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Effects of seed morphology and growing media on germination percentage and growth of field elm (*Ulmus minor* Miller subsp. *minor*)

Auswirkungen der Samenmorphologie und des Substrates auf das Keimungsprozent und das Wachstum der Feldulme (*Ulmus minor* Miller subsp. *minor*)

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Keywords: Seed morphology, germination, seed storage, seedling growth

Schlüsselbegriffe: Samenmorphologie, Keimung, Saatgutlagerung, Keimlingswachstum

Abstract

Dutch elm disease (DED) is a vascular wilt disease that spread through the elm populations in the 20th century and in response, conservation of the genetic resources is crucial to maintain the sustainability of the species. In this context, it is important for aforestation measures to be able to produce large numbers of high quality saplings with both vegetative and generative production techniques. This study was conducted to obtain basic data on the germination characteristics of seeds of *Ulmus minor* Miller subsp. *minor* (field elm) and growth characteristics of the early seedlings in different growing media. Field elm seeds were collected from four trees (seed families) located in the Karadeniz Technical University campus. Seeds were subject to germination trials at two different dates (in May 2018 and in December 2018) in climate chamber. Average seed length (SL) was 5.09 mm, average seed width (SW) 3.81

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mm, average seed wing length (SWL) 15.91 mm and average seed wing width (SWW) 14.97 mm. The measured morphological seed characteristics differed significantly (*p<0.05*) among seed families. The highest average germination percentages (AGP) were 91.7% in the germination trial 1 and 57.7% in the germination trial 2 and this differences were significantly different (*p<0.001*). On the other hand, mean germination times (MGT) were 2.83 days in the germination trial 1 and 0.63 days in the germination trial 2. ANOVA test indicated that MGT were significantly different (*p<0.001*) on the basis of seed families between the germination trials. When repotting seedlings in the nursery we used as three different growing media, peat, forest soil and mixed forest soil+peat (1:1). We then studied the effects of the different growing media on seedling height (SH) and lateral shoots number (LSN). The highest seedling height (8.05 cm) and the highest lateral shoots number (4.23) were obtained for seed family number 4 in the forest soil+peat growing media. Significant differences among the seed families in terms of morphological seed characteristics indicated that there might be genetic differences even in trees growing in close proximity. Significantly different germination percentages between two germination trials suggest that seed storage period and storage conditions are important factors for the germination ability in field elm.

Zusammenfassung

Das Ulmensterben (DED) ist eine durch den Ulmensplinkiefer verbreitete Welkekrankheit, die sich im 20. Jahrhundert über die Ulmenpopulationen ausgebreitet hat und in diesen Zumsammenhang ist die Erhaltung der genetischen Information von entscheidender Bedeutung, um die Nachhaltigkeit dieser Art zu erhalten. So ist es für Aufforstungsmaßnahmen wichtig, eine große Anzahl hochwertiger Setzlinge unter Verwendung von vegetativen als auch mit generativen Produktionstechniken zu produzieren. In dieser Studie wurden Samen von *Ulmus minor* Miller subsp. *minor* (Feldulme) verwendet, die von vier verschiedenen Bäumen auf dem Campus der Technischen Universität Karadeniz gesammelt wurden. Die Samen wurden zu zwei verschiedenen Zeitpunkten (Mai 2018 und Dezember 2018) in Klimaschränken Keimversuchen unterzogen. Die durchschnittliche Samenlänge (SL) war 5.09 mm, die durchschnittliche Samenbreite (SW) 3.81 mm, die durchschnittliche Samenflügellänge (SWL) 15.91 mm und die durchschnittliche Samenflügelbreite (SWW) 14.97 mm. Hinsichtlich dieser morphologischen Samenmerkmale wurden signifikante Unterschiede (*p<0.05*) zwischen den Samenbäumen festgestellt. Der höchste durchschnittliche Keimungsprozentsatz (AGP) konnte im Keimtest 1 mit 91.7% und im Keimtest 2 mit 57.7% festgestellt werden (*p<0.001*). Die mittlere Keimzeit (MGT) betrug jedoch im Keimtest 1 2.83 Tage und im Keimtest 2 0.63 Tage. ANOVA-Tests zeigten, dass die MGT auf der Basis von Samenbäumen sowohl im Keimungstest 1 als auch im Keimungstest 2 signifikant unterschiedlich war (*p<0.001*). Während des Umtopfens in der Baumschule wurden drei verschiedene Wachstumsmedia verwendet, Torf, Waldboden und Waldboden + Torf (1:1). Damit konnten wir die Auswirkungen verschiedener Wachstumsmedien auf die Keimlingshöhe (SH) und die Anzahl der seitlichen Trie-

be (LSN) untersuchen. Die höchste Keimlingshöhe (8.05 cm) und die höchste Anzahl von seitlichen Trieben (4.23) wurden im Waldboden + Torf beobachtet (Samenbaum Nummer 4). Der Umstand, dass es signifikante Unterschiede zwischen den Samenbäumen hinsichtlich der morphologischen Eigenschaften der Samen gibt, weist darauf hin, dass es genetische Unterschiede bei Bäumen geben kann, die in unmittelbarer Nähe wachsen. Signifikante Unterschiede zwischen den Keimungsprozentsätzen auf der Grundlage der Keimversuche zeigen, dass die Samenlagerung entscheiden für die Keimfähigkeit bei Feldulmen ist.

Introduction

After World War I, Dutch elm disease (DED) which was a new vascular wilt disease spread through the elm populations of Eurasia and North America and it caused economic and esthetic losses (Strobel and Lanier 1981, Smalley and Guries 1993). DED also resulted in extensive habitat loss (Tomlinson and Potter 2010) narrowing the genetic diversity of surviving populations (Santini *et al*. 2010).

As climate change emerges as another major threat, impacting genetics, species, community and ecosystem levels, conservation professionals are increasingly concerned about the degradation and loss of biodiversity (Mantyka-Pringle *et al*. 2015). Climate change can interact with land cover change by increasing the impact of habitat loss and fragmentation on biodiversity and the susceptibility of fragmented biological populations to the risk of extinction (Sala *et al*. 2000, Jetz *et al*. 2007, De Chazal and Rounsevell 2009, Mantyka-Pringle *et al*. 2015). As the impacts of climate change and land cover change intensify and interact in the coming decades, the threat to biodiversity may further increase (Sala *et al*. 2000, Jetz *et al*. 2007, Visconti *et al*. 2015).

Turkey is a country rich in terms of biodiversity, where the relations between conservation and sustainable development are important. Woody and herbaceous species have a strong structure in the plant compositions on the basis of different biogeographic regions and different environments in Turkey. There are over 500 species of natural trees and shrubs in Turkey and these species constitute very different types of natural stands (Oktan 2015). European countries have begun to work earlier than Turkey to preserve different native species of trees and shrubs spreading in forest areas. Under the European Forest Genetic Resources Program (EUFORGEN) of International Institute for Plant Genetic Resources (IPGRI), "Broadleaved Tree Species Network" was established in 1996. EUFORGEN aimed to produce plans on the conservation and sustainable use of native broadleaved species, mostly of *Ulmus*, *Acer*, *Fraxinus*, *Tilia*, *Alnus*, *Castanea*, *Juglans* and *Rosaceae* family (Turok *et al*. 1999). Among these species, efforts are underway to ensure the conservation and increase of genetic resources of elms, to fight DED, and to introduce in-situ and ex-situ conservation measures (İncedemiroğlu 2004).

Elm species (*Ulmus* sp.) are fast-growing and able to adapt to various and difficult soil conditions, resistant to pruning and root damage (Santini *et al*. 2010). Elm generally develop very well on deep and moist soils rich in nutrients (Bey 1990, Cooley and Sambeek 1990). Field elm (*Ulmus minor* Miller subsp. *minor*) has been a widespread tree species in Turkey. However, elm forests have been damaged and their areas have decreased significantly because of climate change, human pressure and habitat fragmentation (Caudullo and de Rigo 2016, Martin *et al*. 2019). Especially, Collin (2002 and 2003) and Çiçek and Tilki (2007) stated that elms do not face the danger of extinction due to insect and fungal destruction. But, their genetic variations are reduced because of the restriction of elm habitats and unconscious use of these habitats. Hence, different conservation measures including domestication approaches are needed to preserve rare and extensively used plant species (Dashzeveg *et al*. 2017).

Since elms are threatened by extinction, conservation of the genetic resources of this species is crucial to maintain the sustainability of the species. In this context, it is important to be subjected to afforestation meassures by producing high quality mass saplings with both vegetative and generative production techniques. So, seed characteristics of elm trees and the growth abilities of the seedlings under different growing media should contribute to the studies for in-situ and ex-situ conservation programmes. This study was conducted to obtain basic data on the germination characteristics of field elm seeds and growth characteristics of the early seedlings in different growing media in order to improve mass seedling propagation techniques.

Material and Methods

Material

The seeds used as material in this study were harvested in 24 April 2018 from 4 trees that were in similar phenotypic characteristics (tree age, tree height, diameter at breast height, crown shape and crown density) and located in close proximity to each other (Figure 1). Locations of these seed families are at the Karadeniz Technical University campus (40º59'44" N; 39º46'29" E) in the city centre of Trabzon/Turkey (Figure 2). The altitude of the seed families above sea level is 60 meters and the exposure is 30º north-east. Seeds were collected by hand from the middle-inner part of the crown. Collected seeds were cleared from branches, leaves and stems in greenhouse. After cleaning, the visually injured or damaged ones of the seeds were removed and the extracted seeds with wings were ready for germination trials. Mean 1000 Kernel Weights (g) of the harvested seeds according to seed families were 15.9 g, 17.1 g, 16.9 g and 18.7 g respectively.

Figure 1: General view of seed trees.

Abbildung 1: Gesamtansicht der Samenbäume.

Figure 2: Location of the study region near the Black Sea and the distribution of field elm (Caudullo et al. 2017).

Abbildung 2: Lage der Untersuchungsregions nahe des Schwarzen Meeres und die Verbreitung der Feldulme (Caudullo et al. 2017).

Methods

Determination of morphological seed characteristics

Seed and seed wing size are important morphological criteria that reveal the difference among trees and they are used in classifying seed quality. Seed width (SW), seed length (SL) and seed wing width (SWW) and seed wing length (SWL) of the seeds which were collected from four seed families were measured. The measurements were carried out on 504 seeds in total (126 seeds were selected randomly for each tree). All measurements were done on full seeds. Digital caliper with mm precision was used in measurements.

Processes of the germination trials

Seeds were subjected to germination trials at two different dates (in May 2018 and in December 2018). In the germination trials, keeping the light, temperature and humidity values constant in the growing chamber, the germination capabilities of the seeds from the four trees were tried to be revealed without any pretreatment. Germination was monitored for 18 days in the first germination trial (from May 4 to May 21 in 2018) and for 7 days (from December 15 to December 21 in 2018) in the second germination trial. Until the second germination trial process started on December, the seeds were stored for seven months in closed and airtight containers at +4 ° C with 10% moisture content. The number of germinated seeds was recorded each day. The germination percentage for each tree was determined as a proportion of the initial number of seeds.

We placed 15 seeds on a damp paper towel in each petri dish with 20 replications per tree, checked them every few days and regularly moistened with distilled water (Figure 3). 20/30 °C (16 hours 20 °C-8 hours 30 °C) temperature and 70-75% moisture were used in germination trials (ISTA, 1996). Petri dishes used in germination trials were sterilized in a drying oven at 105 °C for 120 minutes. Contaminated seeds were removed from the environment and replaced with new ones. Contamination were only seen in seeds harvested from seed familiy 1 and the replaced seeds percentage was 15% during the germination trial 1 process. The ones whose roots were at least 2 mm elongated were accepted as germinated and were taken from the environment (Figure 3).

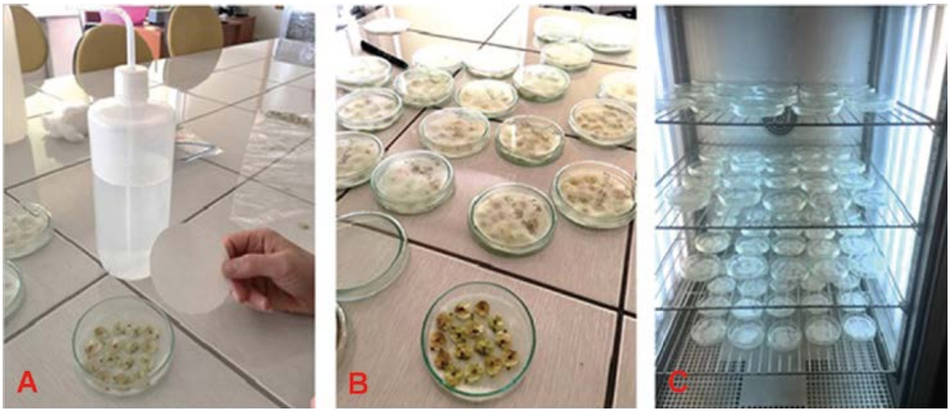

Figure 3: Germination trial (A: Placing seeds on a damp paper towel in a petri dish; B: Replications per tree; C: Germination process in growing chamber).

Abbildung 3: Keimtest (A: Die Samen auf einem feuchten Papiertuch in einer Petrischale platzieren; B: Replikationen pro Baum; C: Keimprozess in der Wachstumskammer).

Determination of germination percentages and mean germination time

Mean germination time (MGT) was calculated by the equation (1) (Ellis and Roberts 1980):

$$\mathrm{MGT} = \frac{(\sum ni)\times(\sum ti)}{T} \qquad (1)$$

Where *ni* is the number of the days, *ti* is the number of seeds germinated in a given number of days, *T* is the total number of germinated seeds.

The germination percentage (GP) was calculated by the equation (2) (Bewley and Black 1994):

$$\mathrm{GP} = ((\sum xi) \div N) \times 100 \qquad (2)$$

Where *xi* is the mumber of germinated seeds on day *i*, *N* is the total number of tested seeds.

Processes of the seedling experiment: Sowing processes, sowing media and determination of the morphological seedling characteristics

The seeds were collected in 24 April 2018 by controlling the physiological maturity stage and sown in 30 April 2018. Seeds were sown in the seedling viols filled with peat, forest soil and peat+forest soil (1:1). Viols were placed in the nursery. Sand was used to cover the sown seeds. No pretreatment was applied to the seeds before sowing. The viols were kept under shade to avoid high temperature and sun light damage. During the observation process of early seedling growth, irrigation was carried out three days a week and weed control was done regularly. Seedling height (SH) and the lateral shoots number (LSN) were measured at 1 month old elm seedlings in 10 June 2018. The measurements were carried out on a total of 3422 seedlings.

Statistical Analysis

In this study, the data are analyzed using the SPSS statistical software. Correlation analysis, Analysis of variance (ANOVA), Duncan's test and Independent samples t-test are used to evaluate the obtained results ($p<0.05$ and $p<0.001$).

Results

Morphological seed characteristics

Average seed length, seed width, seed wing length and seed wing width values and ANOVA and Duncan's Test results of seed families were given in Table 1. It was determined that there were significant differences ($p<0.05$) between seed families in terms of seed length (SL), seed width (SW), seed wing length (SWL) and seed wing width (SWW).

Table 1: Differences in morphological characteristics of seeds (^{a,b,c,d} letters showed the homogenous groups).

Tabelle 1: Unterschiede in den morphologischen Eigenschaften (^{a,b,c,d} Buchstaben zeigten die homogenen Gruppen).

Seed family	Average seed length (SL) (mm)	Average seed width (SW) (mm)	Average seed wing length (SWL) (mm)	Average seed wing width (SWW) (mm)	Sig. level (p<0.05)
1	4.58±0.67^{a}	3.44±0.59^{a}	14.98±1,73^{a}	14.03±1.51^{a}	0.000
2	5.43±0.68^{b}	3.80±0.65^{cd}	16.59±1,96^{cd}	15.63±1.70^{cd}	0.000
3	5.12±0.63^{cd}	3.74±0.55^{cd}	15.73±1,89^{b}	14.85±1.67^{b}	0.000
4	5.21±0.70^{cd}	4.26±0.53^{b}	16.33±1.51^{cd}	15.36±1.36^{cd}	0.000

Germination percentage and mean germination time

Seed storage and storage conditions affected the germination percentage. The highest average germination percentage in the growing chamber was obtained from the seed family number 2 (91.7%) in the first germination trial and the highest value was obtained from the seed family number 1 (57.7%) in the germination trial 2. The lowest average germination percentage was obtained from the seed families number 1 and 4 (88.0%) in the first germination trial and the lowest germination percentage was obtained from the seed family number 4 (0.0%) in the germination trial 2. ANOVA test results showed that while there were no significant differences among seed families on the basis of germination percentage in the germination trial 1, siginificant differences were obtained among seed families in the germination trial 2 (Table 2). As a result of the T-test, it was determined that two germination trials showed a significant difference (t=23.001; $p=0<0.05$) in terms of germination percentage. While quite high average germination percentage obtained in the germination trial 1, the seeds lost their germination ability to a great extent and had lower average germination percentage in the germination trial 2.

Table 2: ANOVA and Duncan Test Results of Germination Percentage ([a,b,c,d] letters showed the homogenous groups).

Tabelle 2: ANOVA- und Duncan-Testergebnisse des Keimungsprozentsatzes ([a,b,c,d] Buchstaben zeigten die homogenen Gruppen).

	Seed family	**Average germination percentage-AGP (%)**	**Standard error**	**Significance level (p<0.05)**
Germination trial 1	1	88.0	2.35	0.638
	2	91.7	2.46	
	3	90.7	2.34	
	4	88.0	2.76	
Germination trial 2	1	57.7[a]	4.31	0.000
	2	9.0[b]	1.95	
	3	2.7[b]	0.75	
	4	0.0[c]	0.0	

Storage time and conditions affected the mean germination time. The highest MGT was 3.55 days and the lowest MGT was 2.06 days. However in the germination trial 2, the highest MGT was 2.00 days and the lowest MGT was 0.00 day. ANOVA Test results showed that MGT was significantly different on the basis of seed families in the germination trial 1 and germination trial 2 (Table 3). As a result of the T-test, it was determined that two germination trials showed a significant difference ($t=9.148$; $p=0<0.05$) in terms of the mean germination time.

Table 3: ANOVA and Duncan Test Resuls of Mean Germination Time ([a,b,c,d] letters showed the homogenous groups).

Tabelle 3: ANOVA- und Duncan-Testergebnisse der Keimzeit ([a,b,c,d] Buchstaben zeigten die homogenen Gruppen).

	Seed family	Mean germination time-MGT (day)	Standart error	Sig. level (p<0.05)
Germination trial 1	1	3.55[a]	0.17	0.000
	2	3.24[a]	0.11	
	3	2.48[c]	0.08	
	4	2.06[b]	0.06	
Germination trial 2	1	2.00[a]	0.22	0.000
	2	0.42[b]	0.08	
	3	0.11[b]	0.03	
	4	0.00[c]	0.00	

Morphological seedling characteristics

The average seedling height (SH), average lateral shoots number (LSN) and standard error values were given in Figure 4 by growing media. The average SH in total was determined as 6.20±2.36 cm. While the highest SH was obtained as 8.05±2.47 cm in forest soil+peat (1:1) media, the lowest SH was determined as 4.25±1.25 cm in peat media. The average LSN in total was determined as 3.7±0.95. While the highest LSN was obtained as 4.23±0.80 in forest soil+peat (1:1) media, the lowest LSN was determined as 3.10±1.69 in peat media.

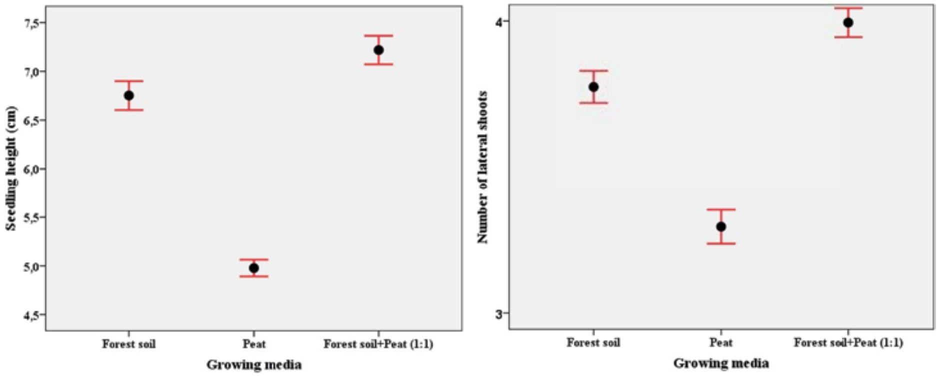

Figure 4: Results of Seedling height (SH) and lateral shoots number (LSN) of the cultivation test.

Abbildung 4: Ergebnisse von der Keimlingshöhe (SH) und die Anzahl der Seitentriebe (LSN).

Average SH and the LSN were significantly different (*p<0.01*) depending on the growing media, seed family and growing media x seed family interactions (R^2 0.259 and Adjusted R^2 0,257 for SH; R^2 0.129 and Adjusted R^2 0.127 for LSN). According to the Duncan Test results, depending on the growing media, the best development in terms of SH and LSN was obtained in forest soil+peat growing media, and the lowest growth was obtained in peat growing media. Also, there were three different groups among growing media in terms of average SH and LSN. When the Duncan Test results were examined on the basis of seed families, the best values in terms of SH and LSN were obtained from the seed family number 4, and there were three different groups among seed families in terms of average SH (seed family 2 and seed family 3 are in the same group), and two different groups in terms of the LSN (Seed family 1, seed family 2 and seed family 3 are in the same group).

Correlation Analysis results (Table 4) showed that there was a positive correlation between seed length (SL), seed wing length (SWL) and seed wing width (SWW). In addition, a positive correlation was found between seed width (SW) and seedling height (SH) and seed wing length (SWL) and seed wing width (SWW).

Table 4: Correlations on the basis of seed and seedling morphological characteristics [Correlation is significant (p<0.05); ** Correlation is significant (p<0.01)].*

Tabelle 4: Korrelationen auf der Grundlage der morphologischen Eigenschaften von Samen und Sämlingen [* die Korrelation ist signifikant (p<0.05); ** Die Korrelation ist signifikant (p<0.01)].

		Seed Length	**Seed Width**	**Seed Wing Length**	**Seed Wing Width**	**Seedling Height**	**Lateral Shoots Number**
Seed Length	Pearson Correlation	1	0.646	0.968*	0.980*	0.706	0.323
	Sig. (2-tailed)		0.354	0.032	0.020	0.294	0.677
	N	4	4	4	4	4	4
Seed Width	Pearson Correlation	0.646	1	0.741	0.734	0.974*	0.929
	Sig. (2-tailed)	0.354		0.259	0.266	0.026	0.071
	N	4	4	4	4	4	4
Seed Wing Length	Pearson Correlation	0.968*	0.741	1	0.998**	0.746	0.467
	Sig. (2-tailed)	0.032	0.259		0.002	0.254	0.533
	N	4	4	4	4	4	4
Seed Wing Width	Pearson Correlation	0.980*	0.734	0.998**	1	0.752	0.450
	Sig. (2-tailed)	0.020	0.266	0.002		0.248	0.550
	N	4	4	4	4	4	4
Seedling Height	Pearson Correlation	0.706	0.974*	0.746	0.752	1	0.856
	Sig. (2-tailed)	0.294	0.026	0.254	0.248		0.144
	N	4	4	4	4	4	4
Lateral Shoots Number	Pearson Correlation	0.323	0.929	0.467	0.450	0.856	1
	Sig. (2-tailed)	0.677	0.071	0.533	0.550	0.144	
	N	4	4	4	4	4	4

Discussion

Morphological seed and seedling characteristics

Within the scope of the study, significant differences were determined among seed families on the basis of the morphological seed characteristics. The differences in the morphological seed characteristics in habitat where the environmental factors are the same are indicators that there may be genetic differences among seed families. Individuals from the same environmental conditions do not have the same morphological characters, indicating that the environment does not affect phenotypes (Wimalasiri *et al*. 2016). In addition, it was stated that morphological features are the results of the interactions between environmental factors and genetic factors, so morphological features can reveal a certain degree of genetic diversity under the same breeding and management conditions (Chen *et al*. 2020; Moose and Mumm 2008; Singh *et al*. 2010). It is always difficult to compare genetic similarity with morphological studies because genetic variability is highly dependent on factors such as species history, breeding methods and ecology (Hamrick 1989, Kaya Altop and Mennan 2011). Yahyaoglu and Genç (2007) stated that genetic structure, in other words genetic quality, can vary from origin to origin as well as differ among families in the same population (origin). In addition, early seedling growth has significant differences depending on both seed characteristics and growing media. In this context, after collecting seeds from individuals in the same population, the ability to grow genetically superior seedlings with the help of morphological seed characteristics is an extremely important preliminary evaluation in terms of in-situ and ex-situ conservation and breeding studies (Wimalasiri *et al*. 2016). Moreover, they can be used to develop new germplasm, as the lack of genetic diversity is a significant burden on future reproductive developments (Carmona *et al.* 2010). Seed and seed wing size are important criteria that reveal the difference among trees and they are used in classifying seed quality. Atar (2013) stated that there were significant differences in terms of seed width, length and thickness among families and populations in *Carpinus betulus* L. Seed size has had a clear effect on the morphological seedling characteristics (Gökdemir 1991). Correlation Analysis results showed that there was a positive correlation between seed length (SL), seed wing length (SWL) and seed wing width (SWW). In addition, it was determined that there was a positive correlation between seed width (SW) and seedling height (SH). As a result, in order to obtain good results in terms of qualitive seedling development, seed size and especially seed width should be taken into consideration before sowing in field elm. However, these results should be supported by the researches in terms of genetic variation and heritable traits.

Regardless of the affect of the growing media, significant differences were found among seed families on the basis of average seedling height and the lateral shoots number. In different two studies conducted on cedar (Gülbaba and Özkurt 1998) and Turkish red pine (Doğan 1997) species, the heights of 2-year-old seedlings were measured and significant differences were found not only among populations but also among families. Also, significant differences obtained among populations and families on the basis of lateral shoot measurements in Turkish red pine (Işık 1997, Işık and Işık 1999). A mixture of forest soil+peat (1:1) provided the best growing media for field elm seedlings. Peat is not very rich in plant nutrients, so it can be much more useful when it is subjected to certain processes and enriched in plant nutrients with various additives (Aksoy 1988, Ayan 1998, Ayan 2001, Ayan 2007). While soils can hold 5% water when irrigated, peat with large pores can hold at least 30% water. In order to provide the necessary water, plants need to be irrigated at short time intervals in forest soil growing media. However, it causes a decrease in the required soil air. The main thing is that the growing media can easily absorb water and it does not loose its porosity.

Germination percentage and mean germination time

Germination characteristics of seeds harvested from different seed families can be different because of the different heritable traits (Yahyaoğlu and Genç 2007, Caron *et al*. 2011). Studies conducted in several species revealed that the seed characters can be indicative of the seed quality expressed by germination percent (Lyngdoh *et al*. 2013, Toon *et al*. 1990). Field elm seeds do not have any dormancy if the matured seeds were sown immediately after harvesting. Çiçek and Tilki (2007) emphasized that although seeds of most elm species require no presowing treatment but seeds of *Ulmus rubra*, *Ulmus americana* and *Ulmus crassifolia* may show dormancy and stratification at 4 °C for 1-2 monthsbefore spring sowing improves germination of these species. İncedemiroğlu (2004) detected a germination rate of 95.1% in *Ulmus minor* at 30/20 °C in seeds without any pretreatment and subjected to germination test right after the seeds were harvested. Germination rate between 90-100% was obtained in the germination trial in *Ulmus thomasii* (Arissumi and Harisson 1961). In this study the highest germination percentage value was 91.7% in the first germination trial, and the value was 57.7% in the second germination trial. Significantly decreased germination percentages were obtained depending on the seed storage time and storage conditions. Obtained results showed that stored seeds at 4 °C with original humidty (10%) for nearly 7 months decreased the germination ability significantly. On the other hand, Phartyal *et al*. (2003) reported that maximum mean germination of 81.81% was recorded in *Ulmus wallichiana* stored at -5 C° with 3.09% moisture content, while significantly minimum mean germination of 11.62% was observed for seeds stored at room temperature with 10.46% moisture content. Phartyal *et al*. (2003) also emphasized that different moisture content and storage temperatures can improve storage time from 30 days to 3 years in *Ulmus wallichiana*. This indicates that elm seeds are short-lived seeds and cannot be stored for a long time under unsuitable humidity and temperature conditions. While there were no significant differences among seed families in terms of germination percentage in the first germination trial, significant differences were found in the second germination trial. This situation can be interpreted as genetic differences between seed families become a more significant characteristic on the germination percentage depending on seed storage time and storage conditions. Buszewicz and Holmes (1963) stated that after drying the seeds of *Ulmus carpinifolia* and *Ulmus glabra* at room temperature for a few days and stored them at 3 °C in airtight closed containers, and at the end of the first year the germination percentage was between 37-50%. Rohmeder (1942) stated that the germination capacity of the seeds sown immediately after collection was high, but the germination capacity of the seeds sown 1-2 months after maturation was low in *Ulmus montana*. Tompsett (1986) investigated the affect of different humidity and temperature conditions on the long-term preservation of *U. minor* seeds, and stated that increasing storage temperature (13-75 °C) and humidity values (3-19%) decreased the germination capacity of the seeds. Statistically significant differences were found between seed families in terms of mean germination time. It has been stated that the average germination time is an indicator of the strength and the quality of the seed (Bewley and Black 1994, Tilki and Çalıkoğlu 1998). The average germination time between two germination trials was noticeably shorter. The short lifespan of the seeds and the decrease in their germination abilities affected the shortening of the mean germination time. Although the germination rate is higher in stored seeds, this may be misleading in terms of seed quality because rather low germination percentage values were obtained in stored seeds compared to seeds that were subjected to germination immediately after collection. Therefore, the early sowing period that the maximum average germination percentage is obtained in the field elm should be preferred in terms of mass seedling production.

Conclusion

Field elm is in danger of extinction. In this context, it is very important to protect and develop elm trees by in-situ and ex-situ conservation programmes. Since elm seeds loose their vitality and thus their germination ability in a short time, it is very important to collect the seeds as soon as possible depending on the physiological maturity stage. This process should be followed very well in seeds that ripen and shed within a period of about 1 month. In addition, more comprehensive studies are needed on suitable storage conditions to maintain seed viability on a larger scale. The growing media has a great importance in terms of seed germination and seedling growth. The emergence of quite different variations in terms of morphological characteristics on the family basis can be interpreted as high genetic diversity among families. Therefore, it is necessary to reach higher information in terms of tree breeding by testing germination characteristics and seedling development in different growing media on the basis of genetic diversity in field elm.

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