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# Determination of Seed Germination and Seedling Characteristics of Amygdalus orientalis (Mill) and Amygdalus turcomanica (Lincz) Almond Species

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**Özet**

Bu çalışma, Türkiye'nin Güneydoğu Anadolu Bölgesinden seçilen *Amygdalus orientalis* (Mill) için 13 genotip ve *Amygdalus turcomanica* (Lincz) için 8 genotipin tohum çimlenme ve çöğür özelliklerinin belirlenmesi amacıyla yapılmıştır. Katlama süresi (gün), çimlenme oranı (%), çıkış oranı (%), çıkış süresi (%), çöğür uzunluğu (cm), gövde çapı (cm), boğum arası uzunluğu ve dallanma durumu iki yabani badem türünde incelenmiştir. En yüksek çimlenme oranları *A. orientalis'in* O13 genotipinden (%79,50) ve *A. turcomanica*'nın T8 genotipinden (%84,76) elde edilmiştir. Çıkış oranları *A. orientalis* (Mill) genotiplerinde %49.40 (O4) ile %85.69 (O12) arasında ve *A. turcomanica* (Lincz) genotiplerinde %57.16 (T1) ve %75.00 (T8) arasında değişmiştir. Çıkış süresi *A. orientalis* (Mill) genotiplerinde 10 ile 31 gün arasında ve *A. turcomanica* (Lincz) genotiplerinde 13 ile 28 gün arasında değişim göstermiştir. Bu sonuçlar, *A. orientalis* (Mill) genotiplerinde çöğür uzunluğunun 21.95 cm ile 48.50 cm arasında ve gövde çapının 2.30 mm ile 5.09 mm arasında ve *A. turcomanica* (Lincz) genotiplerinde çöğür uzunluğunun 12.05 cm ile 30.88 cm arasında ve gövde çapının 2.22 mm ile 3.29 mm arasında değiştiğini ortaya koymuştur.

***Anahtar Kelimeler***

*Yabani badem, çıkış, katlama, gövde kalınlığı*

## *Determination of Seed Germination and Seedling Characteristics of Amygdalus orientalis (Mill) and Amygdalus turcomanica (Lincz) Almond Species*

**Abstract**

This study was conducted to determine the seed germination and seedling characteristics of 13 genotypes for *Amygdalus orientalis* (Mill) and 8 genotypes for *Amygdalus turcomanica* (Lincz) selected from the Southeastern Anatolia region of Türkiye. Stratification time (days), germination rate (%), emergence rate (%), emergence time (%), seedling length (cm), stem diameter (cm), the length of internodes, and branching status were examined in two wild almond species. The highest germination rates were obtained from the O13 genotype (79.50%) of *A. orientalis* and the T8 genotype (84.76%) of *A. turcomanica*. The emergence rates ranged from 49.4% (O4) to 85.69% (O12) in *A. orientalis* (Mill) genotypes and ranged from 57.16% (T1) and 75.00% (T8) in *A. turcomanica* (Lincz) genotypes. Emergence duration varied between 10 and 31 days in A. orientalis (Mill) genotypes and between 13 and 28 days in *A. turcomanica* (Lincz) genotypes. These results demonstrated that seedling length varied between 21.95 cm and 48.50 cm, stem diameter between 2.30 mm and 5.09 mm in *A. orientalis* (Mill) genotypes, whereas seedling length ranged from 12.05 cm to 30.88 cm and stem diameter ranged from 2.22 mm to 3.29 mm in *A. turcomanica* (Lincz) genotypes.

***Keywords***

*Wild almond, emergence, stratification, stem thickness*

## 1. INTRODUCTION

Almond (*Prunus dulcis* (Miller) D.A. Webb) is a member of the species of *Amygdalus*, from the Rosaceae family, from the order of Rosales **(Özbek, 1978)**. This family includes more than thirty almond species. Among these species, *A. orientalis* (Mill), *A. turcomanica* (Lincz), *A. fenzliana* (Fritch), *A. trichamgdalus* (Hand-Mazz) Woronov, *A. arabica* (Oliver), and *A. webbii* (Spach) are widespread in the flora of Türkiye. *A. turcomanica* is common in the natural population of the Southeastern Anatolia region and *A. orientalis* in the Southeastern Anatolia and Central Anatolia regions of Türkiye **(Kester and Asay, 1975; Bayazit et al., 2012; Atlı, 2019)**. *A. orientalis* plants in the form of bushes, which might be 1-2 m in height, leaves with densely hairy, small fruits, and a hard shell whose surface contains grooves. Another bush-formed plant *A. turcomanica* (Lincz), has a multi-stem tree, small, and spherical fruits **(Browicz and Zohary, 1996; Bayazit, 2007)**. These species can be used as rootstock for cultivated almonds and to protect arid areas against erosion **(Mortazavi, 1986)**. Moreover, the species might be used as dwarfing rootstock due to its weak growth vigor compared to cultivated cultivars. The plant height of almond cultivars reaches 8-10 m **(Özbek, 1978; Bayazit, 2007)**, naturally grown plants belonging to the *A. orientalis* species were reported with their plant height from 151 to 238 cm in the regions of Central Anatolia and Southeastern Anatolia of Türkiye. **Kester and Gradziel (1996)** stated that wild almond species can be used directly as seed rootstock, also it is possible to use genotypes produced by crossing wild species with each other or with almond cultivars. **Atlı (2008)** reported that the genotypes of *A. orientalis* did not have any problem with graft incompatibility with the cultivated ones. In addition, he indicated the yield per hectare was 830.8 kg/ha in the 4-year-old Nonpareil cultivar grafted on the Texas cultivar, while 3510 kg/ha in the Nonpareil cultivar grafted on *A. orientalis* because of its lower growth vigor in the ecological conditions of Gaziantep province, in the Southeastern Anatolia of Türkiye.

In breeding studies for cultivated almonds, some characteristics of wild almond species are mainly utilized such as late flowering, self-fertility, resistance to arid, calcareous, and salty soil conditions **(Denisov 1988; Gradziel et al., 2001)**. Currently, many studies have been conducted on the phenological, pomological, morphological, and molecular descriptions of these species **(Martinez-Gomez et al., 2003; Bayazit, 2007; Bayazit et al., 2012)**. In addition, the almond species are important because of their characteristics, abundance, and easy availability of the material to be used as seed rootstock, the high germination rate, and the time to graft **(Baninasab and Rahemi, 2006)**. Studies on the determination of seed emergence and seedling characteristics in wild almond species, which stand out mainly with their rootstock properties, have been quite limited.

Recent studies showed that the most important natural resource of the current century is genetic resources. Protecting these resources requires preserving the genetic materials while turning these resources into benefits because of contributing to the economy.

This research aimed to determine the stratification time, germination and emergence rates, emergence time, and seedling characteristics of genotypes of *A. orientalis* and *A. turcomanica* almond species that can be used as rootstocks for cultivated almonds.

## 2. MATERIALS AND METHODS

This study was carried out in the research field of the Horticulture Department of the Faculty of Agriculture of Hatay Mustafa Kemal University in 2014 and 2015 years. In this research, 13 genotypes of *A. orientalis* (Mill.) and 8 genotypes of *A. turcomanica* selected from the province of Gaziantep were used as materials. Texas cultivar was used as a control for the comparison of seed characteristics. In this study, the determination of stratification time, germination and emergence rates, and seedling characteristics in genotypes of *A. orientalis* (Mill.) and *A. turcomanica* (Lincz) species were carried out according to **Bayazit (2007)**.

To determine the stratification times (days), the seeds of all genotypes were stratified in 1.5-liter rectangular plastic containers in a moist sand environment and all genotypes were taken to cold storage at +4°C at the same time. After the seeds were kept for 40 days in stratification, they were controlled every three days. Then, when rootlets were seen in 50% of the seeds, the stratification process was terminated and this time was accepted as the stratification time of the genotypes.

In the determination of germination rates (%), seeds formed 1 mm or more rootlets were considered as germinated. A total of 30 seeds were taken to stratification with 3 replications and 10 seeds in each replication. The percentage of germination was obtained by dividing the number of germinated seeds by the total number.

To determine emergence rates (%), seeds were sown in tubes at a depth of about 3 cm. At the end of 30 days, the ratio of the plants that emerged to the soil surface was expressed as a percentage. In addition, these seeds were observed for one month by checking every three days and their emergence times were calculated.

In the determination of seedling development in genotypes of wild almond species, a total of 30 plants were used, 10 plants in each replication. Seedling length (cm) was determined by measuring from the soil level to the most extreme point in each seedling. The stem diameter (cm) was determined by measuring 10 cm above the soil level with a 0.01 mm sensitive caliper.

The variance analyses of the obtained data were performed using the SAS package program **(SAS, 2005)**. Means were compared with the LSD test. Angle transformation was applied to the percentage values.

## 3. RESULTS AND DISCUSSION

The results of germination and emergence values obtained from seeds kept in stratification for 40 days are given in **Table 1**. The germination and emergence rates differed according to genotypes and years. Lower values were obtained in the second year of the experiment compared to the results of the first year. The germination rates ranged between 32.39% (O8) and 70.95% (O13) in *A. orientalis* genotypes and between 36.08% (T4) and 84.76% (T8) in *A. turcomanica* genotypes. The germination rates obtained from *A. turcomanica* genotypes were higher than those obtained from *A. orientalis* and Texas in the first and second years of planting, despite having a thicker and harder shell.

The stratification times in the wild almond species varied depending on the genotypes and years. The stratification time in *A. orientalis* genotypes was between 43 and 63 days in the first year and between 55 and 72 days in the second year. Our results showed that the stratification time was shorter in *A. turcomanica* genotypes. In addition, the stratification times were remarkably close to each other in *A. turcomanica* genotypes. While this period varied between 43 days and 46 days in the first year of the study, it was determined as 57 days in all genotypes in the second year of the study **(Table 1)**.

In the study, emergence rates of wild almonds varied based on the genotypes and years, and the differences between the means were statistically significant. The lowest emergence rate in *A. orientalis* genotypes was obtained from the O4 genotype (49.41%), while the highest emergence rate was obtained from the O12 genotype (85.69%). These values ranged between 57.16% (T1) and 73.41% (T8) in *A. turcomanica* genotypes. The emergence rates in genotypes of wild almond species were close to the values obtained from Texas almonds. Emergence rates in wild almond genotypes were lower than germination rates. The first emergence of *A. orientalis* genotypes started on the 10th day and the latest emergence occurred on the 13th day. The completion of emergence differed according to genotypes and varied between 16 days (O1, O11) and 31 days (O8, O12).

The first emergence of *A. turcomanica* started on the 13th day and was completed on the 28th day at the latest. The first emergence in *A. turcomanica* genotypes was 3 days late in *A. orientalis* genotypes. These differences can be due to the genetic structure of the species and the harder and thicker shell structure of *A. orientalis* genotypes. Similarly, **Atlı (2008)** reported that the emergence rates of *A. orientalis* genotypes varied between 30% and 90%. These results were also higher than those obtained by **Rahemi et al. (2011)**, who reported that the germination rate in wild almond species varied between 3.3% (*Prunus eburnean*) and 45.8% (*Prunus elaegnifolia*) depending on the years. Differences in germination values may be due to the differences in temperature, humidity, and altitude to which the seed is exposed during the formation and development of the embryo **(Madani et al., 2006)**. Furthermore, the low germination percentage in some genotypes in our study may be due to the hard coat, which may induce dormancy of the seed coat.

Seedling length and stem thickness characteristics of seedlings were shown in **Tables 2** and **Table 3.** The differences between the means of the genotypes were statistically significant.

**Table 1.** Germination and emergence rates according to genotypes of almond species

| Variables | Stratification duration | | Germination rate (%) | Emergence rate (%) | Emergence (Days) | |
|---|---|---|---|---|---|---|
| | 2014 | 2015 | | | Beginning | End |
| *Genotypes* | | | | | | |
| O1 | 60 | 68 | 48.85 d-h | 64.69 c-j | 10 | 16 |
| O2 | 51 | 62 | 33.00 j | 76.26 a-e | 13 | 19 |
| O3 | 60 | 66 | 45.67 e-I | 69.05 b-h | 10 | 19 |
| O4 | 60 | 66 | 53.81 cg | 49.41 j | 10 | 19 |
| O5 | 60 | 72 | 39.02 h-j | 56.31 h-j | 10 | 19 |
| O8 | 51 | 72 | 32.39 j | 51.39 i-j | 10 | 31 |
| O10 | 63 | 72 | 52.15 c-g | 63.90 c-j | 10 | 19 |
| O11 | 60 | 62 | 61.22 bc | 79.55 ac | 10 | 16 |
| O12 | 51 | 65 | 35.22 ij | 85.69 a | 13 | 31 |
| O13 | 60 | 66 | 70.95 b | 74.20 a-f | 10 | 22 |
| O14 | 63 | 69 | 63.55 bc | 70.50 a-h | 10 | 22 |
| O15 | 43 | 55 | 56.79 c-e | 78.10 ad | 10 | 22 |
| O16 | 43 | 55 | 61.22 bc | 81.39 ab | 10 | 22 |
| T1 | 43 | 57 | 55.82 c-f | 57.16 g-j | 13 | 22 |
| T2 | 46 | 57 | 71.87 b | 62.84 d-j | 13 | 22 |
| T3 | 46 | 57 | 54.24 c-g | 70.69 a-h | 13 | 25 |
| T4 | 43 | 57 | 36.08 ij | 59.90 f-j | 16 | 25 |
| T5 | 43 | 57 | 56.71 c-e | 72.85 a-g | 13 | 22 |
| T6 | 46 | 57 | 44.03 f-j | 60.84 e-j | 13 | 22 |
| T7 | 43 | 57 | 43.37 gj | 66.30 b-i | 13 | 28 |
| T8 | 43 | 57 | 84.76 a | 73.41 a-g | 13 | 28 |
| Texas | 36 | 40 | 59.53 bd | 75.00 a-f | - | - |
| LSD (%5) | | | 12.34 | 16.29 | | |
| *Year* | | | | | | |
| 2014 | | | 60.58 a | 71.29 a | | |
| 2015 | | | 44.89 b | 65.01 b | | |
| LSD (%5) | | | 1.99 | 2.63 | | |

O; A. orientalis, T; A. Turcomanica

**Table 2.** Seedling development in genotypes of almond species in the first year

| | June | | November | |
|---|---|---|---|---|
| Genotypes | Seedling length (cm) | Thickness(mm) | Seedling length (cm) | Thickness (mm) |
| O1 | 28.60 ab | 2.39 d | 49.13 a | 3.731 e |
| O2 | 29.44 a | 2.18 ef | 45.67 abc | 3.69 e |
| O3 | 26.82 bc | 3.24 a | 46.40 a | 5.09 a |
| O4 | 5.54 j | 1.18 m | 25.00 efg | 2.69 ıj |
| O5 | 22.96 e | 2.04 f-h | 42.06 a | 3.63 ef |
| O8 | 19.29 f | 2.08 f-g | 32.05 d | 2.83 hıj |
| O10 | 4.95 j | 1.00 no | 21.95 gh | 2.30 k |
| O11 | 28.41 ab | 2.17 ef | 47.77 a | 3.96 ed |
| O12 | 24.15 de | 2.31 de | 43.23 bc | 4.14 cd |
| O13 | 25.42 dc | 2.77 b | 42.14 c | 4.55 b |
| O14 | 30.09 a | 1.86 ij | 48.50 ab | 3.59 ef |
| O15 | 26.22 c | 2.56 c | 45.84 abc | 4.76 ab |
| O16 | 27.15 bc | 2.63 bc | 45.89 abc | 4.44 bc |
| T1 | 18.26 f | 1.84 jk | 30.88 d | 2.97 ghi |
| T2 | 7.56 hiı | 1.23 m | 30.31 d | 3.19 gh |
| T3 | 6.17 ij | 0.85 o | 12.65 ı | 2.22 k |
| T4 | 14.87 g | 1.67 l | 23.60 fg | 2.52 jk |
| T5 | 19.40 f | 2.00 g-i | 28.63 de | 3.06 ghi |
| T6 | 8.82 h | 1.11 mn | 19.37 h | 2.46 jk |
| T7 | 15.85 g | 1.71 kl | 26.22 ef | 2.69 ıj |
| T8 | 16.25 g | 1.92 h-j | 26.20 ef | 2.96 g-i |
| T9 | 18.19 f | 1.99 g-j | 28.39 de | 3.29 fg |
| *LSD (%5)* | 1.81 | 0.15 | 3.89 | 0.37 |

O; A. orientalis, T; A. turcomanica

Initial measurements in seedlings were carried out on June 01 in the first year and on April 01 in the second year of the experiment. In the measurements performed in November of the first year, seedling lengths in *A. orientalis* genotypes ranged from 21.95 cm (O10) to 49.13 cm (O1), and seedling thicknesses ranged between 2.30 (O10) and 5.09 mm (O3). *In A. turcomanica* genotypes, these values were observed between 12.65 cm (T3) and 30.88 cm (T1) and between 2.22 mm (T3) and 3.29 mm (T9), respectively. These results showed that the seedling growth in both *A. orientalis* and *A. turcomanica* genotypes was very slow depending on the seedling length and stem thickness.

According to the measurement results in November of the second year of the study, the highest and lowest seedling length and thickness values were similar to the first year. Seedling lengths in *A. orientalis* genotypes differed between 39.58 cm (O10) and 71.28 cm (O11), and seedling thicknesses ranged between 3.58 mm (O10) and 7.85 mm (O3). In *A. turcomanica* genotypes, seedling length and thickness values varied between 24.08 cm (T3) and 55.43 cm (T1) and between 3.27 mm (T3) and 5.82 mm (T9), respectively.

Our data clearly showed that the seedling length and stem thickness of *A. orientalis* genotypes were higher than *A. turcomanica* genotypes **(Figure 1)**.

**Figure 1.** General views of plants from A. turcomanica (A, E), A. orientalis (B, D), and Texas (C)

**Table 3.** Seedling development in genotypes of almond species in the second year

| Genotypes | April | | November | |
|---|---|---|---|---|
| | Seedling length (cm) | Thickness (mm) | Seedling length (cm) | Thickness (mm) |
| O1 | 51.13 a | 4.22 c | 64.93 ab | 6.02 b |
| O2 | 48.60 abc | 4.31 c | 63.10 bcd | 6.12 b |
| O3 | 48.37 abc | 5.60 a | 62.46 bcd | 7.85 a |
| O4 | 34.39 ef | 3.23 fg | 57.05 cde | 6.30 b |
| O5 | 43.77 d | 4.08 cd | 56.87 de | 6.14 b |
| O8 | 33.82 efg | 3.12 gh | 52.58 ef | 4.45 de |
| O10 | 25.17 h | 2.41 jı | 39.58 h | 3.58 fg |
| O11 | 49.98 ab | 4.25 c | 71.28 a | 7.66 a |
| O12 | 46.60 bcd | 4.74 b | 63.63 bc | 6.19 b |
| O13 | 46.17 cd | 4.74 b | 62.80 bcd | 6.15 b |
| T1 | 32.83 efg | 3.38 fg | 55.43 ef | 4.59 cd |
| T2 | 34.64 e | 3.58 ef | 51.17 ef | 4.78 cd |
| T3 | 14.25 ı | 2.34 j | 24.08 ı | 3.27 g |
| T4 | 25.08 h | 2.79 hı | 43.04 gh | 3.94 ef |
| T5 | 33.27 efg | 3.54 ef | 53.97 ef | 5.00 cd |
| T6 | 24.69 h | 3.07 gh | 38.47 h | 5.08 c |
| T7 | 31.14 fg | 3.12 gh | 50.92 ef | 4.62 cd |
| T8 | 31.53 efg | 3.33 fg | 49.70 fg | 4.77 cd |
| T9 | 30.87 g | 3.83 de | 49.03 gf | 5.82 b |
| *LSD (%5)* | 3.40 | 0.39 | 6.69 | 0.56 |

O; A. orientalis, T; A. turcomanica

These results were consistent with the findings of **Bayazit (2007)**, who reported that plant heights and stem thicknesses of the *A. orientalis* genotypes selected from the Southeastern Anatolia region were higher than the *A. turcomanica* genotypes; however, they formed a very small canopy in two almond species compared to the cultivated almonds. **Baninasab and Rahemi (2006)** reported that 4 months after the emergence of *A. orientalis*, the seedling length was 19.10 cm and the stem thickness was 1.30 mm. When *P. webbii* is used as a dwarf rootstock for almonds, peaches, and nectarines, these values were between 14.88 cm and 1.40 mm, respectively. These results were also in agreement with that of **Rahemi et al. (2011)** who showed different sizes of wild almond species.

Stem thickening must be rapid to be able to graft for genotypes to be used as rootstocks. **Ağaoğlu et al. (1995)** indicated that the thickness of the rootstocks should be between 0.6 and 2.5 cm to make a T budding. For this reason, the stem diameter development of the almond species used in the study was insufficient for budding.

**Table 4.** Seedling properties of genotypes of almond species

| Genotypes | Seedling strength | Internode lengths | Branching | Leafing | Leaf color |
|---|---|---|---|---|---|
| O1 | Medium | Medium | Medium | Medium | Grey |
| O2 | Medium | Medium | Medium | Medium | Grey |
| O3 | Medium | Short | Medium | Dense | Grey |
| O4 | Strong | Short | Dense | Medium | Green |
| O5 | Medium | Short | Medium | Dense | Grey |
| O10 | Weak | Short | Sparce | Medium | Green |
| O11 | Weak | Medium | Medium | Medium | Grey |
| O 12 | Medium | Medium | Medium | Medium | Grey |
| O13 | Medium | Medium | Medium | Medium | Green |
| O14 | Medium | Medium | Medium | Medium | Grey |
| O15 | Medium | Short | Medium | Dense | Grey |
| O16 | Strong | Medium | Medium | Medium | Grey |
| T 1 | Medium | Short | Medium | Dense | Dark green |
| T 2 | Medium | Medium | Medium | Medium | Light green |
| T 3 | Weak | Short | Sparce | Dense | Light green |
| T 4 | Medium | Short | Dense | Dense | Green |
| T 5 | Medium | Short | Dense | Dense | Light green |
| T 6 | Medium | Short | Dense | Medium | Light green |
| T 7 | Medium | Short | Medium | Dense | Light green |
| T 8 | Medium | Short | Dense | Dense | Green |
| T 9 | Strong | Short | Dense | Medium | Light green |

O; A. orientalis, T; A. turcomanica

Even, in the second year of the experiment, the stem thicknesses of the genotypes of *A. turcomanica* did not reach sufficient thickness for budding. While the stem thickness required for the budding could not be obtained from the *A. orientalis* genotypes in the first year, this value was obtained in the O8 genotype in the second year of the experiment. Even though stem thickness is affected by genetic structure, it is also significantly affected by cultural practices. It is known that the almond species of the experiment have slow growth due to their dwarf characteristics. However, the shoot growth and the stem thickness can increase with the regulation of plant nutrition conditions.

Some seedling characteristics of wild almond species used in the experiment are presented in **Table 4.** Accordingly, the seedling strength of *A. orientalis* and *A. turcomanica* genotypes was observed as 'moderate' and 'weak'.

On the other hand, *A. orientalis* seedlings developed more strongly than *A. turcomanica* seedlings. As a result of the observations, the internode lengths were mainly 'short' in *A. turcomanica* seedlings. Branching and leafing were more frequent in genotypes of *A. turcomanica*. While leaf color was 'grey' in *A. orientalis* genotypes, it was observed as 'green' in seedlings of *A. turcomanica*.

## 4. CONCLUSION

Agricultural lands with mostly calcareous soil structures face salinity problems due to incorrect irrigation and fertilization, and changes in the precipitation regime due to global warming lead to a decrease in water resources. It is very important to select rootstocks that have a high tolerance to biotic and abiotic stress conditions and low vigorously for high-density planting from the natural population and use them directly in cultivation or evaluate them in rootstock breeding programs. In this regard, wild *A. orientalis* and *A. turcomanica* almond species are very valuable genetic resources as rootstocks in solving biotic and abiotic problems in almond growing areas. Currently, there are limited studies on the seed propagation of these wild almond species. The results of this study showed that the germination and emergence rates of *A. orientalis* and *A. turcomanica* genotypes can be used as seed rootstocks. However, slow seedling development delays the production of the budded cultivars. Therefore, to increase the growth rate of seedlings, there is a need for more detailed research on plant nutrition and irrigation programs.

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