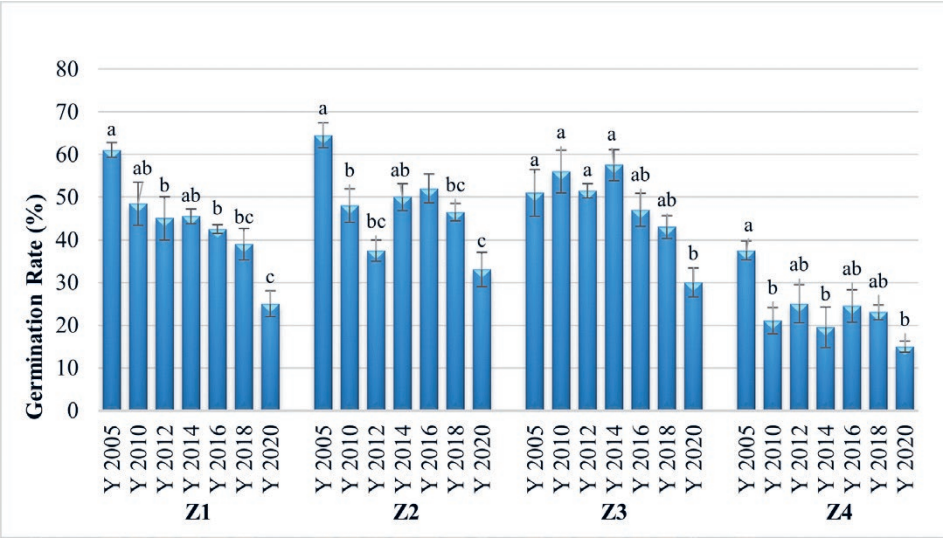

Figure 7. Germination percentages of seeds collected from different elevations in the Anamur region and germinated at 25 °C. (In each zone, means followed by the same lowercase letter are not significantly different at $\alpha = 0.05$ (bars are standard errors))

Slika 7. Postoci klijavosti sjemena sakupljenog s različitih nadmorskih visina u regiji Anamur i klijalog na 25 °C. (U svakoj zoni srednje vrijednosti iza kojih slijedi isto malo slovo ne razlikuju se značajno pri $\alpha = 0,05$ (stupci su standardne pogreške))

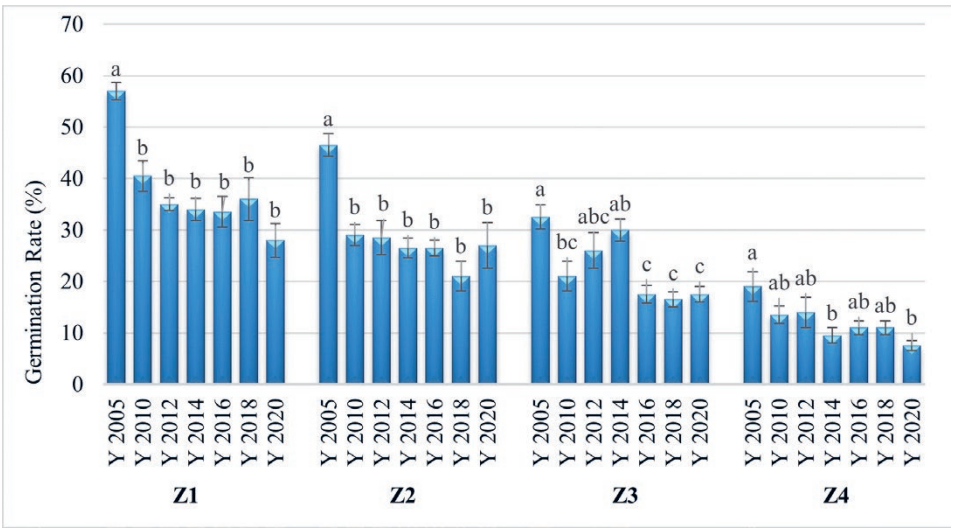

Figure 8. Germination percentages of seeds collected from different elevations in the Mersin region and germinated at 25 °C. (In each zone, means followed by the same lowercase letter are not significantly different at $\alpha = 0.05$ (bars are standard errors))

Slika 8. Postoci klijavosti sjemena sakupljenog s različitih nadmorskih visina u regiji Mersin i klijalog na 25 °. (U svakoj zoni srednje vrijednosti iza kojih slijedi isto malo slovo ne razlikuju se značajno pri $\alpha = 0,05$ (stupci su standardne pogreške))

DISCUSSION
RASPRAVA

The germination percentage of Turkish pine seeds varies according to the region and elevation where the seeds were collected. In general, the highest germination rate is observed in seeds collected at the Z1 elevation step of each region. The effect of regions and zones on the germination rate of Turkish pine seeds was discussed in detail by Çetin 2010. In this study, the stored seeds were germinated at different germination temperatures and the effect of storage time on GP was investigated.

Regardless of the region and zone differences, the highest average germination rate (up to 70%) was obtained at a germination temperature of 20 °C and this rate did not change significantly during storage. Çetin (2010), who investigated the germination characteristics of the same study in the year of seed collection, found that the highest average germination was at 20 °C in seeds obtained from different regions and elevations. In addition, although Turkish pine seeds germinate between 5-25 °C, it has been stated stated in different studies that the optimum germination temperature is between 15-20 °C (Şefik 1964; Thanos and Skordilis 1987;

Thanos 2000). At other germination temperatures (15 °C and 25 °C), the GP values, which were initially lower than 20 °C, did not change significantly during the storage periods (Figure 2). There are many studies in the literature indicating that long-term storage of seeds stored at optimum storage temperature does not have a negative effect on the GP of seeds. For example, Atay et al. (1970) reported that after 8 years of storage of larch seeds at +4 and +5 °C and approximately 8% moisture content, the GP of larch seeds, which was 99% at the beginning, did not change significantly (94%) after eight years. It was also reported that after storage of *Pinus resinosa*, *Pinus banksiana*, *Pinus contorta* and *Pinus strobus* seeds at -20 °C and 7.3-10.7% humidity for 42, 40, 33 and 23 years, seed GP was 83%, 87%, 90% and 97%, respectively, and did not vary significantly from the initial value (Simpson et al. 2004). On the other hand, in a study investigating the effect of 22 years of storage at 5 °C and -16 °C on the GP of *Pinus ponderosa* seeds collected from 20 different regions, the average GP was found to be 64% at both storage temperatures and it was reported that storage temperature had no effect on GP (Van Haverbeke and Peterson 1989). No loss of viability was observed in *Pinus ponderosa* seeds stored at 0 °C for 7 years (Allen 1957).

After 25 years of storage of *Pinus elliottii*, *Pinus patula*, *Pinus radiata* and *Pinus taeda* seeds at room temperature, 2-3 °C and -16 °C, it was reported that the seeds of the other three species, except *Pinus radiata* seed, still had an average GP of 65% after 10 years. There were no problems in obtaining seedlings from seeds of the four species stored at -16 °C for 25 years (Donald and Jacobs 1990).

However, depending on the regions and zones of Turkish pine from which seeds were collected, significant differences in GP may occur depending on the storage period. In the Anamur region, storage time at germination temperatures of 15 °C (except Z4) and 25 °C decreased GP, while at 20 °C GP did not change during storage. In the Mersin region, storage time at germination temperatures of 15 °C (except Z3) and 20 °C (except Z2) had no effect on GP, while storage time at germination temperature of 25 °C significantly decreased GP. According to these results, it can be said that seed characteristics may vary according to the region and elevation where the Turkish pine seeds were collected and that these differences may vary according to the storage period. Ürgenç and Odabaşı (1971) collected Turkish pine cones from different origins and stored them at both room temperature and low temperature (5-7 °C) for 8 years and reported that there were generally decreases in GP. Although there were differences in germination between these origins, germination above 50% was obtained in all origins. However, they stated that storage temperature is important in long-term storage. Similarly, Temel et al. (2011) reported that after 10 years of storage of seeds of 23 different populations of *Pinus nigra*, the percentage of germination decreased from 99.9% in the year of collection to 58.4%. It was emphasized that environmental factors such as humidity and elevation of the region where the seeds were collected were also effective in the decrease in germination percentages.

Similar results were found in many studies on the storage period of seeds of other coniferous tree species. For example, after storage of yellow pine seeds at 5-7 °C and room temperature for 1-1.5 years, 3-3.5 years and 5-5.5 years, while the GP was almost equal to the initial values under storage conditions at 5-7 °C, the GP decreased significantly in samples stored at room temperature for 5.5 years (Boydak 1984). In another study, after 10 years of storage at -18 °C and 2 °C, the GP decreased by 15% and 20%, respectively (Hilli et al. 2003). Atay et al. (1970) reported that after 8 years of storage of larch and Scots pine seeds at +4 - +5 °C and about 8% moisture content, while there was no significant decrease in GP in larch, GP in Scots pine decreased from 83% to 42%.

Apart from pine species, in Eastern spruce (*Picea orientalis* L.), after seeds of 18 different origins were stored at 0-5 °C for 9 years, the GP of the seeds decreased between 41% and 79.1% and these decreases in GP were also different between origins (Göktürk et al., 2019). Regarding the storage time and temperature of *Picea orientalis* seeds, Saatçioğlu (1971) stated that *Picea orientalis* seeds can be stored for 5-6 years between -3 and -15 degrees, while seeds stored at room temperature for 10 years lost their germination properties (Ürgenç 1960). Suszka et al. (2005) found that the germination capacity of *Picea abies* L. seeds decreased by 5% after 12 years of storage (at -3 °C) and by 15% after 29 years of storage (17 years at -5 and -6 °C and 12 years at -3 °C). Bonner (2008) also reported that the survival rate of *Picea sitchensis* (Bong.) seeds decreased by 0-8% after 18 years of storage (2-4 °C).

The results of this and other studies show that storage temperature, storage time, seed moisture and the origin from which the seeds were collected are effective in seed storage. Especially for most of the pine species stored as orthodox, when appropriate storage conditions (humidity and low storage temperature, etc.) are provided, the seeds can be stored for many years without losing their germination properties (Simpson et al. 2004).

CONCLUSIONS
ZAKLJUČAK

Turkish pine does not produce abundant seeds every year, but seedlings and therefore seeds are needed every year in forestry work. Therefore, there is a need for continuous seedling production and a ready stock of seeds that can be used for the continuity of Turkish pine forests and the afforestation of these areas in a short time as a result of unexpec-

ted events such as fire. In this study, it was observed that the seeds collected at altitudes between 0-1200 m in the Anamur region and between 0-400 m in the Mersin region maintained their initial 80-90% germination percentages at 20 °C even under long storage conditions such as 15 years. At germination temperatures other than 20 °C, which is considered to be the optimal germination temperature, the GP decreases. In addition, although there is a small difference according to germination temperature and zones, it can be said that Turkish pine seeds stored at the appropriate temperature for 15 years, provided that they are germinated at 20 °C, preserve their germination properties to a great extent and can be stored for many years. However, since the duration of this storage period varies according to the region and elevation, it was observed that the storage period may vary according to the place of origin where the seed was collected. It is recommended that these issues should be taken into consideration when storing seeds.

REFERENCES
LITERATURA

- Allen, G. S., 1957: Storage behavior of conifer seeds in sealed containers held at 0 °F, 32 °F and room temperature. Journal of Forestry, 55, 278–281.
- Anonim, 2020: Orman Genel Müdürlüğü, Türkiye Orman Varlığı. Orman Genel Müdürlüğü Yayınları, 58 s. Ankara.
- Anonim, 2021: Orman Genel Müdürlüğü Resmi Ormancılık İstatistikleri, Ankara.
- Atay, İ., S. Ürgenç, T. Odabaşı, 1970: Karaçam, Sarıçam ve Doğu Ladini tohumlarının 8 yıllık saklama deneme sonuçları, İ.Ü. Orman Fakültesi Dergisi Seri A, 20 (2), 68-80.
- Barnet, J., 1969: Long-term storage of longleaf pine seeds, Tree Planters Notes, 20: 22-25.
- Bewley, J. D., M. Black, 1994: Seeds: Physiology of Development and Germination. Plenum Press, New York, 445pp.
- Bonner, F. T., 2008: Storage of Seeds, p. 85-87. In: Bonner FT, Karrfalt RP (Eds.). The Woody Plant Seed Manual. Agriculture Hand Book 727, USDA Forest Service.
- Boydak, M., 1984: Sarıcam (*Pinus silvestris* L.) ve karaçam (*Pinus nigra* Arnold. subsp. *Pallasiana* (Lambn.) Holmboe) tohumlarında olgunlaşma zamanı ile saklama sureleri arasındaki ilişkiler İ.Ü. Orman Fakültesi Dergisi. Seri A. Cilt 34. Sayı 2. s. 104-125.
- Boydak, M., H. Dirik, M. Çalıkoğlu, 2006: Kızılçamın (*Pinus brutia* Ten.) Biyolojisi ve Silvikültürü, OGEM-Vakfı Yayınları, 364 s. Ankara.
- Copeland, L. O., M. B. McDonald, 1999: Seed Science and Technology. Kluwer Ac. Pub. Boston, 409 p.
- Çetin, B., 2010: Mersin Yöresinde Kızılçam (*Pinus brutia* Ten.) Kozalak ve Tohumuna Ait Bazı Özelliklerin Yükseltiye Bağlı Değişimi (Doktora Tezi). İ.Ü. Fen Bilimleri Enstitüsü, 185.
- Çetin, B., 2023: The effect of altitude and closed cone (seed) age on germination in red pine (*Pinus brutia* Ten.). Šumarski list, 147 (3-4), 129-135.
- Donald, D. G. M., C. B. Jacobs, 1990: The effect of storage time, temperature and container on the viability of the seed of four pine species. South African Forestry Journal, 154 (1) 41-46.
- Gosling, P., 2007: Raising Trees and Shrubs from Seed. Forestry Commission Practice Guide, Edinburgh.
- Göktürk, A., İ. Solhan, F. Temel, Z. Ölmez, 2019: Saklama Süresinin Doğu Ladini (*Picea orientalis* L.) Tohumlarının Çimlenme Yüzdesi ve Hızı Üzerine Etkisi, Bartın Orman Fakültesi Dergisi. 21 (1) 182-190.
- Hilli, A., E. Tillman-Sutela, A. Kauppi, 2003: Germination of pretreated Scots pine seeds after long-term storage, Canadian Journal of Forest Research, 33 (1) 47-53.
- Kamra S.H.,M., Simak, 1968: Germination studies on Scots pine (*Pinus sylvestris* L.) seed of different provenances under alternating and constant temperatures. Studia Forestalia Suecica 62.14 p.
- Malik, A. R., G. S. Shamet, 2009: Storage of *Pinus gerardiana* seeds: biochemical changes and its applicability as vigour test. Research Journal of Seed Science.
- Nasreen, S., B. R. Khan, A. S. Mohmad, 2004: The effect of storage temperature, storage period and seedmoisture content on seed viability of soya bean, Pakistan Journal of Biological Science, vol. 3, no. 12, pp.
- Pradhan B. K., H. H. Badola, 2012: Effects of microhabitat, light and temperature on seed germination of a critically endangered Himalayan medicinal herb, Swertia chirayita: Conservation implications. Plant Biosystems 146 (2):345– 351.
- Saatcioğlu, F., 1971: Orman AğacıTohumları. 3. Baskı, İ.U. Yayın No:1649, Orman Fakültesi Yayın No:173, İstanbul, 242 s.
- Schmidt, L., 2000: Guide To Handling of Tropical and Subtropical Forest Seed, Danida Forest Seed Centre, Denmark, 511 pp.
- Simpson, J. D., B. S. P., Wang, B. I. Daigle, 2004: Long-term seed storage of various Canadian hardwoods and conifers, Seed Science and Technology, 32 (2), pp. 561-572.
- Skordilis, A., C. A. Thanos, 1995: Seed stratification and germination strategy in the Mediterranean pines *Pinus brutia* and *Pinus halepensis*, Seed Science Research, 5, p. 151-160.
- Suszka, B., P. Chmielarz, R. Walkenhorst, 2005: How long can seeds of spruce (*Picea abies* (L.) Karst.) be stored? Ann. For. Sci., 62, 73-78.
- Şefik, Y., 1964: Kızılçam (*Pinus brutia* Ten.) kozalak ve tohumu üzerine araştırmalar, İ.Ü. Orman Fakültesi Dergisi, Seri A, Cilt XIV, Sayı 2, s. 35-70.
- Temel, F., S. Gülcü, Z. Ölmez, A. Göktürk, 2011: Germination of Anatolian Black Pine (*Pinus nigra* subsp. *pallasiana*) Seeds from the Lakes Region of Turkey: Geographic Variation and Effect of Storage, Not Bot Hort Agrobot Cluj, 39(1):267-274.
- Thanos, C. A., A. Skordilis, 1987: The effects of light, temperature and osmotic stress on the germination of *Pinus halepensis* and *Pinus brutia* seeds, Seed Sciences and Technology, Volume: 15, p. 163-174.
- Thanos, C. A., 2000: Ecophysiology of seed germinatıon in *Pinus halepensis* and *Pinus brutia,* In: G. Ne'eman and L. Trabaud *(eds),* Ecology, Biogeography and Management of *Pinus halepensis* and *Pinus brutia* Forest Ecosystems in the Mediterranean Basin, p. 37-50, Backhuys Publisher, Leiden.

- Ürgenç, S., 1960: Doğu Ladininde (*Picea orientalis* L. Carr.) kozalak ve tohum üzerine araştırmalar, İ.Ü. Orman Fakültesi Dergisi, 68-97.
- Ürgenç, S., 1973: Cold storage test for 10 years on *Pinus nigra* var. *caramanica* and *Pinus brutia* Ten seeds. Proc International Symposium on Seed Processing-Seed Problems, Bergen, Norway. International Union of Forestry Research Organizations. Volume I, Paper No:18,
- Ürgenç, S., T. Odabaşı, 1971: Kızılçam (*Pinus brutia* Ten.) tohumlarının uzun süreli (7 yıl) kozalak içinde saklanmasının diğer saklama metotlarıyla mukayeseli sonuçları, İ.Ü. Orman Fakültesi Dergisi, Seri A, Cilt 21, Sayı 2, s. 82-93.
- Ürgenç, S., 1977: Antalya yöresi alçak ve yüksek kademe kızılçam ormanlarında tohum veriminin değişimi (5 yıllık araştırma sonuçları), İ.Ü. Orman Fakültesi Dergisi, Seri A, Cilt 27, Sayı 2, s. 80-114.
- Ürgenç, S., M. Boydak, T. Özdemir, B. Ceylan, Ü. Eler, 1989: Kızılçam (*Pinus brutia* Ten.) meşçerelerinde aralama ve hazırlama kesimlerinin tepe gelişimi ve tohum hasılatına etkileri üzerine araştırmalar, Ormancılık Araştırma Enstitüsü Yayınları, Teknik Bülten No. 210, 69 s.
- Van Haverbeke, D., G. W. Peterson, 1989: Effect of Storage Temperature on Germination of Seeds of Twenty Sources of Ponderosa Pine. Rocky Mountain Forest and Range Experiment U.S. Forest Service Research Note, 480-525 Sayılar.
- Yahyaoğlu, Z., Z. Ölmez, 2003: Tohum Teknolojisi ve Fidanlık Tekniği Ders Notu, Kafkas Üniversitesi Artvin Orman Fakültesi Yayın No: 2, Artvin, 114 s.
- Yaltırık, F., 1993: Dendroloji ders kitabı I. *Gymnospermae* (Açık Tohumlular) İ.Ü. Orman Fakültesi Yayını, No. 34432/386, 320 s., İstanbul.

SAŽETAK

U ovoj studiji, sjeme brucijskog bora (*Pinus brutia* Ten.), koji je najrasprostranjenija vrsta borova u Turskoj, prikupljeno je u regijama Anamur i Mersin 2005. godine s četiri nadmorske visine: 0-400, 400-800, 800-1200 i iznad 1200 metara (m). Ovo sjeme je skladišteno na +2-4 °C i klijalo je na temperaturama od 15, 20 i 25 °C 2005., 2010., 2012., 2014., 2016., 2018. i 2020. godine. Istraživan je utjecaj vremena skladištenja na postotak klijavosti (GP). Prema općem prosjeku, nije bilo značajne promjene u GP-u sjemena s produljenjem razdoblja skladištenja. Međutim, učinak vremena skladištenja na GP varirao je ovisno o regiji, nadmorskoj visini i temperaturi klijanja. Posebice kod klijanja na 20 °C u nižim nadmorskim visinama, GP se nije puno promijenio na kraju razdoblja od 15 godina ili je uglavnom zadržao stope klijavosti iz 2005. godine. U ostalim zonama dobiveno je 80% početne klijavosti u većini zona, iako je došlo do blagog pada na kraju razdoblja skladištenja. Na 15 °C, pad klijavosti bio je vrlo beznačajan u prvim godinama u oba dijela, ali je postao značajan u sljedećim godinama. Na 25 °C pad klijavosti bio je veći nego na drugim temperaturama klijavosti, a pad je počeo od 5. godine pa nadalje, da bi na kraju razdoblja od 15 godina klijavost pala između 38,0-61,0%. Kao rezultat toga, nakon 15 godina skladištenja sjemena brucijskog bora, primijećeno je da se na 20 °C GP značajno održao, dok se na drugim temperaturama klijanja pad klijavosti povećavao kako se produžilo razdoblje skladištenja. U slučaju skladištenja sjemena vrste, razdoblje skladištenja treba odrediti uzimajući u obzir regiju i nadmorsku visinu na kojoj je sjeme sakupljeno.

KLJUČNE RIJEČI: *Pinus brutia*, vrijeme skladištenja, nadmorska visina, temperatura klijanja