Does Hydro and Osmo-Priming Improve Fennel (Foeniculum vulgare) Seeds Germination and Seedlings Growth?

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Abstract

This experiment was conducted to investigate the effects of hydropriming and osmopriming on germination rate, percentage of, root–shoot length and root–shoot weight of fennel (Foeniculum vulgare) seeds. Priming was done by: hydropriming with distilled water, osmopriming with NaCl at four levels (-0.3, -0.6, -0.9, -1.2 MPa), osmopriming with K₂SO₄ in four levels (-0.3, -0.6, -0.9, -1.2 MPa) and 5. seeds with unprime control at treat. In this study, RCBD experimental design was used for the analysis of experimental factors. The results showed that priming significantly effected at all treatment methods. Maximum and minimum germination percentage were obtained with PEG (-0.9 MPa) applied, and in control. Maximum and minimum germination rates were obtained when K₂SO₄ (-0.3 MPa), NaCl (-0.3 MPa) were used. Maximum and minimum root length were obtained when NaCl [-(-1.2 MPa), PEG (-0.3 MPa)], NaCl (-0.6 MPa) were used. Maximum and minimum shoot length were obtained when PEG (-0.3 MPa), NaCl (-0.6 MPa) were used. Maximum and minimum root weight, root/shoot length were obtained when NaCl (-1.2 MPa), NaCl (-0.6 MPa) were used. Maximum and minimum shoot weight were obtained when NaCl (-1.2 MPa), NaCl (-0.3 MPa) were used. Maximum and minimum root/shoot weight were obtained when [PEG (-0.3 MPa), K₂SO₄ (-0.3, -0.6, -0.9 MPa), NaCl (-0.6, -0.9 MPa), hydropriming] and [PEG (-0.6, -1.2 MPa), NaCl (-1.2 MPa)] were used.

Keywords: fennel, Foeniculum vulgare, NaCl, K₂SO₄, PEG, hydropriming, osmopriming, germination

Introduction

Fennel (Foeniculum vulgare) is an aromatic biennial plant with soft, feathery, almost hair-like foliage. Native to coastal areas in the Mediterranean region, and widely naturalized in Europe and North America (Christman, 2004). Similar to some other medicinal plants (Bannayan et al., 2008; Khazaie et al., 2008) supplemental irrigation would improve its production during dry periods. Fennel belongs to the Umbelliferae (Apiaceae) family, a medicinal plant used as anti-spasmodic, appetite stimulant, stomachic, diuretic, anti-inflammatory, anti-diarrheic, against colic and as a lactation promoter (Marotti et al., 1993; Piccaglia and Marotti, 1993; Cavaleiro et al., 1993). Several components of the essential oil of this plant show important applications, including, fenchone as counterirritant; limonene as solvent, resins, wetting and dispersing agent; trans-anethole, flavoring agent in perfumery, cosmetics, soap; methylchavicol or estragole is used in perfumery and as flavor in foods and liquors; α-pinene, used in manufacture of camphor, insecticides, solvents, perfume bases (Marotti et al., 1993; Piccaglia and Marotti, 1993; Cavaleiro et al., 1993). Seed germination is mostly an issue in medicinal plant seeds emergence (Nadjafi et al., 2006). Good seedling establishment is an important constraint to such crop production (Harris et al., 1999). Poor seedbed, low quality seed, environmental stresses such as high and low temperature and salinity constrains to good establishment include (Weaich et al., 1992; Towned et al., 1996). A robust seedling establishment enhances competitiveness against weeds, improves tolerance to environmental stresses and maximizes biological and grain yields (Ghiyasi et al., 2008).

Several approaches including, hardening, seed priming, seed soaking and seed coating have been employed to precondition seeds to improve germination and seedling growth of various crops (Basra et al., 2003). Seed priming treatments such as osmopriming, hydropriming, matricopriming, hormonal-priming have been employed to accelerate the germination, seedling growth and yield in most of the crops under normal and stress conditions (Basra et al., 2003). Osmopriming is most common type of seed priming in which seeds are soaked in aerated low water potential solution (Farooq et al., 2005). Although, the mechanism of seed priming treatments is not fully understood, it has been observed that physiological and biochemical changes take place during the seed treatments (Basra et al., 2005; Ghiyasi et al., 2008), which could allow seeds to begin the germination sequences before sowing.

Rapid germination and emergence is an important determinant of successful establishment (Harris et al., 1991).
Germination is one of the most salt-sensitive plant growth stages and severely inhibited with increasing salinity both in glycophytes and halophytes (Sosa et al., 2005). Seed priming accelerates seed germination and seedling establishment under both normal and stressful environments (Ashraf and Foolad., 2005). Although priming is one of the physiological methods, which improves seed performance and provides faster and synchronised germination (Sivritepe and Dourado., 1995) it has been shown that NaCl priming could be used as an adaptation method to improve salt tolerance of seeds (Wiebe and Muhlyadin., 1987; Cano et al., 1991; Cayuela et al., 1996). Successful results have been obtained for tomatoes, (Pill et al., 1991) and asparagus (Passam and Kakouriots., 1994) under saline conditions.

Hydropriming is the simplest approach to hydrate seeds and minimize the use of chemicals. However, if the seeds are not accurately hydrated, hydration rate cannot be exactly controlled. It was observed that hydropriming practically ensured rapid and uniform germination accompanied with low abnormal seedling percentage (Singh, 1995; Shivankar et al., 2003). They underline that hydropriming has high potential in improving field emergence and ensures early flowering and harvest under stress conditions especially in dry areas. Hydrated seeds with higher germination percentage under salt stress or micronutrient application increased tolerance of seeds to salt stress. In addition, reported protocol is simple, cheap and does not require expensive chemicals and sophisticated equipment. The protocol has practical importance and could be recommended to farmers to achieve higher germination and uniform emergence under field conditions.

The objective of this study was to explore the effects of two different priming (hydropriming and osmopriming) treatments on germination of fennel seeds (Foeniculum vulgare).

**Materials and methods**

In order to determine the impact of different priming on germination of Fennel seeds, an experiment was conducted at Zabol University in 2007. Seeds were primed with various materials, including hydroprime as seeds were primed with distilled water, osmopriming seeds were treated with three different chemical as NaCl, K, SO₄, polyethylene glycol 6000. All three different osmopriming provided osmotic potential of -0.3, -0.6, -0.9 and -1.2 MPa. Simulating various osmotic potential using PEG was according to Michel and Kaufmann (1973) and Money (1989).

Initially seeds were disinfected by sodium hypochlorite (NaOCl). Seeds were kept in sodium hypochlorite (1.5%) for one minute and then were washed with distilled water. After disinfesting, seeds were put in disinfect Petry dish. Each Petry dish contained 25 seeds. After 24 hours of priming seeds were washed with distilled water and then dried and kept in laboratory room at temperature of 25° C for two hours. Afterwards dried seeds were located in Petry dishes and treated with distilled water at temperature of 25°C for seven days. Statistical experimental design was randomized completely block, with three replications. The differences between the means were compared using Duncan test (P < 0.01).

**Germination tests**

Three replicates of 25 seeds were put between double layered rolled. The papers were replaced every 2 days to prevent accumulation of salts. The rolled paper with seeds was put into sealed plastic bags to avoid moisture loss. Seeds were allowed to germinate at 25 ± 1°C for 7 days. Germination was considered when the radicles were 2 mm long. Germination percentage was recorded every 24 h for 7 days. Root length and shoot length were measured after the 7th day. The germination rate was calculated as follows (according to Bannayan et al., 2006):

\[
\text{Germination rate} = \frac{\sum_{n=1}^{45} n \cdot i}{n}\ 
\]

where, n is the days of incubation.

**Results and discussion**

For NaCl primed seeds the germination rate increased at osmotic pressure of -0.6 and -0.9 MPa, but germination rate decreased with increasing the osmotic pressure to -1.2 MPa (Tab. 1). The germination percentage of NaCl primed seeds decreased by increasing the osmotic pressure to -0.6 MPa, but germination percentage increased by increasing the osmotic pressure to -0.9 and -1.2 MPa. However, the best results of germination percentage in NaCl primed seeds were obtained with -0.3 MPa pressure (Tab. 1). The root length of NaCl primed seeds decreased with increasing the osmotic pressure to -0.6 MPa, but root length increased.

<table>
<thead>
<tr>
<th>Osmotic level (MPa)</th>
<th>Control</th>
<th>Hydropriming</th>
<th>NaCl</th>
<th>K₂SO₄</th>
<th>PEG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>G.Rate</td>
<td>G.Per</td>
<td>G.Rate</td>
<td>G.Per</td>
<td>G.Rate</td>
</tr>
<tr>
<td>0</td>
<td>9.6cd</td>
<td>4.3g</td>
<td>9.3cd</td>
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<td>0.6f</td>
<td>18.0b</td>
<td>12.0a</td>
<td>17.6bc</td>
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<tr>
<td>-0.6</td>
<td>10.2cd</td>
<td>15.0f</td>
<td>9.1de</td>
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<td>-0.9</td>
<td>9.5cd</td>
<td>16.0de</td>
<td>10.3bcd</td>
<td>17.3bcd</td>
<td>10.8ab</td>
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<td>8.8de</td>
<td>15.6ef</td>
<td>9.3cd</td>
</tr>
</tbody>
</table>
at the osmotic pressure of -0.3, -0.9 and -1.2 MPa. Maximum root length was obtained at NaCl level providing -1.2 MPa osmotic pressure. This might be due to the fact that seedlings send their photosynthesis products to roots when they were exposed to salt stress in order to tolerate the imposed stress, and minimum root length was obtained at -0.6 MPa (Tab. 2). The shoot length at NaCl primed seeds decreased with increasing the osmotic pressure to -0.6 and -0.9 MPa, but shoot length increased as the osmotic pressure increased to -1.2 MPa (Tab. 2). Root weight and shoot weight of NaCl primed seeds increased with increasing the osmotic pressure, and maximum root weight and shoot weight was obtained at -1.2 MPa pressure (Tab. 3). Maximum and minimum (R/S) length in NaCl primed seeds were obtained at -0.9 MPa and -0.3 MPa pressure, respectively (Fig. 1, 2).

The maximum germination rate of K$_2$SO$_4$ primed seeds was obtained at -0.3 MPa pressure and beyond that pressure the germination rate decreased (Tab. 1). The germinated percentage of K$_2$SO$_4$ primed seeds decreased with increasing the osmotic pressure (Tab. 1). The root length of K$_2$SO$_4$ primed seeds increased with increasing the osmotic pressure (Tab. 2). Both shoot length and root weight showed significant effects of priming with K$_2$SO$_4$ at all potentials, except -0.9 MPa (Tab. 2, 3). Shoot weight of K$_2$SO$_4$ primed seeds decreased with increasing the osmotic pressure (Tab. 3). Maximum R/S length and R/S weight of K$_2$SO$_4$ primed seeds were obtained at -0.9 MPa pressure. Minimum R/S length and R/S weight in K$_2$SO$_4$ seeds primed were obtained at -0.3 MPa and -1.2 MPa pressures, respectively (Fig. 1, 2).

Using PEG priming, the germination rate increased at -0.6 and -0.9 MPa pressures (Tab. 1). The germination percentage of PEG primed seeds almost decreased by increasing solution concentration, except at -0.9 MPa pressure. Maximum germination percentage of PEG primed seeds was obtained at -0.9 MPa pressure and all seeds in Petry dishes were germinated (Tab. 1). The root length and shoot length of PEG primed seeds decreased with increasing osmotic pressure, and maximum root and shoot length were obtained at -0.3 MPa (Tab. 2). The root weight in PEG primed seeds generally decreased, but in PEG -0.6 MPa increased (Tab. 3). The shoot weight of PEG primed seeds decreased, except -0.9 MPa pressure, when increased again (Tab. 3). Maximum R/S weight and R/S length were obtained at -0.3 MPa pressure, and minimum R/S weight and R/S length were obtained at -0.9 MPa pressure (Fig. 1, 2). Several authors described positive effects of seed priming with water alone (Harris et al., 1999, 2002, 2004; Rashid et al., 2002). Seedlings from seeds primed with water alone are known to emerge more quickly and grow more vigorously than those from non-primed seeds (Rashid et al., 2002; Arif et al., 2005; Miraj, 2005). Our data confirmed that simple seed priming with water is an effective way to increase all characteristics compared to control treatment (Tab. 1, 2, 3 and Fig 1, 2).

It is evident from the results that NaCl salinity caused growth inhibition in fennel seeds due to a decrease in total germination. These effects of salinity on fennel seeds supported by the previous findings (Franco et al., 1993, 1997; Botia et al., 1998; Carvajal et al., 1998) studying on melon cultivars. Accumulation of Na ion changes ion balances such as Na:Ca and K:Na in plant cells under saline conditions. While the change in Na:Ca balance results in

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**Tab. 2. Comparison of root length and shoot length of fennel seedling treated with NaCl, K$_2$SO$_4$, and PEG.**

<table>
<thead>
<tr>
<th>Osmotic level (MPa)</th>
<th>Control</th>
<th>Hydropriming</th>
<th>NaCl</th>
<th>K$_2$SO$_4$</th>
<th>PEG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R.length</td>
<td>S.length</td>
<td>R.length</td>
<td>S.length</td>
<td>R.length</td>
</tr>
<tr>
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<td>2.9cd</td>
<td>6.3bc</td>
<td>3.4abcd</td>
<td>6.1bc</td>
</tr>
<tr>
<td>-0.3</td>
<td>6.1bc</td>
<td>3.2abcd</td>
<td>6.2bc</td>
<td>3.9ab</td>
<td>8.2a</td>
</tr>
<tr>
<td>-0.6</td>
<td>0.5d</td>
<td>0.3e</td>
<td>6.2bc</td>
<td>3.2abcd</td>
<td>5.0c</td>
</tr>
<tr>
<td>-0.9</td>
<td>5.8bc</td>
<td>2.7d</td>
<td>5.2bc</td>
<td>2.7d</td>
<td>5.5bc</td>
</tr>
<tr>
<td>-1.2</td>
<td>9.2a</td>
<td>3.9ab</td>
<td>6.5b</td>
<td>3.5ab</td>
<td>6.2bc</td>
</tr>
</tbody>
</table>

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Fig. 1. Root/Shoot length (cm) of fennel seedling primed by hydropriming, NaCl, K$_2$SO$_4$, PEG and control

Fig. 2. Root/Shoot weight (mg plant$^{-1}$) of fennel seedling primed by hydroprime, NaCl, K$_2$SO$_4$, PEG and control
increased cell permeability, the change in K:Na balance cause decreasing use of metabolic energy (Levitt, 1980).

Priming may improve germination by accelerating imbibition, which in turn would facilitate the emergence phase and the multiplication of radicle cells (McDonald, 1999). This process is important because allows the subsequent development of the embryo, especially in seeds characterised by a morphological dormancy (immature embryo), like Chamaecyparis nootkatensis seeds (Schimtz et al., 2001). In tomato, priming improved the germination capacity by increasing endosperm volume (Dahal et al., 1990).

The technique of seed priming is becoming familiar to farmers in several parts of the world, and has now been promoted there on a range of crops, for example wheat (Harris et al., 2001), maize (Harris et al., 2002), and mung bean (Rashid et al., 2004), where similar responses to those reported here have been found. Equally encouraging results have been found for these crops in other countries, and for other crops, such as chickpea in India and Bangladesh (Harris et al., 1999; Musa et al., 2001), upland rice in India (Harris et al., 1999, 2002), and finger millet in India (Kumar et al., 2002).

In many coated seeds, germination and subsequent seedling growth can be inhibited by mechanical restriction exerted by the seed coat (Sung and Chiu., 1995). Priming may be helpful in reducing the risk of poor stand establishment under drought and salt stress and permit more uniform growth under conditions of irregular rainfall and drought on saline soils.

References


Harris, D., A. Joshi, P. A. Khan, P. Gothkar and P. S. Sodhi


