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Seed and germination characteristics of wild Onobrychis taxa in Turkey

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Abstract: Turkey is of great importance for the biodiversity of genus Onobrychis Adans. and hosts 55 species that are adapted to dry and poor environments. This study was conducted to evaluate 35 Onobrychis taxa in terms of 1000-seed weight, germination percentage, mean germination time, and hard and swollen seeds and to determine the suitability of mechanical scarification for dormancy breaking in species with hard or impermeable seed coats. Seed dormancy was detected in 19 of the investigated species and 14 of the endemic species. Germination percentages of these taxa ranged from 5.5% to 98.0%. The lowest germination rate (5.5%) and the highest hard seed rate (93.0%) were determined in Onobrychis lasiostachya Boiss. Increased germination and decreased hard seed rates were achieved using mechanical scarification with sandpaper in Onobrychis gracilis Besser. Germination of O. lasiostachya, Onobrychis oxyodonta Boiss., and Onobrychis podperae Sirj. increased after mechanical scarification. It was concluded that mechanical scarification is an effective method for improving germination of wild Onobrychis taxa.

Key words: Onobrychis, germination, dormancy, hard seed, mechanical scarification

1. Introduction
There are approximately 170 species of genus Onobrychis, and they are found mainly in southwestern Asia, the Mediterranean region, and temperate Europe and Asia (Cronquist, 1981; Zohary, 1987; Aktoklu, 2001). Turkey has 55 Onobrychis species under 5 different sections, and 28 of them are endemic (Hedge, 1970; Davis et al., 1988; Duman and Vural, 1990; Aktoklu, 2001; Yıldırımli, 2004). These species are an important source of nourishment for farm animals and soil fertility as they fix atmospheric nitrogen and have important potential for pasture and meadow improvement, land conservation, and rehabilitation; they can also serve as important genetic sources for breeding (Cavallarin et al., 2005; Özaslan Parlak and Parlak, 2008).

One of the most desirable characteristics in the agricultural production of forage crops under field conditions is rapid and uniform germination ability. The seeds of many wild plant species cannot germinate properly, even under suitable environmental conditions (Kimura and Islam, 2012), since the seeds of many wild species have an impermeable seed coat that inhibits water uptake and the exchange of gases (Argel and Paton, 1999; Reino et al., 2011).

Low germination due to hard seed coat in wild Onobrychis taxa is the major obstacle to cultivation. On the other hand, unsynchronized and poor germination permits the survival of wild species under natural conditions. There are very few studies on germination and breaking seed dormancy in this genus. Majidi and Barati (2011) determined seed dormancy in Onobrychis vicifolia Scop., Onobrychis sintenisii Bornm., and Onobrychis melanotricha Boiss. and noted the beneficial effects of acid scarification to overcome dormancy. Several researchers reported that wild legume plants have seed dormancy resulting from impermeable seed coats, which inhibit water access to the seed (Uzun and Aydin, 2004; Patane and Gresta, 2006; Can et al., 2009; Reino et al., 2011). Demir and Ermis (2004) and Kimura and Islam (2012) reported that the effectiveness of scarification depends on the genus and species and the type of treatment. Some of the treatments used include heating, freezing, wetting, humidifying, and mechanical and acid scarification.

The objective of this study was to determine the seed dormancy frequency of 35 Onobrychis taxa in Turkey and study the efficiency of mechanical scarification for breaking seed dormancy.

2. Materials and methods
This study was carried out at the Department of Field Crops, Faculty of Agriculture, Eskişehir Osmangazi University, Turkey. The seeds of 35 Onobrychis taxa were
collected from natural pastures in Turkey between 2006 and 2008 and planted in the experimental gardens of the Department of Field Crops of Ankara University in order to produce sufficient seed material under the same conditions. The seeds were collected during 2009, hand-separated from the pods, and stored in paper bags in a seed storage room (temperature: 15–25 °C; humidity: 40–60%) until use. Seed material was treated with fungicide (Thiram, 80%) before the germination test. From each species, 4 replicates of 50 seeds were germinated in 3 moistened, rolled filter papers using 8 mL of double distilled water. Each rolled paper was then put into a sealed plastic bag to prevent evaporation. Seeds were allowed to germinate at 20 ± 1 °C in the dark for 14 days (ISTA, 2003). A seed was considered germinated when the emerged radicle reached 2 mm. Germination percentage was recorded every 24 h for 14 days. At the end of the germination test, the percentage of germinated seeds and hard and swollen seeds and the mean germination time (MGT) were determined for each species (ISTA, 2003). Swollen seeds imbibed but did not germinate, and hard seeds failed to imbibe water, as described by Patane and Gresta (2006). To determine 1000-seed weight (TSW), 4 replicates of 100 seeds from each taxon were counted by hand and weighed using an electronic scale with 0.01 g accuracy (Kaya et al., 2012; Tonguç and Erbaş, 2012).

Mechanical scarification was performed by vigorously rubbing the seeds with 100 grit sandpaper to abrade the seed coat by hand until the yellowish area (endosperm) of the seed was visible.

The experimental design was 1 factor arranged in a completely randomized design with 4 replications. Data given in percentages were subjected to arcsine transformation before statistical analysis. Analysis of variance was performed for all investigated parameters using SPSS 16. Significant differences among mean values were compared by least significant difference (LSD) test (P < 0.05).

3. Results

The distribution of 35 Onobrychis taxa in Turkey is shown in Table 1. They are adapted to altitudes ranging from 15 to 2796 m. Among the investigated Onobrychis taxa, a significant difference was found (P < 0.05) for TSW, germination percentage, MGT, and hard and swollen seeds (Table 2). Among wild Onobrychis taxa there was wide variation in seed characteristics and germination patterns. The germination percentage of the taxa ranged from 5.5% to 98.0%, and the lowest germination was determined in O. lasiostachya in the section Onobrychis. Germination percentage was adversely influenced by hard seed coat, and 19 species had germination percentages below 65%, while mechanical scarification for Onobrychis aequidentata (Sibth. & Sm.) d’Urv. (54% germination) could not be performed due to an insufficient number of seeds. Among 20 endemic taxa 11 species showed dormancy due to hard seed coat (below 50% germination). MGT was delayed when hard seeds increased, resulting in a drop in germination to below 50%. Lower MGT was obtained from Onobrychis taxa with high germination percentages.

Among the investigated Onobrychis taxa, the maximum hard seed percentages (93.0%) were detected in O. lasiostachya. Higher hard seed percentages were the main cause of lower germination, with significant variation among species for hard seed. The highest swollen seed percentage was determined in Onobrychis albiflora Hub. & Mor. at 15%.

Due to their hard seed coats, 18 Onobrychis taxa with germination percentages below 65% were transferred to mechanical scarification for dormancy breaking. Germination characteristics of taxa suffering from hard seed coats after mechanical scarification with sandpaper are shown in Table 3. Germination increased with sandpaper application, and the maximum germination percentage (92%) was achieved in O. gracilis. The beneficial effects of mechanical scarification were observed in O. lasiostachya, O. oxyodonta, and O. podperae. Onobrychis taxa in which MGT could not be calculated due to insufficient germination before mechanical scarification produced sufficient germination percentage after scarification; all the taxa germinated at rates higher than 50%. The minimum MGT value was obtained from Onobrychis ciliicata Kit Tan & Sorger at 2.29 days. The hard seed rate decreased significantly after mechanical scarification; however, it remained high in Onobrychis pisidica Boiss. (26.0%), Onobrychis elata Boiss. & Bal. (22.0%), and O. podperae (12.5%) compared to other taxa. A wide variation in swollen seeds after scarification with sandpaper was observed. O. albiflora, Onobrychis araxina Schischkin, Onobrychis beata Sirj., and Onobrychis tournefortii (Willd.) Desv. showed the maximum swollen seed percentages. After mechanical scarification, broken seeds were determined, and the highest broken seed percentage was detected in O. elata (15.5%). Onobrychis stenostachya Freyn. subsp. sosnowskyi (Grossh.) Hedge had the minimum broken seed percentage (2.0%).

4. Discussion

Seed dormancy caused by hard seed coat in legume crops is a common problem, and as a result, several propagation methods such as cuttings (Avci et al., 2010) and tissue culture (Çeliktaş et al., 2006; Karamian and Ranjbar, 2008) have been developed to overcome germination problems. In many hard coated seeds, the first action of a hard seed coat is to inhibit water uptake, which is essential for germination (Roberts, 1974; Dittus and Muir, 2010).
Table 1. Designation and geographical origin of wild *Onobrychis* taxa.

<table>
<thead>
<tr>
<th>Species</th>
<th>Latitude (N)</th>
<th>Longitude (E)</th>
<th>Altitude (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Laphobrychis section</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Onobrychis caput-galli</em> Lam.</td>
<td>40°14′14″</td>
<td>26°27′04″</td>
<td>17</td>
</tr>
<tr>
<td><em>Onobrychis crista-galli</em> Lam.</td>
<td>36°14′22″</td>
<td>36′06′16″</td>
<td>224</td>
</tr>
<tr>
<td><em>O. aequidentata</em></td>
<td>40°14′02″</td>
<td>26°26′34″</td>
<td>15</td>
</tr>
<tr>
<td><strong>Onobrychis section</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>O. lasiostachya</em></td>
<td>37°54′59″</td>
<td>29°09′43″</td>
<td>330</td>
</tr>
<tr>
<td><em>O. gracilis</em></td>
<td>37°24′31″</td>
<td>31°52′44″</td>
<td>780</td>
</tr>
<tr>
<td><em>Onobrychis fallax</em> Freyn &amp; Sint. ex Freyn var. longifolia* Aktoklu</td>
<td>39°00′02″</td>
<td>38°12′27″</td>
<td>1410</td>
</tr>
<tr>
<td><em>Onobrychis fallax</em> var. fallax* Freyn &amp; Sint.</td>
<td>38°12′31″</td>
<td>38°53′05″</td>
<td>1156</td>
</tr>
<tr>
<td><em>Onobrychis elata</em> Boiss. &amp; Bal.</td>
<td>38°40′43″</td>
<td>34°51′09″</td>
<td>1046</td>
</tr>
<tr>
<td><em>Onobrychis sulphurea</em> Boiss. &amp; Bal. var. sulphurea (C.Koch) Tenzel.</td>
<td>38°37′38″</td>
<td>35°31′39″</td>
<td>1514</td>
</tr>
<tr>
<td><em>O. ciliica</em></td>
<td>36°41′38″</td>
<td>33°37′27″</td>
<td>1095</td>
</tr>
<tr>
<td><em>O. pisidica</em></td>
<td>38°06′04″</td>
<td>31°13′27″</td>
<td>1341</td>
</tr>
<tr>
<td><em>O. oxyodonta</em></td>
<td>41°12′42″</td>
<td>32°57′21″</td>
<td>370</td>
</tr>
<tr>
<td>Onobrychis armena* Boiss. Et Huet.</td>
<td>39°53′14″</td>
<td>39°21′01″</td>
<td>2102</td>
</tr>
<tr>
<td><em>O. stenostachya</em> subsp. sosnowskyi</td>
<td>40°13′42″</td>
<td>41°30′23″</td>
<td>1987</td>
</tr>
<tr>
<td><em>Onobrychis mutensis</em> Kit Tan &amp; Sorger</td>
<td>36°32′18″</td>
<td>33°26′32″</td>
<td>125</td>
</tr>
<tr>
<td><em>O. araxina</em></td>
<td>40°55′38″</td>
<td>43°03′30″</td>
<td>2796</td>
</tr>
<tr>
<td><em>O. viciifolia</em></td>
<td>39°05′53″</td>
<td>29°28′51″</td>
<td>887</td>
</tr>
<tr>
<td><em>Onobrychis marashensis</em> H. Duman &amp; Vural</td>
<td>37°38′33″</td>
<td>37°02′08″</td>
<td>1850</td>
</tr>
<tr>
<td><em>O. beata</em></td>
<td>37°24′23″</td>
<td>35°02′55″</td>
<td>1435</td>
</tr>
<tr>
<td><em>O. podperae</em></td>
<td>39°02′22″</td>
<td>29°25′42″</td>
<td>820</td>
</tr>
<tr>
<td>Onobrychis kotschyana* Fenzl</td>
<td>37°01′09″</td>
<td>37°18′57″</td>
<td>897</td>
</tr>
<tr>
<td>Onobrychis altissima* Grossh.</td>
<td>40°41′54″</td>
<td>43°09′55″</td>
<td>1819</td>
</tr>
<tr>
<td>Onobrychis hajastana* Grossh.</td>
<td>39°33′42″</td>
<td>41°44′32″</td>
<td>1872</td>
</tr>
<tr>
<td><em>Onobrychis lasistanica</em> Sirj.</td>
<td>40°38′00″</td>
<td>40°01′00″</td>
<td>2426</td>
</tr>
<tr>
<td><strong>Hymenobrychis section</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>O. tournefortii</em></td>
<td>38°40′09″</td>
<td>35°51′49″</td>
<td>1060</td>
</tr>
<tr>
<td>Onobrychis hypargyrea* Boiss.</td>
<td>40°17′27″</td>
<td>33°00′57″</td>
<td>1161</td>
</tr>
<tr>
<td>Onobrychis meschettica* Grossh.</td>
<td>40°45′10″</td>
<td>43°38′00″</td>
<td>1536</td>
</tr>
<tr>
<td><em>O. albiflora</em></td>
<td>39°27′34″</td>
<td>37°49′14″</td>
<td>1246</td>
</tr>
<tr>
<td>Onobrychis galegfolia* Boiss.</td>
<td>37°02′01″</td>
<td>37°18′06″</td>
<td>894</td>
</tr>
<tr>
<td>Onobrychis radiata* (Desf.) M.Bieb.</td>
<td>40°45′25″</td>
<td>42°58′00″</td>
<td>1609</td>
</tr>
<tr>
<td><em>Onobrychis cappadocica</em> Boiss.</td>
<td>38°13′14″</td>
<td>38°57′36″</td>
<td>1138</td>
</tr>
<tr>
<td><strong>Heliobrychis section</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Onobrychis argyrea</em> subsp. argyrea</td>
<td>40°54′07″</td>
<td>33°47′24″</td>
<td>818</td>
</tr>
<tr>
<td><em>Onobrychis huetiana</em> Boiss. &amp; Huet</td>
<td>40°17′26″</td>
<td>37°49′00″</td>
<td>799</td>
</tr>
<tr>
<td><em>Onobrychis ornata</em> (Willd.) Desv.</td>
<td>39°40′56″</td>
<td>32°49′25″</td>
<td>1077</td>
</tr>
<tr>
<td><em>Onobrychis atropatana</em> Boiss. var. grandiflora* Aktoklu</td>
<td>40°11′12″</td>
<td>42°37′43″</td>
<td>1562</td>
</tr>
</tbody>
</table>

*: Endemic species.
Table 2. Germination patterns of wild *Onobrychis* taxa of Turkey.

<table>
<thead>
<tr>
<th>Species</th>
<th>Germination (%)</th>
<th>MGT (days)</th>
<th>Hard seeds (%)</th>
<th>Swollen seeds (%)</th>
<th>TSW (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Laphobrychis section</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>O. caput-galli</em></td>
<td>71.5 ± 3.77</td>
<td>2.65 ± 0.25</td>
<td>25.5 ± 3.86</td>
<td>3.0 ± 0.57</td>
<td>10.22 ± 0.04</td>
</tr>
<tr>
<td><em>O. crista-galli</em></td>
<td>91.0 ± 1.73</td>
<td>2.75 ± 0.18</td>
<td>7.50 ± 2.63</td>
<td>1.5 ± 0.95</td>
<td>20.45 ± 1.71</td>
</tr>
<tr>
<td><em>O. aequidentata</em></td>
<td>54.0 ± 1.41</td>
<td>2.75 ± 0.13</td>
<td>44.5 ± 1.50</td>
<td>1.5 ± 0.95</td>
<td>29.40 ± 0.47</td>
</tr>
<tr>
<td><strong>Onobrychis section</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>O. lasiostachya</em></td>
<td>5.5 ± 1.25</td>
<td>-</td>
<td>93.0 ± 1.91</td>
<td>1.5 ± 0.95</td>
<td>5.50 ± 0.10</td>
</tr>
<tr>
<td><em>O. gracilis</em></td>
<td>22.0 ± 2.44</td>
<td>-</td>
<td>77.5 ± 2.63</td>
<td>0.5 ± 0.50</td>
<td>7.85 ± 0.06</td>
</tr>
<tr>
<td><em>O. fallax var. longifolia</em></td>
<td>36.5 ± 4.85</td>
<td>2.15 ± 0.18</td>
<td>63.5 ± 4.85</td>
<td>-</td>
<td>10.15 ± 0.21</td>
</tr>
<tr>
<td><em>O. fallax var. fallax</em></td>
<td>16.5 ± 2.50</td>
<td>-</td>
<td>82.0 ± 3.36</td>
<td>1.0 ± 0.57</td>
<td>6.17 ± 0.07</td>
</tr>
<tr>
<td><em>O. elata</em></td>
<td>28.5 ± 4.78</td>
<td>-</td>
<td>70.0 ± 4.96</td>
<td>1.0 ± 0.57</td>
<td>7.60 ± 0.07</td>
</tr>
<tr>
<td><em>O. sulphurea var. sulphurea</em></td>
<td>63.5 ± 6.70</td>
<td>8.57 ± 0.52</td>
<td>30.5 ± 3.94</td>
<td>5.0 ± 3.00</td>
<td>12.15 ± 0.20</td>
</tr>
<tr>
<td><em>O. ciliaris</em></td>
<td>16.0 ± 1.41</td>
<td>-</td>
<td>82.5 ± 1.70</td>
<td>-</td>
<td>7.85 ± 0.13</td>
</tr>
<tr>
<td><em>O. pisidica</em></td>
<td>14.0 ± 2.16</td>
<td>-</td>
<td>86.0 ± 2.16</td>
<td>-</td>
<td>10.35 ± 0.12</td>
</tr>
<tr>
<td><em>O. oxyodonta</em></td>
<td>13.0 ± 2.64</td>
<td>-</td>
<td>82.0 ± 3.91</td>
<td>1.0 ± 1.29</td>
<td>6.97 ± 0.13</td>
</tr>
<tr>
<td><em>O. armena</em></td>
<td>79.0 ± 1.29</td>
<td>6.33 ± 0.47</td>
<td>70.0 ± 4.96</td>
<td>1.5 ± 1.89</td>
<td>12.92 ± 0.13</td>
</tr>
<tr>
<td><em>O. stenostachya subsp. sosnowskyi</em></td>
<td>48.5 ± 2.50</td>
<td>-</td>
<td>50.0 ± 2.16</td>
<td>0.5 ± 0.95</td>
<td>4.00 ± 0.00</td>
</tr>
<tr>
<td><em>O. mutensis</em></td>
<td>36.0 ± 2.82</td>
<td>-</td>
<td>59.5 ± 3.86</td>
<td>1.0 ± 1.29</td>
<td>8.02 ± 0.20</td>
</tr>
<tr>
<td><em>O. araxina</em></td>
<td>27.5 ± 0.50</td>
<td>-</td>
<td>63.5 ± 1.89</td>
<td>0.0 ± 1.73</td>
<td>8.27 ± 0.30</td>
</tr>
<tr>
<td>O. viciifolia</td>
<td>79.0 ± 1.41</td>
<td>6.33 ± 0.47</td>
<td>15.5 ± 2.36</td>
<td>1.5 ± 1.89</td>
<td>12.92 ± 0.13</td>
</tr>
<tr>
<td><em>O. marashensis</em></td>
<td>77.5 ± 1.70</td>
<td>7.28 ± 0.16</td>
<td>1.0 ± 0.57</td>
<td>5.0 ± 2.06</td>
<td>17.40 ± 0.38</td>
</tr>
<tr>
<td><em>O. beata</em></td>
<td>62.0 ± 2.16</td>
<td>4.60 ± 0.26</td>
<td>15.5 ± 2.50</td>
<td>0.0 ± 2.06</td>
<td>13.37 ± 0.23</td>
</tr>
<tr>
<td><em>O. podperae</em></td>
<td>10.0 ± 0.00</td>
<td>-</td>
<td>89.0 ± 0.57</td>
<td>0.0 ± 0.50</td>
<td>5.60 ± 0.04</td>
</tr>
<tr>
<td>O. kotshyana</td>
<td>28.5 ± 4.03</td>
<td>-</td>
<td>63.0 ± 4.43</td>
<td>4.0 ± 0.50</td>
<td>4.00 ± 0.04</td>
</tr>
<tr>
<td>O. altissima</td>
<td>85.0 ± 2.64</td>
<td>4.65 ± 0.28</td>
<td>11.0 ± 2.64</td>
<td>5.0 ± 0.00</td>
<td>14.17 ± 0.11</td>
</tr>
<tr>
<td>O. hajastana</td>
<td>79.0 ± 1.29</td>
<td>-</td>
<td>18.0 ± 2.16</td>
<td>5.5 ± 1.73</td>
<td>12.05 ± 0.11</td>
</tr>
<tr>
<td><em>O. lasistanica</em></td>
<td>50.5 ± 2.98</td>
<td>10.29 ± 0.72</td>
<td>40.0 ± 3.74</td>
<td>3.0 ± 2.21</td>
<td>15.45 ± 0.13</td>
</tr>
<tr>
<td><strong>Hymenobrychis section</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>O. tournefortii</em></td>
<td>61.0 ± 3.78</td>
<td>4.28 ± 0.13</td>
<td>35.5 ± 3.94</td>
<td>1.5 ± 0.95</td>
<td>8.35 ± 0.18</td>
</tr>
<tr>
<td>O. hypargyrea</td>
<td>82.0 ± 2.16</td>
<td>7.45 ± 0.43</td>
<td>16.5 ± 1.89</td>
<td>2.5 ± 0.95</td>
<td>11.92 ± 0.19</td>
</tr>
<tr>
<td>O. meschetica</td>
<td>76.5 ± 3.59</td>
<td>3.87 ± 0.30</td>
<td>23.0 ± 5.00</td>
<td>3.0 ± 1.29</td>
<td>10.62 ± 0.10</td>
</tr>
<tr>
<td><em>O. albigiflora</em></td>
<td>46.5 ± 4.27</td>
<td>3.33 ± 0.15</td>
<td>38.0 ± 2.50</td>
<td>15.0 ± 1.91</td>
<td>12.62 ± 0.19</td>
</tr>
<tr>
<td>O. galegifolia</td>
<td>88.5 ± 2.36</td>
<td>1.90 ± 0.04</td>
<td>2.0 ± 0.81</td>
<td>9.5 ± 2.50</td>
<td>21.95 ± 0.32</td>
</tr>
<tr>
<td>O. radiata</td>
<td>78.0 ± 3.65</td>
<td>3.36 ± 0.49</td>
<td>17.5 ± 3.20</td>
<td>4.5 ± 0.95</td>
<td>11.32 ± 0.11</td>
</tr>
<tr>
<td><em>O. cappadocica</em></td>
<td>77.5 ± 3.40</td>
<td>3.74 ± 0.49</td>
<td>9.0 ± 2.38</td>
<td>13.5 ± 1.89</td>
<td>10.20 ± 0.20</td>
</tr>
<tr>
<td><strong>Heliochrysis section</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>O. argyrea subsp. argyrea</em></td>
<td>92.5 ± 1.70</td>
<td>2.94 ± 0.23</td>
<td>0.5 ± 0.50</td>
<td>7.0 ± 1.91</td>
<td>11.85 ± 0.08</td>
</tr>
<tr>
<td><em>O. huertiana</em></td>
<td>87.0 ± 3.31</td>
<td>3.30 ± 0.24</td>
<td>0.25 ± 0.25</td>
<td>12.5 ± 2.87</td>
<td>11.10 ± 0.24</td>
</tr>
<tr>
<td><em>O. ornata</em></td>
<td>90.0 ± 0.81</td>
<td>2.33 ± 0.10</td>
<td>0.5 ± 0.50</td>
<td>9.5 ± 0.95</td>
<td>12.55 ± 0.13</td>
</tr>
<tr>
<td><em>O. atropatana var. grandiflora</em></td>
<td>85.5 ± 2.06</td>
<td>4.31 ± 0.34</td>
<td>0.0 ± 0.00</td>
<td>14.5 ± 2.06</td>
<td>14.12 ± 0.27</td>
</tr>
<tr>
<td>LSD (P &lt; 0.05)</td>
<td>9.44</td>
<td>1.01</td>
<td>9.19</td>
<td>4.77</td>
<td>1.09</td>
</tr>
</tbody>
</table>

Data represent mean ± standard error of 4 replicates; *: endemic species.
Several treatments such as scarification, soaking, and wetting have been improved for breaking the dormancy caused by hard seed coat, and helpful results have been achieved by Demir and Ermis (2004) in okra, Patane and Gresta (2006) in *Astragalus hamosus* L. and *Medicago orbicularis* (L.) Bartal., Hay et al. (2010) in *Trifolium ambiguum* M.Bieb., and Sadeghi and Khaef (2012) in 3 annual medics.

Our findings revealed that there was seed dormancy resulting from hard seed coat in 18 *Onobrychis* taxa, 14 of them endemic to Turkey. The results showed that mechanical scarification decreased hard seed coat dormancy in the seeds of *Onobrychis* taxa by allowing water uptake. Uzun and Aydin (2004) indicated that disruption with sandpaper was the most effective method of breaking the dormancy of forage legumes, especially *Medicago* and *Trifolium* species. In addition, mechanical scarification with sandpaper clearly achieved both enhanced germination rates and reduced MGT. The results are in line with findings in *Medicago scutellata* (L.) Mill. and *Medicago rigidula* (L.) All. (Khaef and Sadeghi, 2011), *A. hamosus* and *M. orbicularis* (Patane and Gresta, 2006), and *Sabal palmetto* (Walter) Lodd. ex Schult. & Schult.f. and *Thrinax morrisii* H. Wendl. palms (Dewir et al., 2011); in each case, rapid germination after mechanical scarification with sandpaper was reported. Mechanical scarification diminished the rate of hard and swollen seeds. In general, the hard seed rate increased as the swollen seed rate decreased. Patane and Gresta (2006) indicated that acid scarification caused a decreased hard seed rate in *A. hamosus* and *M. orbicularis*. It is concluded that the superiority of mechanical scarification with sandpaper for germination could be the result of penetrating the hard seed coat, which allows the seeds to absorb water. Despite the beneficial effects of mechanical scarification for breaking dormancy, the seeds of *Onobrychis* taxa were slightly crushed. The broken seed percentage ranged from 2.0% to 15.5%.

### Table 3. Germination patterns of wild *Onobrychis* taxa seeds after mechanical scarification.

<table>
<thead>
<tr>
<th>Species</th>
<th>Germination (%)</th>
<th>MGT (days)</th>
<th>Hard seeds (%)</th>
<th>Swollen seeds (%)</th>
<th>Broken seeds (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Onobrychis</em> section</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>O. lasiostachya</em></td>
<td>85.5 ± 3.86</td>
<td>2.72 ± 0.06</td>
<td>5.5 ± 2.50</td>
<td>4.0 ± 1.41</td>
<td>4.5 ± 0.95</td>
</tr>
<tr>
<td><em>O. gracilis</em></td>
<td>92.0 ± 2.16</td>
<td>2.91 ± 0.04</td>
<td>3.0 ± 1.29</td>
<td>1.5 ± 0.50</td>
<td>3.5 ± 1.70</td>
</tr>
<tr>
<td><em>O. fallax</em> var. <em>longifolia</em></td>
<td>83.0 ± 3.10</td>
<td>2.54 ± 0.12</td>
<td>8.5 ± 2.50</td>
<td>1.0 ± 0.57</td>
<td>7.5 ± 0.95</td>
</tr>
<tr>
<td><em>O. fallax</em> var. <em>fallax</em></td>
<td>84.5 ± 2.63</td>
<td>2.68 ± 0.14</td>
<td>4.5 ± 2.06</td>
<td>2.0 ± 1.41</td>
<td>9.0 ± 1.29</td>
</tr>
<tr>
<td><em>O. elata</em></td>
<td>59.5 ± 5.18</td>
<td>2.79 ± 0.11</td>
<td>22.0 ± 2.70</td>
<td>3.0 ± 1.73</td>
<td>15.5 ± 2.21</td>
</tr>
<tr>
<td><em>O. sulphurea</em> var. <em>sulphurea</em></td>
<td>80.5 ± 3.77</td>
<td>3.10 ± 0.24</td>
<td>4.0 ± 1.82</td>
<td>2.5 ± 0.95</td>
<td>13.0 ± 2.08</td>
</tr>
<tr>
<td><em>O. ciliaca</em></td>
<td>82.5 ± 4.64</td>
<td>2.29 ± 0.09</td>
<td>10.0 ± 2.94</td>
<td>2.0 ± 0.81</td>
<td>5.5 ± 1.70</td>
</tr>
<tr>
<td><em>O. pisidica</em></td>
<td>62.5 ± 6.84</td>
<td>2.68 ± 0.25</td>
<td>26.0 ± 5.47</td>
<td>2.0 ± 1.41</td>
<td>9.5 ± 1.70</td>
</tr>
<tr>
<td><em>O. oxyodonta</em></td>
<td>86.0 ± 2.94</td>
<td>5.61 ± 0.55</td>
<td>4.0 ± 1.63</td>
<td>3.5 ± 1.50</td>
<td>6.5 ± 1.70</td>
</tr>
<tr>
<td><em>O. stenostachya</em> subsp. <em>sosnowskyi</em></td>
<td>89.0 ± 1.91</td>
<td>3.77 ± 0.12</td>
<td>4.5 ± 1.50</td>
<td>4.5 ± 0.95</td>
<td>2.0 ± 0.81</td>
</tr>
<tr>
<td><em>O. mutensis</em></td>
<td>77.0 ± 5.50</td>
<td>4.73 ± 0.70</td>
<td>7.5 ± 3.20</td>
<td>11.0 ± 2.51</td>
<td>4.5 ± 0.95</td>
</tr>
<tr>
<td><em>O. araxina</em></td>
<td>75.5 ± 2.75</td>
<td>2.90 ± 0.14</td>
<td>3.5 ± 1.25</td>
<td>18.5 ± 2.21</td>
<td>2.5 ± 1.25</td>
</tr>
<tr>
<td><em>O. beata</em></td>
<td>72.0 ± 0.81</td>
<td>4.67 ± 0.25</td>
<td>2.0 ± 1.15</td>
<td>16.0 ± 1.63</td>
<td>10.0 ± 2.16</td>
</tr>
<tr>
<td><em>O. podperae</em></td>
<td>67.0 ± 5.00</td>
<td>4.23 ± 0.10</td>
<td>12.5 ± 4.03</td>
<td>10.5 ± 2.06</td>
<td>10.0 ± 2.16</td>
</tr>
<tr>
<td><em>O. kotschyanica</em></td>
<td>86.0 ± 1.41</td>
<td>2.46 ± 0.12</td>
<td>2.5 ± 2.50</td>
<td>1.5 ± 0.50</td>
<td>10.0 ± 2.44</td>
</tr>
<tr>
<td><em>O. lasistanica</em></td>
<td>84.0 ± 2.16</td>
<td>4.43 ± 0.30</td>
<td>4.5 ± 1.70</td>
<td>3.5 ± 0.95</td>
<td>8.0 ± 2.16</td>
</tr>
<tr>
<td><em>Hymenobrychis</em> section</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>O. tournefortii</em></td>
<td>84.0 ± 2.94</td>
<td>2.56 ± 0.12</td>
<td>1.5 ± 0.50</td>
<td>12.0 ± 2.94</td>
<td>2.5 ± 0.50</td>
</tr>
<tr>
<td><em>O. albiflora</em></td>
<td>71.5 ± 5.37</td>
<td>3.35 ± 0.08</td>
<td>3.0 ± 1.29</td>
<td>21.5 ± 3.94</td>
<td>4.0 ± 1.15</td>
</tr>
<tr>
<td>LSD (P &lt; 0.05)</td>
<td>10.91</td>
<td>0.86</td>
<td>8.21</td>
<td>5.87</td>
<td>4.68</td>
</tr>
</tbody>
</table>

Data represent mean ± standard error of 4 replicates; *: endemic species.
The results of this study show that mechanical treatment greatly promoted germination and a decline in the number of hard seeds, particularly in *O. lasiostachya*, *O. oxyodonta*, and *O. podperae*. The advantage of mechanical scarification was correlated with an increase in the water imbibition rate of seeds. Therefore, scarified seeds eliminate the adverse effect of the seed coat and provide more rapid germination by removing hard seed coats. Mechanical scarification is easy to apply to small seed lots, is inexpensive, and does not require expensive chemicals or a complicated apparatus. This protocol should be effective for improving germination and can be applied by breeders who do not currently have sufficient seed material.

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**References**


