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MORPHOLOGICAL AND PHYSIOLOGICAL SEED CHARACTERISTICS OF TAURUS FIR (*ABIES CILICICA* /ANT. ET KOTSCHY/ CARRIÉRE) IN TURKEY

Morfološka i fiziološka svojstva sjemena cilicijske jele (*Abies cilicica* /Ant. et Kotschy/ Carriére) u Turskoj

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Summary:

Taurus fir (*Abies cilicica* /Ant. et Kotschy/ Carriére) is a tree species mostly found in the Taurus mountains in Turkey. The objective of this study was to determine the morphological and physiological characteristics of the seed of the Taurus fir. The seeds were collected from five different provenances of natural distribution, including Göksun, Saimbeyli, Kozan, Anamur, and Bucak. In the laboratory, for each of the different provenances, we measured the1000-seed weight; the length, width, and thickness of the seeds; and the weights of the individual seeds. The morphological characteristics of the seeds varied according to their provenances. To determine the necessary duration of pre-chilling, we attempted to germinate the seeds from each of the five different provenances, after pre-chilling at 4 °C for 0, 2, 4, and 6 weeks. We determined that the optimum pre-chilling duration was six weeks. In order to determine the optimum germination temperature, the seeds from three provenances were subjected to a germination test at each of four different temperatures (12, 16, 20, and 24 °C) after three different pre-chilling durations (2, 4, and 6 weeks). This resulted in various germination rates and speeds. The seeds germinated best at 20 °C and 24 °C.

KEY WORDS: *Abies cilicica*, seed, dormancy, pre-chilling, germination

INTRODUCTION
UVOD

The Taurus Fir (*Abies cilicica* /Ant. et Kotschy/ Carriére), a shade-tolerant tree growing to 35 m, is found only in Turkey, Syria, and Lebanon. Their distribution is limited in Lebanon and Syria, and the largest concentration is in southern Turkey, primarily in the deep valleys and north-facing slopes of the Taurus Mountains, at elevation from 1150 m to 2000 m (Bozkuş 1988). The wood of *A. cilicica* has been utilized for many different purposes, including furniture, paneling, boxes, packaging, boards, and toys. The ecological amplitude of this species is comparatively limited (M'Hirit 1999). *A. cilicica* is represented by two subspecies (Davis 1965-1985; Yaltırık 1993): (1) *A. cilicica* subsp. *cilicica* occurs in the eastern part of its range, and it is identified by its buds, which have no resin, and by the hairy shoots it forms when young; (2) *A. cilicica* subsp. *isaurica* Coode et Cullen has glabrous shoots when young and resinous buds, and is distributed in the West Taurus (Browicz 1982).

There are about 40 species of fir, and they are generally sensitive to environmental effects (Yaltırık 1993; Edwards 2008). In recent decades, a decline in the number of fir spe-

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Table 1. Seed materials collected from five different provenances.
Tablica 1 Sjemenski materijal iz pet provenijencija na području Turske

Provenance Provenijencija	Subspecies Vrsta/podvrsta	Latitude Geogr. širina	Longitude Geogr. dulj.	Altitude Nadmorska Visina (m)	Aspect Ekspozicija
Göksun (K.Maraş)	*A. cilicica* subsp. *cilicica*	38°02′	36°24′	1650	North
Saimbeyli (Adana)	*A. cilicica* subsp. *cilicica*	38°01′	36°04′	1450	North
Kozan (Adana)	*A. cilicica* subsp. *cilicica*	37°45′	35°35′	1400	North
Anamur (Mersin)	*A. cilicica* subsp. *isaurica*	36°17′	32°54′	1414	North
Bucak (Burdur)	*A. cilicica* subsp. *isaurica*	37°23′	30°37′	1350	North

cies has been recorded in many locations and species throughout the northern hemisphere (Raftoyannis et al. 2008; Kvitko et al. 2011; Politi et al. 2011; Ficko et al. 2011). Loss of the Taurus Fir is also of current concern in the Taurus Mountains (Kanat and Laz 2005).

The reproductive system of the various species of *Abies* is generative, and the natural regeneration period depends on the production of seed, the proportion of those seeds that are sound, the germination rate, and the successful formation of seedlings (Owens and Molder 1985; Crawford and Oliver 1990; Rawat et al. 2008). Seed dormancy is very prevalent in *Abies* seeds, and cold-moist stratification is often applied in order to eliminate this (Gogala and Vardjan 1989; Edwards 1996; Jensen 1997). On the other hand, the correct germination temperature is generally very effective at causing germination, and a wide temperature range implies seed vigor (Grabe 1976; Yilmaz 2008).

The Taurus Fir has the largest cones and seeds among all fir trees (RBG Kew 2014), but neither the morphological nor the physiological characteristics of its seeds have been extensively studied. Understanding how the seeds of this species vary between the different provenances of this species is important both in theory and in practice.

In this study, both the morphological (length, width, thickness, and weight) and physiological (dormancy level and pretreatments) characteristics of the seed of the Taurus Fir were investigated for the seeds collected from five different provenances. The effects of temperature on the germination behavior were also checked for the seeds of three provenances.

MATERIAL AND METHODS
MATERIJALI I METODE

Seed materials – *Sjemenski materijal*

The seeds were collected from five different provenances in southern Turkey in October, 2009 (Table 1; Figure1). Of species collected at the five provenances, three of them were

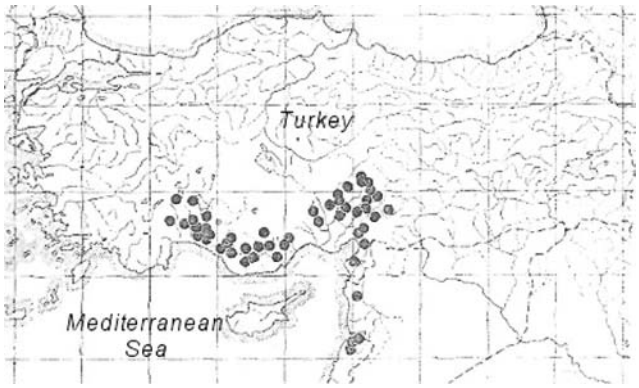

Figure 1. The natural distribution of A. cilicica (Ant. et Kotschy) Carriére (Browicz 1982).
Slika 1. Područje prirodnog rasprostiranja A. cilicica (Ant. et Kotschy) Carriére (Browicz 1982).

A. cilicica subsp. *cilicica*, eastern distribution, and two of them were *A. cilicica* subsp. *isaurica* Coode et Cullen, western distribution. The seeds were air dried to 6 % MC, which took about a week, and they were then refrigerated in closed bottles until used.

Measurement of morphological characteristics – *Izmjera morfoloških svojstava sjemena*

50 seeds from each provenance were randomly selected and measured. For each seed, four traits (length, width, thickness, and weight) were measured. 1000-seed weights were also calculated from 800 (8 × 100) seeds according to the ISTA (1996) rules.

Dormancy Level and Pretreatment Requirements – *Stupanj dormantnosti i predsjetvena priprema*

To find out the dormancy level and the pre-chilling requirement of the species, seeds from five different populations (Table 1) were subjected to 0 (control), 2, 4, and 6 weeks (w) pre-chilling at 4 °C. Pretreatments were applied in plastic bottles covered with perforated aluminum foil in the dark. The top of the bottle was covered with perforated aluminum foil to allow for gas exchange. During the pretrea-

Table 2. Morphological characteristics of the seed of *A. cilicica.*
Tablica 2. Morfološka svojstva sjemena A. cilicica

Provenance Provenijencija	Length Duljina mm	Width Širina mm	Thickness Debljina mm	Weight Težina g	1000-seed weight Težina 1000 sjemenki g
Göksun	14.54ab	7.11b	4.38bc	0.150c	149.4
Saimbeyli	15.04a	7.30b	4.13c	0.169b	167.4
Kozan	13.97b	7.70a	4.66ab	0.162bc	161.3
Anamur	12.99c	6.51c	4.28c	0.165b	171.1
Bucak	14.74a	7.04b	4.73a	0.202a	198.9
Average – Prosječno	14.26	7.13	4.44	0.170	169.7

[1] The values on the same line followed by the same letters are not significantly different at $p < 0.01$
[1] Vrijednosti označene istim malim slovom ne razlikuju se na razini signifikantnosti od $p < 0.01$

tments, the bottles were weighed weekly to check for altered moisture content of the seeds, and distilled water was added by spraying, if needed. The germination tests were performed on two-layered filter paper in 15-cm diameter Petri dishes with 150 (3 × 50) seeds at 20 °C. Seeds were rinsed with distilled sterile water for five minutes prior to the germination test. The seeds were considered germinated when their radicles protruded 3 mm and showed geotropism. The Petri dishes were examined every two days, and the germinated seeds were counted and removed. Germination tests were terminated on day 28.

The effects of temperature – *Utjecaj temperature*

To determine the effect of temperature on the germination response, seeds from 3 different provenances (Bucak, Kozan, Saimbeyli) were pre-chilled without media for 2, 4, and 6 w in a refrigerator (4 °C). Pre-chilling was applied in the plastic bottles covered with perforated aluminum foil in the dark. Seeds were subjected to germination tests at 12 °C, 16 °C, 20 °C, and 24 °C after the pre-chilling treatments.

Germination Parameters – *Parametri klijanja*

In the germination tests, the germination percentage (GP) and mean germination time (MGT) were calculated according to the following formulas (Bewley et al. 2013):

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

where GP (%) is the germination percentage, n_i is the number of germinated seeds at week i, and N is the total number of incubated seeds per test; and

$$MGT = \frac{\sum (t_i . n_i)}{\sum n_i}$$

where MGT is the mean germination time, t_i is the number of weeks from the beginning of the test, and n_i is the number of germinated seeds recorded on week $t_{(i)}$.

Statistical Analyses – *Statistička analiza*

The data on seed weight, seed length, thickness, width, germination percentage, and mean germination time were analyzed using ANOVA. The treatment means were tested by Duncan's multiple range test. The percent values (GP) were normalized by transformation by the arcsine square root ($\sqrt{P}$), prior to the variance analyses.

RESULTS
REZULTATI

Morphological Characteristics – *Morfološka svojstva sjemena*

The average 1000-seed weight for the five provenances was 169.7 g at about 6 % MC. There were significant differences between provenances in terms of seed dimensions and weights (Table 2). The average seed length, width, thickness, and weight were 14.26 mm, 7.13 mm, 4.44 mm, and 0.170 g, respectively. The weight of the seed from Bucak was distinctly heavier than those from the other provenances.

Dormancy Level and Pretreatment Requirements – *Stupanj dormantnosti i predsjetvena priprema*

There were apparent differences between the pre-chilling treatments in terms of the percentage of seeds that germinated at 20°C (Table 3; Figure 1). Pre-chilling treatments of 2 and 4 w were insufficient, but 6 w of pre-chilling was found to totally eliminate seed dormancy and led to the highest GP.

The average GPs were 35.6 %, 55.7 %, 63.6 %, and 79.6 % after treatment with 0-w (control), 2-w, 4-w, and 6-w pre-chilling, respectively. About half of the seeds germinated without any pre-chilling. Following the 2-w and 4-w pre-chilling durations, some of the ungerminated were found to be sound, but after the 6-w pre-chilling, the ungerminated seeds were found to be either decayed or infected.

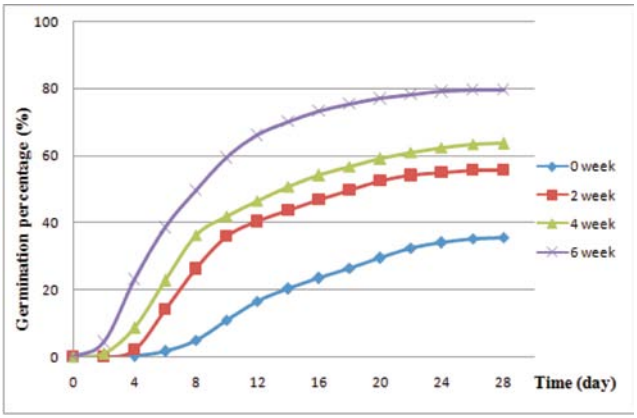

Figure 2. The overall average germination curve of five *A. cilicica* populations at germination temperature of 20 °C: fresh and after 2, 4, and 6 weeks pre-chilling duration.

Slika 2. Srednje ukupne krivulje postotka klijavosti pri temperaturi od 20 °C za pet provenijencija sjemena *A. cilicica:* svježe sjeme i nakon različito dugačke stratifikacije (2, 4 i 6 tjedana).

The dormancy level differed by provenance. The seeds from Saimbeyli reached their maximum GP after 2 w of pre-chilling, while those from the other s required about 6 w of pre-chilling for the dormancy to be completely removed. We also note that, after 6 w of pre-chilling, the GPs of the seeds from the various provenances differed.

There was a distinctive difference between the GPs for the seeds from different provenances after fully eliminating dormancy by pre-chilling for 6 w. The *A. cilicica* subsp. *cilicica* seeds from the Göksun, Saimbeyli, and Kozan provenances demonstrated the highest GPs, while the overall GPs of Anamur and Bucak (*A. cilicica* subsp. *isaurica*) were lower than those of other populations due to a lower germination potential (Table 2).

The pre-chilling duration also significantly affected the germination speed. The longer the pre-chilling period, the faster the germination occurred. Average MGT was 16.5, 13.2, 12.3, and 9.1 d at control (0-w), 2-w, 4-w, and 6-w duration of pre-chilling, respectively (Table 3). Population factor was also effective on the MGT. In general, the seeds of eastern populations (*A. cilicica* subsp. *cilicica*) germinated faster than those of western populations (*A. cilicica* subsp. *isaurica*).

The average GP and MGT for each of the five populations are clearly seen in Figure 2. With an increasing duration of pre-chilling, the average GP increases and the average MGT decreases.

Figure 3 clearly shows that the dormancy is less deep in the Saimbeyli and Göksun populations. After six weeks of pre-chilling, the germinations curves clearly fall into two groups. The eastern Taurus populations (those from Saimbeyli, Kozan, and Göksun) formed relatively similar germination curves, which show similarities in terms of the physiological characteristics of their seeds. Similarly, the western populations (Anamur and Bucak) demonstrated curves that were identical in terms of rate and speed of germination.

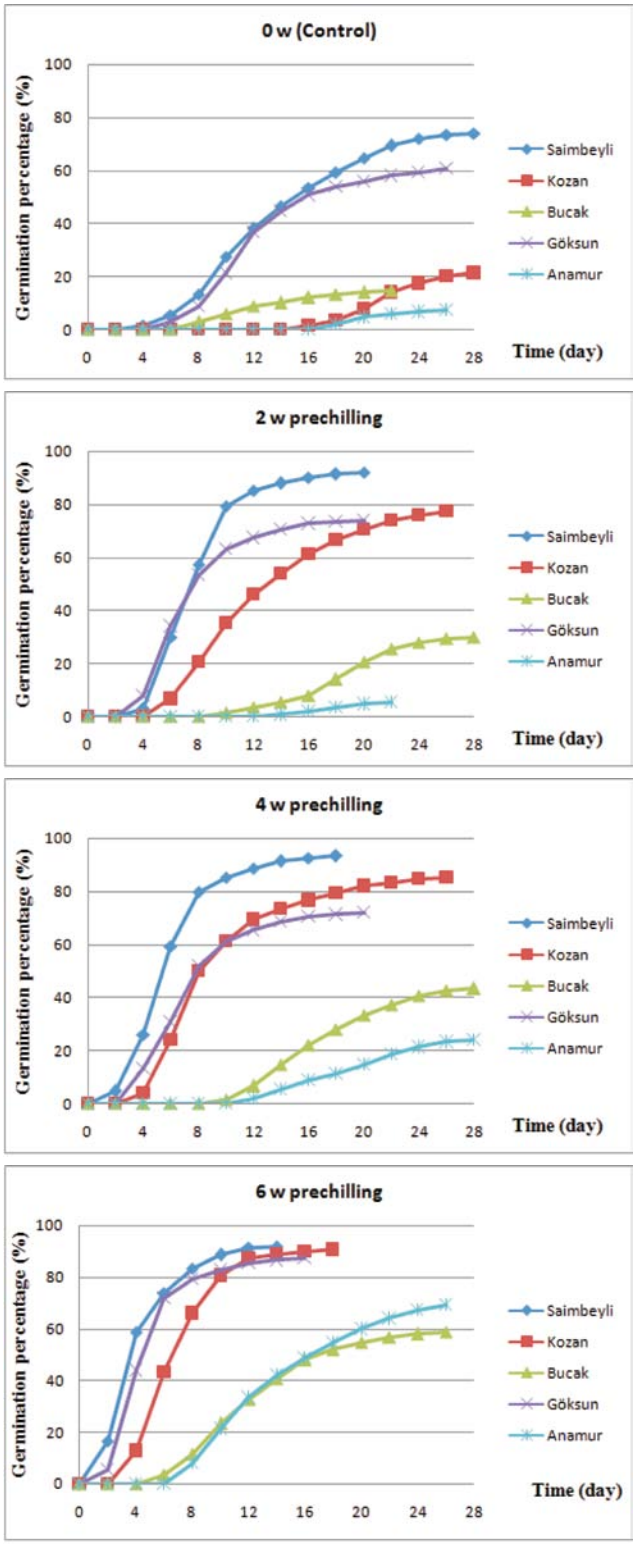

Figure 3. Germination curves of *A. cilicica* populations: fresh and after 2, 4, and 6 weeks pre-chilling duration.

Slika 3. Krivulje postotka klijavosti pet istraživanih provenijencija sjemena *A. cilicica* bez stratifikacije (kontrola) i nakon 2, 4 i 6 tjedana stratifikacije.

Table 3. Two, four, and six week pre-chilled *A. cilicica* seed germination percentages at 20 °C.
Tablica 3. Postoci klijavosti sjemena A. cilicica pri 20 °C bez stratifikacije i nakon 2, 4, i 6 tjedana stratificiranja,

Provenance Provenijencija	Pre-chilling Duration Trajanje stratifikacije				Average Prosječno
	0 (Control) kontrola	2 weeks 2 tjedna	4 weeks 4 tjedna	6 weeks 6 tjedana	
Göksun	60.7b[1]	74.0b	72.0b	87.3a	73.5B[2]
Saimbeyli	74.0b	92.0a	93.3a	92.0a	87.8A
Kozan	21.3c	77.3b	85.3ab	90.7a	68.7B
Anamur	7.3c	5.3c	24.0b	69.3a	26.5D
Bucak	14.7d	30.0c	43.3b	58.7a	36.7C
Average – Prosječno	35.6d	55.7c	63.6b	79.6a	

[1] The values on the same line followed by the same letters are not significantly different at $p < 0.01$
[1] Vrijednosti u istom retku označene istim malim slovom ne razlikuju se na razini signifikantnosti od $p < 0.01$
[2] The values on the same column followed by the same capital letters are not significantly different at $p < 0.01$
[2] Vrijednosti u istoj koloni označene istim velikim slovom ne razlikuju se na razini signifikantnosti od $p < 0.01$

Table 4. Mean germination times of *A. cilicica* seeds after different pretreatments at germination temperature of 20 °C.
Tablica 4. Srednje vrijeme klijanja sjemena *A. cilicica* pri temperaturi od 20 °C nakon različite predsjetvene pripreme.

Provenance Provenijencija	Pre-chilling Duration Trajanje stratifikacije				Average Prosječno
	0 (Control) kontrola	2 weeks 2 tjedna	4 weeks 4 tjedna	6 weeks 6 tjedana	
Göksun	13.1c[1]	8.0b	8.0b	5.6a	8.7A[2]
Saimbeyli	13.9d	8.6c	6.7b	5.0a	8.5A
Kozan	22.0d	12.8c	9.9b	7.7a	13.1B
Anamur	20.7c	17.8b	19.2bc	14.5a	18.1D
Bucak	12.9a	18.9b	17.5b	13.0a	15.6C
Average – Prosječno	16.5d	13.2c	12.3b	9.1a	

[1] The values on the same line followed by the same letters are not significantly different at $p < 0.01$
[1] Vrijednosti u istom retku označene istim malim slovom ne razlikuju se na razini signifikantnosti od $p < 0.01$
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[2] Vrijednosti u istoj koloni označene istim velikim slovom ne razlikuju se na razini signifikantnosti od $p < 0.01$

Effects of temperature on the germination behavior after different durations of pre-chilling – *Utjecaj temperature na klijavost sjemena nakon različitog trajanja stratifikacije*

In general, the effect of temperature, the duration of pre-chilling, the provenance of the population, and their interactions affected the GP and MGT (Table 5). Both pretreatment and population significantly affected the germination percentage of *A. cilicica* seeds. The pretreatment × population interaction effect was also found to be significant for GP.

After different durations of pre-chilling, the Taurus fir seeds had different GPs. The highest (76.2 %) and the lowest (56.3 %) were obtained after pre-chilling for 6 w and 2 w, respectively.

On average, these three populations reached their highest germination rates at 20 °C and 24 °C; there was no significant difference between the rates of germination at 20 °C and 24 °C. Similarly, at germination temperatures of 12 °C and 16 °C, there was no statistically significant difference between the percentages of germination. The germination percentages at 12 °C and 16 °C were significantly lower than those at 20 °C and 24 °C (Table 6).

There were significant differences between provenances in terms of the overall average percentage of germination. The seeds from Saimbeyli reached the highest germination percentage (89.3 %), while the seeds with the lowest germination percentage (38.2 %) were from Bucak.

A pre-chilling interval of 4 w and 2 w seems to be sufficient for Kozan and Saimbeyli, respectively, due to the reduced depth of their dormancy. On the other hand, germination rates generally increased as the duration of pre-chilling was extended.

Table 5. Effects of temperature on germination percentage (GP) and mean germination time (MGT) of *A. cilicica* seeds, results of a factorial ANOVA.
Tablica 5. Utjecaj temperature na postotak klijavosti (GP) i srednje vrijeme klijanja (MGT) sjemena *A. cilicica*, rezultat provedene čimbenične ANOVA-e

Source	df	GP			MGT		
		MS	F	P-value	MS	F	P-value
Temperature (A) Temperatura (A)	3	573.7	40.4	0.000	191.4	584.6	0.000
Pre-chilling (B) Stratifikacija (B)	2	1438.6	101.3	0.000	138.1	421.8	0.000
Population (C) Populacija (C)	2	10629.7	748.6	0.000	638.1	1949.2	0.000
A × B	6	174.4	12.3	0.000	3.5	10.7	0.000
A × C	6	89.7	6.3	0.000	13.5	41.3	0.000
B × C	4	430.7	30.3	0.000	16.1	49.0	0.000
A × B × C	12	67.2	4.7	0.000	4.9	14.8	0.000
Error – Pogreška	72	14.2			0.3		

Table 6. Germination percentages of *A. cilicica* populations after pre-chilling for durations of 2 w, 4 w, and 6 w at various germination temperatures.
Tablica 6. Postotak klijavosti istraživanih provenijencija *A. cilicica* pri trajanju stratifikacije od 2, 4 i 6 tjedana pri različitim temperaturama.

Pre-chilling Stratifikacija (sedmice)	Germination temperature Temperatura klijanja	Saimbeyli	Kozan	Bucak	Average pre-chilling temperature Prosječna temperatura stratifikacije	Average germination temperature Prosječna temperatura klijanja
2 w	12 °C	82.0c[1]	30.0d	13.3 f	56.3C[2]	12 °C = 61.0B
	16 °C	88.0abc	36.7d	17.3 f		
	20 °C	92.0ab	77.3b	30.0 f		
	24 °C	92.7ab	84.7ab	31.3de		16 °C = 61.6B
4 w	12 °C	92.7ab	86.7ab	27.3e	68.9B	
	16 °C	88.7abc	63.3c	39.3cd		
	20 °C	93.3a	85.3ab	43.3bc		20 °C = 73.6A
	24 °C	91.3ab	80.0b	35.3cde		
6 w	12 °C	85.3abc	80.7b	51.3ab	76.2A	
	16 °C	84.7bc	83.3ab	53.3a		
	20 °C	92.0ab	90.7a	58.7a		24 °C = 72.1A
	24 °C	89.3abc	87.3ab	57.3a		
Average – Prosječno		89.3A[3]	73.8B	38.2C		

[1] The values on the same column followed by the same small letters are not significantly different at $p < 0.05$
[1] Vrijednosti u istoj koloni označene istim malim slovom ne razlikuju se na razini signifikantnosti od $p < 0.05$
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[3] Vrijednosti u istom retku označene istim velikim slovom ne razlikuju se na razini signifikantnosti od $p < 0.01$

The duration of pre-chilling, the temperature, the provenance of the population, and the interactions between these factors significantly affected the MGT (Table 7). The average mean germination time varied according to the different periods of pre-chilling. The lowest rate and fastest speed of germination occurred after 2-w and 6-w of pre-chilling, respectively.

In this study, we saw that temperature had a large effect on germination speed. As the temperature increased, the germination accelerated. Therefore, the lowest rate and fastest speed of germination occurred at 12 °C and 24 °C, respectively. The plotted curves (Figure 6) clearly show that germination occurs at a faster rate with increasing temperature and with increased duration of pre-chilling.

The average germination speeds also greatly varied according to the seeds' provenances. MGTs were 7.7 d, 11.9 d, and 16.1 d for Saimbeyli, Kozan, and Bucak, respectively.

DISCUSSION
RASPRAVA

Abies species demonstrate great variation in terms of seed weight. *A. cilicica* has the largest seeds (both in terms of weight and dimensions) among the *Abies* genus (Young and

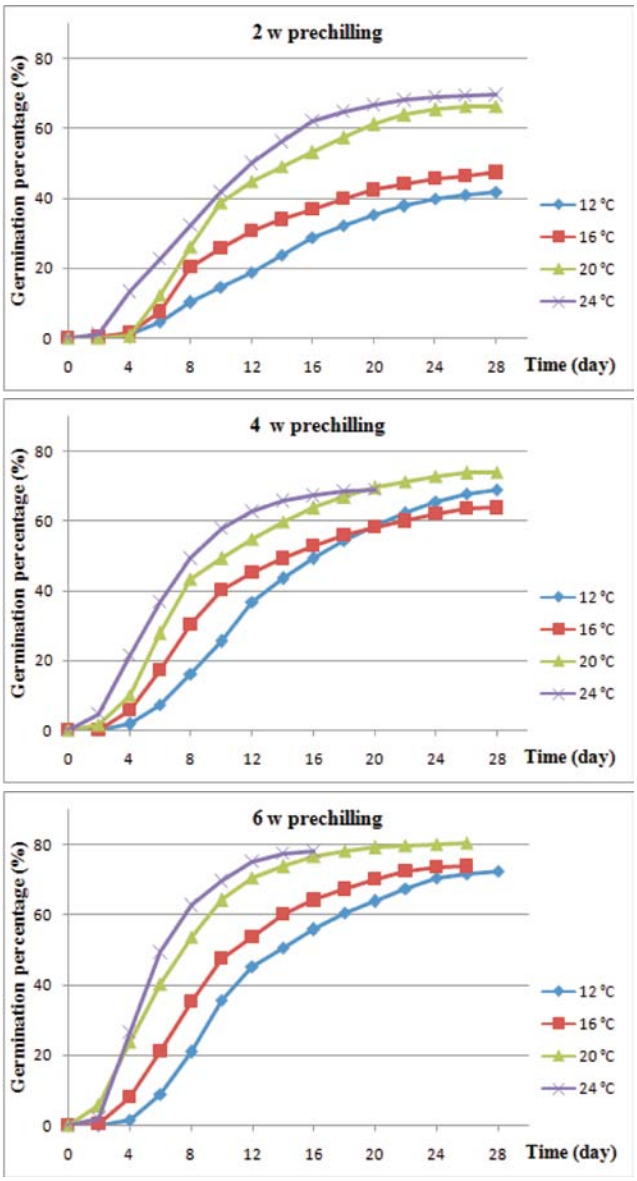

Figure 4. Average germination curves for the three *A. cilicica* populations after pre-chilling for 2, 4, or 6 weeks at various germination temperatures (12 °C, 16 °C, 20 °C, and 24 °C).

Slika 4. Prosječne krivulje postotka klijavosti sjemena *A. cilicica* za tri provenijencije nakon stratifikacije od 2, 4 i 6 tjedana pri temperaturama od 12 °C, 16 °C, 20 °C, i 24 °C

Young 1992; RBG Kew 2014). The average 1000-seed weight was 169.7 g, while that of *A. sachalinensis* (F. Schmidt) Mast. var. *gracilis* (Kom.) Farjon, the lightest seeds, was 4.2 g. In another study (Keskin and Şahin 2000), the 1000-seed weight of *A. cilicica* was found to be 139.1 g and 226.0 g in poor and mast seed years, respectively. The 1000-seed weight of *A. nordmanniana* (Steven) Spach subsp *equi-trojani* (Asch. et Sinb.) Coode et Cullen and *A.n.* subsp. *bornmuelleriana* (Mattf.) Coode et Cullen, other *Abies* taxa in Turkey, were 63.2 g (Aslan 1982) and 82.9 g (Turna et al. 2010), respectively.

There was a great variation between and within the provenances in terms of the morphological traits of the seeds. The average length, width, thickness, and weight of a seed were 14.26 mm, 7.13 mm, 4.44 mm, and 0.170 g, respectively. Similar variations are generally due to different genetic characteristics, environment, and events during the period of seed development (Leishman et al. 2000; Desai 2004).

We found that, for seed from all five provenances, 6 w of pre-chilling fully eliminated dormancy and produced an overall average germination percentage of 79.6 %. The average GP in *Abies* seeds is less than that of many other conifer species due to empty and insect-infected seeds (Edwards 2008). Keskin and Şahin (2000) obtained about 50 % GP at 23 °C to 25 °C in *A. cilicica* seeds.

The real germination capacity of the dormant seeds is generally seen after the full elimination of dormancy (Copeland and McDonald 1999; Baskin and Baskin 2001; Smith et al. 2002). After pre-chilling for 6 w, which fully removed dormancy, the provenances divided into two groups in terms of GP and germination speed (Figure 3). The average GP of *A. cilicica* subsp. *isaurica* seeds (Anamur and Bucak) was significantly lower than that of *A. cilicica* subsp. *cilicica* (Kozan, Saimbeyli, Göksun). Further research over several consecutive years is needed to determine the true differences between the two subspecies.

In general, germination accelerates with increased temperature and increased duration of pre-chilling (Edwards 2008; Yilmaz 2008 and 2010). Similarly, we found that germination speeds increased with the duration of pre-chilling and an increase in the germination temperature (Table 6, 7; Figure 4).

This study clearly revealed that the seed of *A. cilicica* has non-deep physiological dormancy. The fresh (no pre-chilling) seeds from the provenances of Göksun and Saimbeyli demonstrated relatively high percentages of germination. On the other hand, the GPs of non-chilled seeds from the other three provenances (Kozan, Anamur, Bucak) were very low, due to physiological dormancy. The dormancy depth changes each year depending on the timing of collecting the cones (Fenner and Thompson 2005). Since these cones were all collected late in autumn before natural dispersal, the dormancy depth may be reduced because they were still on the trees. Studies over several consecutive years of *A. cilicica* seeds from the same provenance are likely to give more meaningful information about the depth of dormancy.

The duration of pre-chilling necessary to fully remove dormancy varied by the provenances. Although 2 w pre-chilling was sufficient for the seeds from Saimbeyli, the seeds from Kozan required 4 w pre-chilling to achieve full elimination of dormancy. Seeds from the other three provenances required 6 w of pre-chilling to attain full removal of dormancy. Based on the results of these five provenances, pre-chilling for 4 w to 6 w can be recommended for *A. cilicica* seeds; this is in agreement with the average pre-chilling requirement of *Abies* seeds, 4 w to 8 w (Gosling 1999;

Table 7. Mean germination time of each *A. cilicica* population after pre-chilling for 2, 4, or 6 weeks at various germination temperatures.
Tablica 7. Srednje vrijeme klijanja sjemena *A. cilicica* svake od pet provenijencija nakon stratifikacije od 2, 4 i 6 tjedana pri različitim temperaturama.

Pre-chilling Stratifikacija	Germination temperature Temperatura klijanja	Saimbeyli	Kozan	Bucak	Average pre-chilling Temperature Prosječna temperatura stratifikacije	Average germination temperature Prosječna temperatura klijanja
2 weeks 2 tjedna	12 °C	12.2h[1]	17.4g	19.0cd	13.9C[2]	12 °C= 15.0D
	16° C	9.3f	15.8f	18.9cd		
	20 °C	8.6e	12.8e	18.9cd		
	24 °C	5.9b	13.8e	13.9b		16 °C = 12.7C
4 weeks 4 tjedna	12 °C	10.0g	15.6f	20.9e	11.9B	
	16° C	7.4d	10.4d	20.2de		
	20 °C	6.7c	9.9cd	17.5c		20 °C = 11.1B
	24 °C	5.2a	8.6bc	10.2a		
6 weeks 6 tjedana	12 °C	8.8ef	13.7e	17.8c	10.0A	
	16° C	7.9d	10.6d	14.1b		24 °C = 8.7A
	20 °C	5.0a	7.7a	13.0b		
	24 °C	5.5ab	6.3a	9.2a		
Average – Prosječno		7.7A[3]	11.9B	16.1C		

[1] The values on the same column followed by the same small letters are not significantly different at $p < 0.01$
[1] Vrijednosti u istoj koloni označene istim malim slovom ne razlikuju se na razini signifikantnosti od $p < 0.01$
[2] The values on the same column followed by the same capital letters are not significantly different at $p < 0.01$
[2] Vrijednosti u istoj koloni označene istim velikim slovom ne razlikuju se na razini signifikantnosti od $p < 0.01$
[3] The values on the same line followed by the same capital letters are not significantly different at $p < 0.01$
[3] Vrijednosti u istom retku označene istim velikim slovom ne razlikuju se na razini signifikantnosti od $p < 0.01$

Edwards 2008; RBG Kew 2014). *A. cilicica* seeds can germinate at low temperatures either on or under snow (Irmak 1961; Avsar and Ayyıldız 2004) or during the pre-chilling process in a refrigerator (4 °C). In order to avoid pregermination during the pre-chilling, the moisture content of the seeds can be lowered to about 85 % to 90 % of the maximum level, which is enough for the pre-chilling process but the shortage of moisture prevents germination (Suszka et al. 1996; Poulsen 1996).

Germination temperatures greatly affect the germination parameters (Schmidt 2000). In this study, the seeds of *A. cilicica* from all three provenances demonstrated better germination performance (germination percentage and germination speed) at 20 °C and 24 °C. The range of the germination temperature widens after dormancy is removed (Yilmaz 2008). Similarly, after 4 w or 6 w of pre-chilling, higher GPs occurred at 12 °C and 16 °C. In general, 20 °C and 24 °C seem to be the most appropriate temperatures for *A. cilicica* seeds. Where there is a risk of fungal infection, 20 °C is preferred.

The natural distribution of *A. cilicica* is primarily in Turkey, and this species is one of the important species in Turkish forests. However, in recent decades, many individuals of this species have been dying off. *Abies* species are generally very susceptible to climate change and environmental stress. Moreover, widespread insect attacks have been observed on *A. cilicica* in the past decades. Therefore, future research on the seed storage and raising of *A. cilicica* is very important for the ex-situ conservation of the species.

CONCLUSIONS
ZAKLJUČCI

A. cilicica is mainly distributed in Turkey. The species has the largest seeds both in terms of weight and dimensions among *Abies* species. The average 1000-seed weight, seed length, width, and thickness were 169.7 g, 14.26 mm, 7.13 mm, and 4.44 mm, respectively. The study demonstrated that the seed of *A. cilicica* has non-deep physiological dormancy. The seed required about 2–6 w of pre-chilling for dormancy removal depending on the provenances. The overall average germination percentage was 79.6 %. The seeds presented better germination performance at 20 °C and 24 °C and 20 °C should be preferred due to fungal infection risk at 24 °C. The average GP of *A. cilicica* subsp. *isaurica* seeds was surprisingly lower than that of *A. cilicica* subsp. *cilicica*. Further research over several consecutive years is recommended to conclude differences between the two subspecies. The studies on the storage of *A. cilicica* seeds are also needed for the ex-situ conservation of the species.

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Sažetak

Cilicijska jela (*Abies cilicica* /Ant. et Kotschy/ Carriére) vrsta je koju u Turskoj nalazimo uglavnom u gorju Taurus. Cilj istraživanja bio je odrediti morfološka i fiziološka svojstva sjemena taurske jele. Sjeme je sakupljano sa pet različitih područja njena prirodnog rasprostranjenja, kako slijedi: Göksun, Saimbeyli, Kozan, Anamur, and Bucak. Na uzorku svake od pet provenijencija u laboratoriju je mjerena: težina 1000 sjemenki, duljina, širina i debljina sjemena i težina pojedinačne sjemenke. Morfološki parametri pokazali su određeni stupanj varijacije u odnosu na uzorkovane provenijencije. Da bi se odredilo potrebno vrijeme stratifikacije, naklijavano je sjeme testiranih provenijencija nakon stratifikacije od 2, 4 i 6 tjedana pri temperaturi od 4 °C. Sjeme je potom stavljano u klijalice u 4 različita temperaturna režima (12, 16, 20, and 24 °C). Rezultati su bili različiti u smislu klijavosti i brzine klijanja. Najbolja klijavost postignuta je pri temperaturama od 20 i 24 °C.

KLJUČNE RIJEČI: *Abies cilicica*, sjeme, dormantnost, stratifikacija, klijanje