

## Effects of Different Temperature and Dormancy Breaking Treatments on Germination of *Lotus corniculatus* Seeds\*

*Lotus corniculatus* Tohumlarının Çimlenmesi Üzerine Farklı Sıcaklık ve Dormansi Kırma Uygulamalarının Etkileri

Bilal KESKİN<sup>1\*</sup>, Naim UCA<sup>2</sup>

### Abstract

This research was carried out in the laboratory according to the factorial experimental design in completely randomized with 4 replications in order to determine the germination temperatures and appropriate dormancy breaking methods of birdsfoot trefoil seeds collected in 3 (three) locations in Suveren (A), Melekli (B) and Aşağı Çamurlu (C) regions of Iğdır province. The germination rates of normal, abnormal and dormant seeds were determined in birdsfoot trefoil seeds at 5 different constant (15, 20, 25, 30 and 35 °C) and 4 variable (15/25, 15/30, 20/30 and 20/35 °C) temperatures. The highest normal germination rates were determined at (20/30 °C). Even at the highest normal germination temperature, it was determined that there was a dormancy rate of 85.0% in the birds of birdsfoot trefoil collected in natural areas. There was no significant difference between the abnormal germination of birdsfoot trefoil seeds at different locations. In addition, there was no significant difference between the abnormal germination at different temperatures. Dormant seed rates were higher at locations B and C. The highest dormant seed rate was seen in birdsfoot trefoil seeds germinated at the lowest temperature (15 °C). In order to break the dormancy, gibberellic acid, potassium nitrate, sulfuric acid, hydrochloric acid, salicylic acid, soaking in warm water, mechanical scarification and soaking in hot water were applied to the birdsfoot trefoil seeds. Compared to the control treatment, sulfuric acid and potassium nitrate increased normal germination rates, gibberellic acid and mechanical scarification did not affect on normal germination rates, and hydrochloric acid and salicylic acid decreased germination rates. According to the research results, it was determined that dormancy was high in seeds collected in natural environments and that the seeds needed to be kept in 95-98% sulfuric acid for 12 minutes to break the dormancy. Soaking *Lotus corniculatus* seeds in sulfuric acid for 12 minutes increased the normal germination rate to 79%. Sulfuric acid application also caused an increase in the abnormal germination rate.

**Keywords:** Birdsfoot trefoil, Germination, Gibberellic acid, Mechanical scarification, Sulfuric acid

<sup>1</sup>\*Sorumlu Yazar/Corresponding Author: Bilal Keskin, Iğdir University, Faculty of Agriculture, Department of Field Crops, Iğdir, Türkiye. E-mail: [bilalkeskin66@yahoo.com](mailto:bilalkeskin66@yahoo.com)  ORCID: 0000-0001-6826-9768

<sup>2</sup>Naim Uca, Iğdir University, Faculty of Agriculture, Department of Field Crops, Iğdir, Türkiye. E-mail: [naimuca7621@gmail.com](mailto:naimuca7621@gmail.com)  ORCID: 0009-0006-6926-5391

**Atf:** Keskin, B., Uca, N. (2026). *Lotus corniculatus* tohumlarının çimlenmesi üzerine farklı sıcaklık ve dormansi kırma uygulamalarının etkileri. *Tekirdağ Ziraat Fakültesi Dergisi*, 23(2): 412-421.

**Citation:** Keskin, B., Uca, N. (2026). Effects of different temperature and dormancy breaking treatments on germination of *Lotus corniculatus* seeds. *Journal of Tekirdag Agricultural Faculty*, 23(2): 412-421.

\*This study was summarized from the Naim Uca MSc thesis.

©Bu çalışma Tekirdağ Namık Kemal Üniversitesi tarafından Creative Commons Lisansı (<https://creativecommons.org/licenses/by-nc/4.0/>) kapsamında yayınlanmıştır. Tekirdağ 2026

**Öz**

Bu araştırma Iğdır ilinin Suveren (A), Melekli (B) ve Aşağı Çamurlu (C) bölgelerinde olmak üzere 3 (üç) lokasyonda toplanan sarıçiçekli gazal boynuzu tohumlarının çimlenme sıcaklıkları ve uygun dormansi kırma yöntemlerini belirlenmesi amacıyla tesadüf parsellerinde faktöriyel deneme desenine göre 4 tekerrürlü olarak laboratuvarında yürütülmüştür. Gazal boynuzu tohumları 5 farklı sabit (15, 20, 25, 30 ve 35 °C) ve 4 değişken (15/25, 15/30, 20/30 ve 20/35 °C) sıcaklık derecesinde normal, anormal çimlenme ile dormant tohum oranları belirlenmiştir. En yüksek normal çimlenme oranları (20/30 °C) sıcaklık derecesinde tespit edilmiştir. En yüksek normal çimlenmenin olduğu sıcaklık derecesinde bile doğal alanlarda toplanan gazal boynuzu tohumlarında %85.0 oranında dormansi olduğu belirlenmiştir. Farklı lokasyonlardaki gazal boynuzu tohumlarının anaormal çimlenmeleri arasında önemli bir fark görülmemiştir. Aynı zamanda farklı sıcaklık derecelerindeki anormal çimlenmeler arasında önemli farklar olmamıştır. Dormant tohum oranları B ve C lokasyonlarında daha yüksek olmuştur. En yüksek dormant tohum oranı en düşük sıcaklık derecesinde (15 °C) çimlendirmeye alınan gazal boynuzu tohumlarında görülmüştür. Dormansinin kırılması amacıyla gazal boynuzu tohumlarına giberallik asit, potasyum nitrat, sülfürik asit, hidroklorik asit, salisilik asit, ılık suda bekletme, mekanik aşındırma ve sıcak suda bekletme uygulamaları yapılmıştır. Kontrol uygulamasına göre sülfürik asit ve potasyum nitrat normal çimlenme oranlarını artırırken, giberallik asit, mekanik aşındırma normal çimlenme oranı üzerine etkisi olmamış, hidroklorik asit ve salisilik asit ise çimlenme oranlarını düşürmüştür. Araştırma sonuçlarına göre doğal ortamdan toplanan tohumlarda dormansinin yüksek olduğu, dormansinin kırılması için tohumların %95-98'lik sülfürik asitte 12 dakika bekletilmesi gerektiği belirlenmiştir. *Lotus corniculatus* tohumlarının 12 dakika süreyle sülfürik asitte bekletilmesi normal çimlenme oranını %79'a kadar ulaştırmıştır. Sülfürik asit uygulaması aynı zamanda anormal çimlenme oranında da artışa neden olmuştur.

**Anahtar Kelimeler:** Gazal boynuzu, Çimlenme, Giberallik asit, Mekanik aşındırma, Sülfürik asit

## 1. Introduction

Natural areas are areas that contain plant diversity and genetic resources. Although the humidity, temperature and light required for germinating plant seeds are suitable, the seeds may not germinate. It can be said that dormancy is present in these seeds (Temel et al., 2023; Keskin et al., 2023). Most of the plant seeds in natural areas show high dormancy and thanks to this feature, the plants can continue their generations (Baroux and Grossniklaus, 2019). However, high seed dormancy is not desired when cultivating and growing plants in these natural areas. Knowing the appropriate germination temperatures and dormancy breaking methods of seeds in natural areas will increase the potential for culturing and growing plants. It is desired that the seeds to be used for cultivation do not have dormancy or that methods that will easily eliminate dormancy in the seed are known (Quintero et al., 2018). Intensive research is being conducted on determining the germination temperatures of seeds, dormancy rates, and which methods are appropriate to break dormancy in these seeds (Szalai and Ferchl, 2016; Ren et al., 2017; Temel et al., 2023; Keskin et al., 2023).

In the *Fabaceae* family, *Lotus* contains about 200 species of annual and perennial plants spread across different ecological regions. The most cultivated species within the *Lotus* genus is *Lotus corniculatus*. *Lotus corniculatus* is more resistant to drought conditions than many *Lotus* species and is also among the plants used in the improvement of natural pasture (Blumenthal and McGraw, 1999; Ferat et al., 2008; Gür and Şen, 2016; Özpınar et al., 2019; Beyaz, 2023).

It was observed that *Lotus corniculatus* seeds collected in natural areas had a high rate of dormancy and the seeds showed a germination rate of 7.7% even at the most suitable temperature (Ren et al., 2017). Germination rates of seeds decrease significantly at temperatures below 15 °C and above 30 °C (Woods and MacDonald, 1971). Studies have been carried out to break dormancy of birdsfoot trefoil seeds in natural areas by applying applications such as soaking in warm water, soaking in sulfuric acid, mechanical scarification, soaking in boiling water and gibberellic acid (Brown, 1955; Artola et al, 2003; Clua and Gimenez, 2003; Ren et al., 2017).

Due to the characteristics of the birdsfoot trefoil plant such as its high feed value, its ability to improve the soil and provide nitrogen to the soil, its tolerance to salinity and its ability not to cause bloat in animals, this study was carried out to determine the germination temperatures of the seeds of this plant in their natural areas, their dormancy status and the most appropriate methods to be used in breaking the dormancy.

## 2. Materials and Methods

In the research, *Lotus corniculatus* population seeds collected from Suveren (A), Melekli (B) and Aşağı Çamurlu (C) regions of Iğdir province were used (Figure 1). The research was carried out under laboratory conditions.

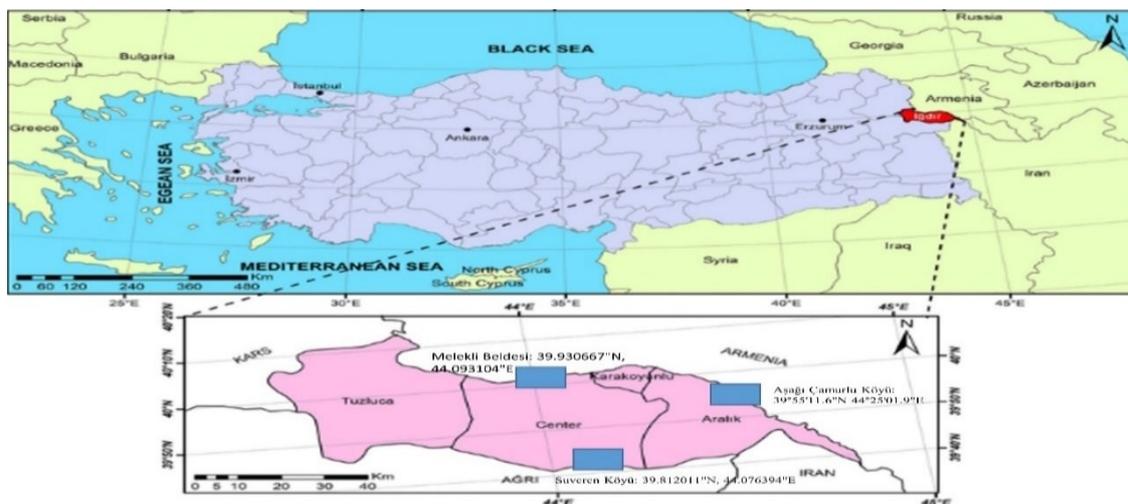


Figure 1. Locations where seeds were collected

### 2.1. Determination of germination temperatures of seeds

Seeds collected at locations were threshed and cleaned from broken and foreign materials. Seeds were stored in nylon bags at room temperature until germination. Then, *Lotus corniculatus* seeds were germinated in a cooled incubator device under 12/12 hours of light/darkness at 5 different constant (15, 20, 25, 30 and 35 °C) and 4 variable (15/25, 15/30, 20/30 and 20/35 °C) temperatures (Woods and MacDonald, 1971; Ren et al., 2017). To prevent pathogen damage during germination, the seeds were kept in 2% sodium hypochlorite for 10 minutes and then washed with pure water. After 25 seeds were placed on coarse filter paper in a glass petri dish, the germination papers were moistened with 10 ml of a 2% solution of fungicide containing 80% thiram in order to prevent fungicide damage. Glass petri dishes were placed in refrigerated incubators set at specified temperatures. The germination study lasted 15 days and the first counts started on the 5th day and daily counts continued until the 15th day. Humidity levels in petri dishes were monitored and pure water was added to petri dishes with decreasing moisture content. Normal germination rates were determined by counting seeds with a radicle length of 2 mm daily (Prado et al., 2000). On the 15th day of the seed germination study, the petri dishes were removed from the incubator and normal, abnormal and dormant seeds were counted. Seeds with a radicle length of 2 mm were counted as normal germination (N), seeds less than 2 mm as abnormal germination (A) and seeds that did not germinate were counted as dormant seeds (D) and their ratios were determined according to the formula below (AOSA, 1993).

$$N, A, D \text{ germination rate (\%)} = \left( \frac{\text{seed germination status}}{\text{number of seeds in the germination container}} \right) \times 100 \quad (\text{Eq. 1})$$

### 2.2. Dormancy breaking applications

It has been observed that *Lotus corniculatus* seeds growing in natural environments have a dormancy rate of 19% to 90% (Brown, 1955; Ren et al., 2017). In the seed populations collected in 3 (three) locations in Iğdır province, the highest normal germination rate at 20/30 °C was 12.7% and 85.0% dormancy was observed in the seeds. Eight different dormancy breaking methods were applied to eliminate dormancy in seeds. After all dormancy breaking applications, 25 seeds were placed in each petri dish in 4 replications and germination status was monitored for 15 days in a cooled incubator set at 20/30 °C, where the highest normal germination rate was determined.

The seeds were kept in 200, 400 and 600 ppm gibberellic acid (Ren et al., 2017) for 24 hours in the dark; in 0.1%, 0.2% and 0.3% potassium nitrate for 24 hours in the dark; in 95-98% sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) (Ren et al., 2017) for 3, 6, 9 and 12 minutes; in 30-32% hydrochloric acid (HCL) for 2, 4, 6 minutes; in salicylic acid solution prepared at 200, 400 and 600 ppm for 12 hours in the dark; and in warm water so that they remained completely submerged for 1, 2 and 3 days. After the seeds were placed in sandpaper, they were subjected to mechanical scarification in a shaking device for 10, 20 and 30 minutes (Ren et al., 2017; Clua and Gimenez, 2003; Li and Hill, 1989) and kept in boiling water for 2, 4, 8 and 12 minutes (Li and Hill, 1989).

The data obtained from the research were subjected to variance analysis using the JMP 5.0.1 package program according according to the completely randomized factorial experimental design. The comparison and grouping of the significant means as a result of variance analysis were done according to the LSD test.

## 3. Results and Discussion

### 3.1. Determine Germination Temperatures

The values of normal and abnormal germination rates and dormant seed rates of birdsfoot trefoil seeds in different locations and temperatures are given in *Table 1*. When *Table 1* is examined, the highest normal germination and the lowest dormant seed rates were obtained in the birdsfoot trefoil seeds collected at location A. Compared to location A, normal germination was lower and dormant seed ratio was higher in birdsfoot trefoil seeds collected in locations B and C. It has been stated in many studies that there may be significant differences in the germination and dormancy status of seeds of different species, varieties and locations (Woods and MacDonald, 1971; Hill and Luck, 1991; Blumenthal et al., 1996; Özpınar et al., 2019). Dormant seed rates varied between 85.0% and 93.7% depending on locations and temperatures. At the lowest temperature (15°C) 5.3% normal germination occurred. The highest normal germination rates were obtained at variable temperature of 20/30

°C. There were no significant differences in abnormal germination rates in seeds at different temperatures and locations. Different temperatures had effects on the dormant seed rates. Accordingly, it was determined that the rate of dormant seeds was high at low temperatures (15 °C). There were no significant differences between the dormant seed ratios at other temperatures (except 20/30 °C). The lowest dormant seed ratio was obtained at 20/30 °C.

Studies have reported that the highest germination rate in *Lotus corniculatus* seeds was obtained at 20-21 °C (Hur and Nelson, 1985; Charlton, 1989; Mujica and Rumi, 1993), and in some studies, the highest germination was obtained at variable temperature degrees of 25/29 °C (Ren et al., 2017). In a study conducted by Hill and Luck (1991), it was reported that the highest germination of *Lotus corniculatus* and *Lotus pedunculatus* seeds was at 20/24 and 15/20 °C, respectively. It has also been found that seed germination of *Lotus corniculatus* seeds decreases significantly at temperatures below 15 °C and above 30 °C (Woods and MacDonald, 1971; Blumenthal et al., 1996; Lopes and Franke, 2011). As seen in current research findings and many studies, it is seen that germination rates remain at very low levels due to the high hard seed content in Lotus species.

**Table 1. Germination rates (%) at different locations and temperatures**

Locations	Normal (%)	Abnormal (%)	Dormant seed (%)
A	9.9 a	2.3	87.9 b
B	8.6 b	1.2	90.9 a
C	7.3 b	1.8	90.2 a
Temperatures (°C)			
15	5.3 c	1.0	93.7 a
20	8.0 b	2.7	89.3 b
25	9.3 b	1.3	89.3 b
30	7.7 b	1.7	90.7 b
35	8.0 b	2.3	89.7 b
15/25	8.7 b	1.3	90.3 b
15/30	8.7 b	1.7	89.7 b
20/30	12.7 a	2.3	85.0 c
25/35	9.0 b	1.7	89.3 b

There is no statistically significant difference between numbers indicated by the same letters.  $P < 0.01$

### 3.2. Dormancy Breaking Applications

Due to the high rate of dormancy in *Lotus corniculatus* seeds collected in natural environments (Table 1), after 8 (eight) dormancy breaking applications were made to the seeds, the seeds were germinated again for 15 days at 20/30 °C, where the highest normal germination was determined. The values of normal and abnormal germination and dormant seed rates of seeds in different locations are given in Table 2. When Table 2 was examined, it was determined that there was no significant difference between the normal and abnormal germination rates and dormant seed rates of birdsfoot trefoil seeds in different locations. It is estimated that the low germination rate and high dormancy in seeds collected in natural environments cause the differences in normal and abnormal germination and dormant seed rates in these seeds to be insignificant.

**Table 2. Germination rates of birdsfoot trefoil seeds in different locations (%)**

Locations	Normal (%)	Abnormal (%)	Dormant seed (%)
A	12.0	5.0	83.0
B	10.0	3.0	87.0
C	10.0	4.0	86.0

The values of normal and abnormal germination and dormant seed rates obtained as a result of dormancy breaking methods applied at different levels are given in Table 3.

Different gibberellic acid levels significantly affected on normal and abnormal germination and dormant seed rates. The lowest dormant seed rates and the highest abnormal and normal germination percentages were determined from control, 200 and 400 ppm applications. However, the highest gibberellic acid application (600

ppm) decreased the germination percentage of seeds and increased the rate of dormant seeds (*Table 3*). In the present study, gibberellic acid application did not break dormancy. Ren et al. (2017) reported in their study that gibberellic acid application alone was not successful in breaking dormancy in *Lotus corniculatus* seeds, but it was successful in breaking dormancy when applied together with cold moist storage and mechanical scarification applications. It has been reported that applying gibberellic acid to the legume plant *Astragalus gummifer* seeds, which have hard seed characteristics, was unsuccessful in breaking dormancy (Gürel et al., 2022). On the other hand, it has been determined that applying gibberellic acid to the seeds of *Alhagi pseudalhagi*, a legume plant, is a successful method in breaking dormancy (Keskin et al., 2023).

**Table 3. Germination rates (%) of different dormancy breaking treatments and levels**

Application	Level	Normal (%)	Abnormal (%)	Dormant seed (%)
Gibberellic acid (ppm)	Control	10.7 a*	4.0 a	85.3 b
	200	11.3 a	4.7 a	84.0 b
	400	11.0 a	4.3 a	84.7 b
	600	6.3 b	1.3 b	92.7 a
Potassium nitrate (%)	Control	10.7 c	4.0 b	85.3 a
	0.1	14.0 b	2.3 c	83.7 ab
	0.2	14.0 b	4.7 b	81.3 b
	0.3	16.7 a	6.7 a	76.7 c
Sulfuric acid (minute)	Control	10.7 d	4.0 c	85.3 a
	3	51.0 c	3.7 c	45.3 b
	6	74.7 ab	6.0 c	19.3 c
	9	71.3 b	14.3 a	14.3 d
	12	79.0 a	10.3 b	10.7 e
Hydrochloric acid (minute)	Control	10.7	4.0 ab	85.3 b
	2	9.7	2.0 c	88.3 a
	4	11.3	2.7 bc	86.0 ab
	6	10.7	5.3 a	84.0 b
Salicylic acid (ppm)	Control	10.7 a	4.0 a	85.3 c
	200	6.7 b	1.7 b	91.7 b
	400	4.3 c	1.3 b	94.3 a
	600	5.0 bc	2.3 b	92.7 ab
soaking in warm water (gün)	Control	10.7 b	4.0 a	85.3 b
	1	14.0 a	2.7 ab	83.3 b
	2	8.7 b	1.7 b	89.7 a
	3	10.7 b	1.3 b	88.0 a
Mechanical scarification (minute)	Control	10.7 a	4.0 a	85.3 b
	10	6.3 b	1.0 c	92.7 a
	20	10.0 a	2.7 ab	87.3 b
	30	11.0 a	2.0 bc	87.0 b
Soaking in hot water (minute)	Control	10.7 b	4.0 c	85.3 a
	2	20.0 a	13.3 b	66.7 b
	4	5.0 c	28.3 a	66.7 b
	8	3.7 c	29.3 a	67.0 b
	12	4.3 c	31.0 a	64.7 b

There is no statistically significant difference between numbers indicated by the same letters.  $P < 0.01$ .

Compared to the control, increasing potassium nitrate doses increased normal and abnormal germination rates and decreased the rate of dormant seeds (*Table 3*). Relative to the control, the highest application of potassium nitrate (0.3%) increased normal germination by only 6%. When previous studies were examined, it was seen that potassium nitrate application was unsuccessful in breaking dormancy in many legume plants (Gürel et al., 2022; Keskin et al., 2023).

When the sulfuric acid application time was increased compared to the control, the seeds' normal and abnormal germination rates increased significantly, and the dormant seed rate decreased (*Table 3*). This decrease in the proportion of dormant seeds is related to sulfuric acid significantly eliminating dormancy in birdsfoot trefoil seeds. It is estimated that increased sulfuric acid application time causes damage to the seed embryo and significantly increases the rate of abnormal germination. When the studies were examined, it was reported that sulfuric acid application significantly removed dormancy in *Lotus corniculatus* seeds (Brown, 1955; Ren et al., 2017; Jones et al., 2022). On the other hand, it has been reported that *Alhagi pseudalhagi* seeds, in the legume family in sulfuric acid do not affect breaking dormancy (Keskin et al., 2023). In the seeds of the Lotus genus, the seeds usually start to lose moisture after harvest and the seed coats become too hard to hold water. For seeds with hard coat to germinate, the coats must be damaged (Gresta et al., 2011; Smýkal et al., 2014). In this respect, sulfuric acid has significantly damaged the hard coat.

The duration of soaking in hydrochloric acid did not affect normal germination. On the other hand, it was observed that the highest dormant seed rate and the lowest abnormal germination rate were obtained in soaking in hydrochloric acid for 2 and 4 minutes (*Table 3*). When the studies were examined, it was reported that hydrochloric acid application significantly broke the dormancy in *Lotus corniculatus* seeds (Burton, 1939).

Applying salicylic acid to birdsfoot trefoil seeds collected in natural environments did not affect breaking seed dormancy, on the contrary, it caused a decrease in germination rates (*Table 3*). Applying salicylic acid to *Cynodon dactylon* seeds significantly affected breaking seed dormancy (Fakhire and Shahriari, 2018). Dormancy breaking applications may show different responses in different plant species.

Compared to the control, the normal germination rate of seeds kept in warm water for 1 day increased slightly, while the normal germination rate of seeds kept in warm water for a longer period decreased. Soaking seeds in warm water for a long time reduced the abnormal germination rate and increased the rate of dormant seeds (*Table 3*). In some studies, it was determined that soaking in warm water did not affect breaking dormancy in birdsfoot trefoil seeds (Artola et al., 2003; Clua and Gimenez, 2003).

Compared to the control, 10 minutes of mechanical scarification application reduced the normal germination rate, while 20 and 30 minutes did not create significant differences compared to the control. As the duration of mechanical scarification application increased, abnormal germination rates decreased. Compared to the control, the dormant seed ratio increased in 10 minutes of mechanical scarification, and applying mechanical scarification to the seeds for a longer time did not cause any change in the dormant seed ratio (*Table 3*). In the present study, mechanical scarification of birdsfoot trefoil seeds did not affect breaking dormancy. However, when previous studies were examined, it was seen that mechanical scarification application to the seeds of species of the *Lotus* genus was successful in breaking dormancy (Brown, 1955; Li and Hill, 1989; Clua and Gimenez, 2003; Cristaudo et al., 2008; Szalai and Ferschl, 2016; Ren et al., 2017).

Compared to the control, soaking in hot water for 2 minutes increased the normal germination rate, but soaking in hot water for a longer time caused a significant decrease in the normal germination rate. As the soaking time in hot water increased, abnormal germination rates increased. Soaking in hot water for 2 minutes caused a decrease in the dormant seed rate. However, the decrease in dormant seed rates did not continue with the application of soaking in hot water for a longer period (*Table 3*). It was determined that soaking in hot water for 2 minutes of birdsfoot trefoil seeds would break the seed's dormancy, while soaking for longer periods would increase abnormal germination rates. It has been determined that soaking in hot water of birdsfoot trefoil seeds successfully breaks dormancy in the seeds, but prolonged soaking in hot water increases the rate of abnormal germination and dormant seeds (Li and Hill, 1989). It has been reported that there is a high rate of dormancy in the seeds of *Astragalus gummifer* and *Alhagi pseudalhagi* from the legume family collected in natural environments, and soaking the seeds in hot water is successful in breaking the dormancy (Gürel et al., 2022; Keskin et al., 2023).

#### 4. Conclusions

Dormancy rates of 87.9% to 90.9% were found in birdsfoot trefoil seeds collected in natural environments, depending on the location. In the study where constant and variable temperatures were used, 5.3% normal germination was achieved in seeds at the lowest temperature (15 °C). The highest normal germination rate was observed at 20/30 °C. Compared to the control treatment, sulfuric acid and potassium nitrate applications affected

breaking the dormancy in seeds. In contrast, gibberellic acid, hydrochloric acid, salicylic acid, soaking in warm water and mechanical scarification did not break the dormancy in seeds. Soaking *Lotus corniculatus* seeds in sulfuric acid for 12 minutes significantly affected breaking dormancy in the seeds and normal germination rate reached up to 79%. Sulfuric acid application also caused an increase in abnormal germination rate.

#### **Acknowledgment**

This work supported supported by the IĞDIR UNIVERSITY Scientific Research Projects Coordination Unit (Project No ZİF0424Y12), Türkiye.

#### **Ethical Statement**

There is no need to obtain permission from the ethics committee for this study.

#### **Conflicts of Interest**

We declare that there is no conflict of interest between us as the article authors.

#### **Authorship Contribution Statement**

Concept: Keskin, B., Uca, N.; Design: Keskin, B., Uca, N.; Data Collection or Processing: Keskin, B., Uca, N.; Statistical Analyses: Keskin, B.; Literature Search: Keskin, B., Uca, N.; Writing, Review and Editing: Keskin, B., Uca, N

## References

- AOSA (Association of Official Seed Analysts). (1993). Rules for testing seeds. *Journal of Seed Technology*, 16(3): 1-113.
- Artola, A., Carrillo-Castaneda, G. and de los Santos, G. G. (2003). Hydropriming: a strategy to increase *Lotus corniculatus* L. Seed vigor. *Seed Science and Technology*, 31(2): 455-463. <https://doi.org/10.15258/sst.2003.31.2.22>
- Baroux, C. and Grossniklaus, U. (2019). Seeds-An evolutionary innovation underlying reproductive success in flowering plants. *Current Topics in Developmental Biology*, 131: 605-642. <https://doi.org/10.1016/bs.ctdb.2018.11.017>
- Beyaz, R. (2023). Germination and seedling properties of *Lotus corniculatus* L. under simulated drought stress. *Journal of Tekirdag Agricultural Faculty*, 20(4): 879-889. <https://doi.org/10.33462/jotaf.1226444>
- Blumenthal, M. J., Aston, S. C. and Pearson, C. J. (1996). Effect of temperature and moisture potential on germination and emergence in *Lotus* sp. *Australian Journal of Agricultural Research*, 47(7): 1119-1130. <https://doi.org/10.1071/AR9961119>
- Blumenthal, M. and McGraw, R. (1999) *Lotus* Adaptation, Use and Management. In: Trefoil: The Science and Technology of *Lotus*. Ed(s): Beuselink, P. American Society of Agronomy, pp. 97-120. <https://doi.org/10.2135/cssaspecpub28.c6>
- Brown, C. S. (1955). *Hard seed in birdsfoot trefoil*. (Ph.D. Thesis). Cornell University, Michigan, U.S.A.
- Burton, G. W. (1939). Scarification studies on southern grass seeds. *Journal of the American Society of Agronomy*, 31(3): 179-187.
- Charlton, J. F. L. (1989). Temperature effects on germination of Grasslands Maku *Lotus* and other experimental *Lotus* selections. *Proceedings of the New Zealand Grassland Association*, 50: 197-201. <https://doi.org/10.33584/jnzc.1989.50.1883>
- Clua, A. A. and Gimenez, D. O. (2003). Environmental factors during seed development of narrow-leaved bird's-foot-trefoil (*Lotus tenuis*) influences subsequent dormancy and germination. *Grass and Forage Science*, 58(4): 333-338. <https://doi.org/10.1046/j.1365-2494.2003.00385.x>
- Cristaudo, A., Gresta, F., Avola, G. and Miano, V. (2008). Germination capability of immature seeds of *Lotus ornithopodioides* L. and *Scorpiurus subvillosus* L. *Options Méditerranéennes, Series A*, (79): 289-292.
- Fakhire, S. and Shahriari, A. (2018). Analysis of seed germination characteristics of *Cynodon dactylon* affected by treatments of salicylic acid, gibberellic acid and potassium nitrate. *Journal of Plant Research (Iranian Journal of Biology)*, 31(1): 166-174. <https://dor.isc.ac/dor/20.1001.1.23832592.1397.31.1.17.3>
- Ferat, U., Sulak, M. and Serdal, U. (2008). The important of birdsfoot trefoil species for Turkey. *Türk Bilimsel Derlemeler Dergisi*, 1(2): 45-54.
- Gresta, F., Avola, G., Onofri, A., Anastasi, U. and Cristaudo, A. (2011). When does hard coat impose dormancy in legume seeds? *Lotus* and *Scorpiurus* case study. *Crop Science*, 51 (4): 1739-1747. <https://doi.org/10.2135/cropsci2010.12.0700>
- Gür, M. and Şen, C. (2016). Some properties of the vegetation on grazing, protected and abandoned natural rangelands. *Journal of Tekirdag Agricultural Faculty*, 16(1): 61-69.
- Gürel, G., Keskin, B. and Temel, S. (2022). The effects of some dormancy breaking treatments and temperature on seed vigor of gum tragacanth (*Astragalus gummifer* Labill.). *Yuzuncu Yil University Journal of Agricultural Sciences*, 32(2): 266-279. <https://doi.org/10.29133/yyutbd.1026792>
- Hill, M. J. and Luck, R. (1991). The effect of temperature on germination and seedling growth of temperate perennial pasture legumes. *Australian Journal of Agricultural Research*, 42(1): 175-189. <https://doi.org/10.1071/AR9910175>
- Hur, S. N. and Nelson, C. J. (1985). Temperature effects on germination of birdsfoot trefoil and seombadi. *Agronomy Journal*, 77(4): 557-560. <https://doi.org/10.2134/agronj1985.00021962007700040013x>
- Jones, T. A., Bushman, B. S., Crockett, R. T. and Forsyth, K. C. (2022). Scarification and pre-chilling requirements for germination of the native forb Utah trefoil (*Lotus utahensis* Ottley). *Native Plants Journal*, 23(2): 148-155. <https://doi.org/10.3368/npj.23.2.148>
- Keskin, B., Temel, S., Gürel, G. and Özden, E. (2023). Effects of some temperature and dormancy-breaking applications on germination rates of camelthorn (*Alhagi pseudalhagi* (Bieb.) Desv.) Seeds. *Research in Agricultural Sciences*, 54(1): 22-30. <https://doi.org/10.5152/AUAF.2023.220307>
- Li, Q. and Hill, M. J. (1989). Seed development and dormancy characteristics in *Lotus corniculatus* L. *New Zealand journal of agricultural Research*, 32(3): 333-336. <https://doi.org/10.1080/00288233.1989.10421749>
- Lopes, R. R. and Franke, L. B. (2011). Thermal-biological aspects on seed germination of hairy bird's-foot trefoil under different temperatures. *Revista Brasileira de Zootecnia*, 40(10): 2091-2096. <https://doi.org/10.1590/S1516-35982011001000004>
- Mujica, M. M. and Rumi, C. P. (1993). Effect of three different constant temperature treatments on germination of *Lotus tenuis* (Waldst. et Kit). *Lotus Newsletter*, 24: 35-37.
- Özpinar, H., Avcı, M., Acar, A. A., Aksu, S., İnal, F. N., Ay, E., İnal, İ., Gündel, F. D., Aktaş, A. and Hatipoğlu, R. (2019). Determination of yields of bird's-foot trefoil (*Lotus corniculatus* L.) genotypes under Mediterranean climatic conditions. *ANADOLU Journal of Aegean Agricultural Research Institute*, 29(1): 15-24. <https://doi.org/10.18615/anadolu.568782>

- 
- Prado, F. E., Boero, C., Gallardo, M. and Gonzalez, J. A. (2000). Effect of NaCl on germination, growth, and soluble sugar content in *Chenopodium quinoa* Willd. Seeds. *Botanical Bulletin of Academia Sinica*, 41: 27-24.
- Ren, J., Song, L., Dai, W. and Ou, Y. (2017). Effects of different treatment methods on germination rate of hard seeds of wild *Lotus corniculatus* L. *Agricultural Science and Technology*, 18(5): 785-788.
- Quintero C. M. F., Guillen C. O., Delgado S. P., Marín-Sánchez J., Guzmán A. I., Sánchez A. and Guzmán J. M. (2018). Relieving dormancy and improving germination of Piquín chili pepper (*Capsicum annuum* var. *glabriusculum*) by priming techniques. *Cogent Food and Agriculture*, 4(1): 1550275. <https://doi.org/10.1080/23311932.2018.1550275>
- Smykal, P., Vernoud, V., Blair, M. W., Soukup, A. and Thompson, R. D. (2014). The role of the testa during development and in establishment of dormancy of the legume seed. *Frontiers in Plant Science*, 5(article: 351): 1-19. <https://doi.org/10.3389/fpls.2014.00351>
- Szalai, Z. and Ferschl, B. (2016). The effect of seed treatments on the germination of different fabaceae species of a natural meadow-like association. *Analecta Technica Szegedinensia*, 10 (1): 58-63. <https://doi.org/10.14232/analecta.2016.1.58-63>
- Temel, S., Keskin, B. and Çakmakçı, S. (2023). Effect of different dormancy-breaking methods on seed germination and vigour of *Atraphaxis spinosa*. *Zemdirbyste-Agriculture*, 110 (1): 39-46. <https://doi.org/10.13080/z-a.2023.110.006>
- Woods, L. E. and MacDonald, H. A. (1971). The effects of temperature and osmotic moisture stress on the germination of *Lotus corniculatus*. *Journal of Experimental Botany*, 22 (3): 575-585. <https://doi.org/10.1093/jxb/22.3.575>