Effects of on-farm seed priming with zinc sulfate and urea solutions on emergence properties, yield and yield components of three rainfed wheat cultivars

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ABSTRACT

In order to determine the effects of on-farm seed priming by urea and zinc solutions on speed and percentage emergence, yield and yield components an experiment was conducted in Hamedan in 2009. The total amount of precipitation during the growing season was 388.6 mm. Experiment was factorial in a randomized complete block design with three replications. First factor included three rainfed wheat cultivars (Sardari, Azar 2 and Sardari 39) and second factor included five on-farm seed priming treatments (0.2% zinc sulfate solution, 0.9% urea solution, compound -zinc sulfate with urea- solution, tap water and no primed). Seeds soaking duration in all priming treatments was 10 hours. Results showed that speed and percentage emergence, number of tillers per plant, number of spikes per square meter, 1000 grains weight, number of grains per spike, biological and grain yields were affected positively by seed priming. Among seed priming treatments, using zinc sulfate and then compound solutions had greatest effect on all of traits. Grain yield in zinc sulfate treatment (2320 kg/ha) was increased by 26.3% compared to no primed treatment (1837 kg/ha) because of higher speed and percentage emergence and more tillers. Sardari and Sardari 39 had greater yield than Azar 2 due to more tillers and spikes per their plants.

Key words: on-farm seed priming, rainfed wheat, urea, zinc sulfate, emergence, yield.

INTRODUCTION

One of the major problems in the production of crops, especially in dry and semi arid regions is poor establishment [26]. Rainfed wheat yield directly related to early seedling emergence and rapid stand establishment [20].

In this regard there is a seed technology which is called seed priming with many advantages including help in improving speed of seed germination and early seedling establishment [24]. This technology can increase the range of seed germination and emergence under stress conditions such as drought [32], salinity [1], low and high temperatures [5,6].

One of the most practical and cheapest methods of seed priming is on-farm seed priming using tap water [18,19]. Research has shown that on-farm seed priming which consists of soaking seeds in water (usually overnight) then surface drying and planting the same day, resulted in yield increases and has already been adopted by thousands of resource-poor farmers for many crops in many countries in both Asia and Africa [19]. Furthermore, seed priming
can be used to overcome soil micro- and macro-nutrient deficiencies [3,17]. Das and Choudhury (1996) reported that wheat seed soaking in potassium hydro phosphate (KH2PO4) monobasic enhanced germination, emergence, growth, and grain yield. Studies by Harris et al. (2001) showed hydroprimed seed in India, Nepal and Pakistan has increased yield of wheat by amount 5 to 36 percent. Also Harris et al. (2002) reported that priming in corn improved seedling establishment, plant growth and caused earlier flowering and increasing yield. In these plants, increased yield was attributed to both priming and zinc.

Since a wide range of soils in the world are deficient in zinc, seed priming combined with zinc element can be effective for the treatment of zinc deficiency in the soil. Results showed that seed hydropriming with zinc sulfate not only increased weed competition ability of corn but also increased its grain yield [18]. Hemantaranjan and Gray (1988) stated that application of iron and zinc in wheat increased 1000 grains weight, number of grains per spike and grain yield due to the increase in leaves chlorophyll and indole-3-acetic acid (IAA). Cakmak (2008) reported that zinc has important role in protecting and stabilizing the structure of cell membranes. In barley, seed priming with zinc solution improved seed germination and seedling vigor index [2]. This indicates of important physiological role of zinc during germination process [35].

Also there are studies that have focused on the influence nitrogen during seed priming on speed emergence, seedling establishment and yield increase [3,6]. It seems that providing nitrogen during seed priming causes to increase the germination enzymes such as alpha-amylase (Sun and Chang, 1993). Bose and Pandy (2003) reported that presoaking of okra seeds in nitrate solution increased embryo growth and seedling vigor.

The aim of this study was to investigate the effect of on-farm seed priming with zinc sulfate and urea solutions on seedling emergence properties, yield and yield components of three rainfed wheat cultivars in Hamedan.

MATERIALS AND METHODS

To study the effect of on-farm seed priming with two nutrient solutions (zinc sulfate and urea) on emergence properties, yield, yield components and harvest index of three rainfed wheat cultivars, an experiment was conducted at agriculture and natural resources research center of Hamedan (34.87° N, 48.54° E and 1757 m) in 2009. Annual average precipitation over the last 30 years have been reported 310 mm. Details of the amount of precipitation during the growth months can be seen in Tale 1. Soil was clay-loam with pH 8.3, nitrogen 0.05% and zinc 0.38 ppm. The experiment was factorial in a randomized complete block design with three replications. First factor included three rainfed wheat cultivars (Sardari, Azar 2 and Sardari 39) and second factor included five on-farm seed priming treatments (0.2% zinc sulfate solution, 0.9% urea solution, compound-zinc sulfate with urea-solution, tap water and no primed). Seeds soaking duration in all priming treatments was 10 hours, that was determined with a preliminary test for determining time and solutions concentration. Wheat cultivars were prepared by agriculture dry land research institute of Kermanshah.

Each plot was consisted of 8 rows grown just 5 m in length and row spacing 20 cm. Planting density was 300 seeds per square meter. Primed or no primed seeds were disinfected with Vitawax fungicide before planting. Planting was done by hand on October 11th. According to the results of soil tests, 150 and 50 kg/ha respectively triple superphosphate and urea fertilizers was applied before planting.

In order to measure the speed and percentage emergence after starting seed emergence (after effective rainfall on November 8th), once every three days for 20 days in a specified line, emerged seedling were counted for each experimental unit. Angular conversion (arcsin $\sqrt{x}$) was used for normaling percentage of germination. Seedling emergence speed was calculated by using equation 1, [12]:

Equation1: Emergence rate = $\frac{\sum n_i}{\sum m_i d_i}$

ni and di are respectively number of emerged seeds and the number of days from planting time in $i^{th}$ counting. At the end of the growing season, for measuring the yield of each plot, 2 square meters was harvested. To measure the average number of tillers per plant and yield components, 10 plants of each plot were used randomly. Statistical analysis was performed by using SAS and MSTATC statistical softwares and the comparison of means was conducted by LSD (Least Significant Difference) test at 5%.
RESULTS AND DISCUSSION

Emergence speed and emergence percentage
According to results of analysis of variance (Table 2) only priming treatments had significant effect at 1% on speed and percentage emergence. Increased germination rate in seeds of corn, rice, chickpea by priming has also been reported [19]. In primed seed increased of bio-energy level (ATP), increasing of RNA and DNA synthesis and enhancement of mitochondrial performance have been reported [14]. Among priming treatments, priming with zinc sulfate was superior although other priming treatments had higher speed and percentage emergence than control (no primed) treatment (Table 3). Seed priming with zinc sulfate increased speed and percentage emergence by 35.7% and 24.6% respectively. Nagar et al. (1998) showed that hydropriming has increased percent and rate of corn emergence in farm. Generally primed seeds especially with nutrient solution showed better emergence characteristics. Mumtaz Khan et al., (2003) reported that primed seeds have more protein metabolism ability. Also in primed seeds enzymes activity increases such as esterase, glycerol 3-phosphate dehydrogenase and alpha amylase that cause to increase metabolism of seed storage materials like carbohydrates, lipids and proteins [25,42]. Rowse (2001) reported that hydroprimed corn seeds had better germination and establishment due to reduction in time of water absorption.

Zinc sulfate superiority is probably due to zinc role in protein synthesis, cell membrane function and cell elongation [10]. Also application of urea solution has been useful though not significantly different from tap water. Guzman and Olave (2006) reported seed priming by nitrate solution increased melon seeds vigor. According to compound treatment results, it can be concluded that the use of zinc is more important than nitrogen in seed priming of wheats. Musa et al. (2001) reported that on-farm seed priming in chickpea caused increasing of emergence percentage because of priming.

Number of tillers per plant
Results of the analysis of variance (Table 2) shows that priming and cultivar effects separately are significant at 1% and 5% respectively on tiller production.

According to Table 3, seed priming especially with zinc sulfate increased tillers per plant compared to control. Sharma and Bandana (2003) reported that seed priming increased the number of wheat spikes per square meter resulted of increasing the number of wheat tillers. This feature can be useful in the late planting dates, because of decreasing tillers in the late planted wheat (Shah et al., 1994). Sander and Eghbal (1999) explained that decreased tillers due to delay in planting, limits root growth and nutrients uptake. Thus, it appears that priming treatments can cause better root development [31].

Also among wheat cultivars, Sardari had more tillers although there was no significant difference with Sardari 39 (Table 4). Difference between cultivars tillering is likely due to genetic differences.

Number of spikes per square meter
As can be seen in Table 2, Both priming and cultivar separately had significant effects on this trait at 1%. Priming treatments including zinc sulfate, compound (zinc + urea), urea solutions and tap water increased number of spikes per square meter 18, 16.2, 12.6 and 8.7 percent respectively comparing no primed treatment (Table 3). Plants derived from primed seeds be deployed faster [2,4]. These plants develop a root system in shorter time thus they can uptake water and nutrient elements efficiently and reach autotroph stage as soon as possible.

This study confirms the results reported by Harris et al. (2002). They stated that zinc will affect increasing the number of corn ear by increasing the amount of growth regulators, helping to metabolism and reproductive process. Also Harris et al. (2001) observed that formation and evolution of the ear in primed corn was significantly accelerated. In this study Sardari and Sardari 39 cultivars had higher spikes significantly comparing Azar 2 cultivar (Table 4).

Number of spikelets per spike
Effects of seed priming, cultivar and their interaction on the number of spikelets per spike were significant at 1% (Table 2). According to Table 5, in Azar 2 and Sardari 39 cultivars, priming with zinc sulfate and compound solutions respectively caused highest number of spikelets per spike however in Sardari cultivar seed priming not only did not increase this trait but also decreased it except tap water priming treatment. In coordination with Azar 2
cultivar result, Khan et al., (2008) reported that soil application of zinc sulfate increased number of spikelets per spike. It seems to be priming effect on the number of spikelets per spike in wheat depends on type of nutrient solution and wheat cultivar. Harris et al. (2002) reported that seed priming is effective on reproductive development, and it can cause increasing the potential number of grain ovule that is determined in the early stages of emergence.

**Number of grains per spikelet**

Priming treatments did not have significant effect on this trait and just cultivar had significant effect at 1% (Table 2). It seems that this trait is under the control of plant genetics [39]. Azar 2 cultivar had highest number of grains per spikelet among cultivars, perhaps an attempt to compensate for the lower number of tillers and spikes generated by the other two cultivars (Table 4).

**Number of grains per spike**

The number of grains per spike was impressed by priming and cultivar at 1% (Table 2). Means comparison for priming effect shows that priming with zinc sulfate, urea, compound solutions and tap water increased the number of grains per spike by 18, 12.6, 16.2 and 8.7 percent respectively compared with control (Table 3). Also among cultivars, Azar 2, Sardari and Sardari 39 had respectively the highest to lowest number of grains per spike (Table 4). The results indicate that priming regardless nutrient elements has less effect on this important trait. Less seed formation due to zinc deficiency represents a crucial role of zinc in the development of the anthers and pollen viability [29].

**1000 grains weight**

The results of analysis of variance showed that effect of seed priming and cultivar on the 1000 grains weight were significant at 1% (Table 2). Means comparison for priming effect shows that priming with zinc sulfate, urea, compound solutions and tap water increased the 1000 grains weight by 13.6, 6.2, 11.1 and 4.0 percent respectively compared with control (Table 3). Bakht et al. (2010) reported that primed seeds produced larger grains. Also, Farooq et al. (2006) reported priming rice seeds before planting increased its 1000 grains weight significantly at harvest time. Kaur et al. (2005) reported that the sink activities was higher than control treatment in chickpea plants were grown from hydroprimed seeds. That was determined through the more activity of enzymes involved in sucrose metabolism that caused yield and 1000 grains weight increase. Harris et al. (2002) also reported seed weight increasing by priming effect.

According to major zinc role in increasing grain weight (Table 3), Yilmaz et al. (1997) reported that zinc is an important nutrient element that motivate more photosynthetic assimilates to developing grains in wheat crop. Among the studied cultivars, the highest and lowest seed weight were related to Sardari 39 and Azar 2 respectively (Table 4).

| Table 1: The amount of precipitation during the growth months (mm) |
|---------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| October | November | December | January | February | March | April | May | June | July | Total |
| 1.3 | 115.3 | 40.2 | 5.5 | 46.8 | 45.5 | 54.3 | 75.3 | 4.4 | 0 | 388.6 |

**Grain yield**

Due to the results of analysis of variance the main effects on grain yield were significant respectively at 1% and 5% (Table 2). Means comparison for priming effect shows that priming with zinc sulfate, urea, compound solutions and tap water increased the grain yield by 26.3, 16.9, 22.2 and 11.5 percent respectively compared with control (Table 3). Control treatment had not significant different with tap water treatment then it can be concluded nutrient elements especially zinc had a privileged role in seed priming process. Harris et al. (2007) reported that seed priming with zinc sulfate and water alone increased the grain yield of maize respectively 27% and 14% that is consistent with the results of this study. They concluded that the contribution of water alone and zinc contributed about equally to the overall increase. Also Harris et al. (2005) reported 16% wheat yield increase by on-farm seed priming with zinc sulfate solution. They stated this yield increase is due to the rapid emergence and early flowering. Also Rashid et al. (2004) reported that hydropriming of bean seeds during 8 hours increased yield. Ghasemi et al. (2008) showed that hydropiriming increased yield and yield components through increasing speed and percentage emergence. Bastia et al. (1999) improved the number of plant per unit area, number of heads per plant, number of grains per plants,1000 grains weight and yield of safflower by using seed hydropiriming treatments and changing planting date.
Table 2: Analysis of variance for cultivar and seed priming on different properties of rainfed wheats
(ns, *, **: Non-significant, significant at the 5% and 1% probability levels, respectively)

<table>
<thead>
<tr>
<th>S.O.V</th>
<th>df</th>
<th>Emergence Speed</th>
<th>Emergence Percentage</th>
<th>No Tiller/Plant</th>
<th>No Spike/m²</th>
<th>No Spikelet/Spikelet</th>
<th>No Grain/Spikelet</th>
<th>No Grain/Spike</th>
<th>1000 Grains Weight (g)</th>
<th>Grain Yield (kg/ha)</th>
<th>Biological Yield (kg/ha)</th>
<th>Harvest index (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td>2</td>
<td>0.000003**</td>
<td>74.38**</td>
<td>0.152**</td>
<td>874.4**</td>
<td>5.5**</td>
<td>0.44**</td>
<td>9.3**</td>
<td>81.8**</td>
<td>52470.8**</td>
<td>58696.8**</td>
<td>0.0004**</td>
</tr>
<tr>
<td>Priming</td>
<td>4</td>
<td>0.0002**</td>
<td>395.18**</td>
<td>0.549**</td>
<td>5593.1**</td>
<td>1.4**</td>
<td>0.034**</td>
<td>22.1**</td>
<td>29.23**</td>
<td>331043.6**</td>
<td>2924381.4**</td>
<td>0.0005**</td>
</tr>
<tr>
<td>Cultivar</td>
<td>2</td>
<td>0.00002**</td>
<td>26.87**</td>
<td>0.078**</td>
<td>8068.1**</td>
<td>11.4**</td>
<td>0.835**</td>
<td>95.07**</td>
<td>349.07**</td>
<td>383801.8**</td>
<td>3913917.3**</td>
<td>0.006**</td>
</tr>
<tr>
<td>Priming*Cultivar</td>
<td>8</td>
<td>0.0000006**</td>
<td>7.93**</td>
<td>0.027**</td>
<td>203.1**</td>
<td>1.6**</td>
<td>0.036**</td>
<td>0.311**</td>
<td>0.32**</td>
<td>25711.4**</td>
<td>628594.7**</td>
<td>0.001**</td>
</tr>
<tr>
<td>Error</td>
<td>28</td>
<td>0.000009</td>
<td>27.33</td>
<td>0.022</td>
<td>725.06</td>
<td>0.29</td>
<td>0.029</td>
<td>1.15</td>
<td>1.78</td>
<td>74550.5</td>
<td>289549.6</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Table 3: Means comparison of priming treatments on measured traits.

<table>
<thead>
<tr>
<th>Priming Treatments</th>
<th>Emergence Speed</th>
<th>Emergence Percentage</th>
<th>No Tiller/Plant</th>
<th>No Spike/m²</th>
<th>No Spikelet/Spikelet</th>
<th>No Grain/Spikelet</th>
<th>1000 Grains Weight (g)</th>
<th>Grain Yield (kg/ha)</th>
<th>Biological Yield (kg/ha)</th>
<th>Harvest index (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc sulfate</td>
<td>0.057</td>
<td>89.5</td>
<td>3.4</td>
<td>392</td>
<td>22</td>
<td>36.7</td>
<td>2320</td>
<td>7706</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urea</td>
<td>0.048</td>
<td>82.1</td>
<td>2.9</td>
<td>374</td>
<td>20.5</td>
<td>34.3</td>
<td>2148</td>
<td>7044</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tap water</td>
<td>0.046</td>
<td>80.2</td>
<td>2.8</td>
<td>361</td>
<td>19.5</td>
<td>33.6</td>
<td>2049</td>
<td>6881</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compound (zinc + urea)</td>
<td>0.053</td>
<td>86.2</td>
<td>3.1</td>
<td>386</td>
<td>21.5</td>
<td>35.9</td>
<td>2246</td>
<td>7249</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (no primed)</td>
<td>0.042</td>
<td>71.8</td>
<td>2.7</td>
<td>332</td>
<td>18.1</td>
<td>32.3</td>
<td>1837</td>
<td>6225</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD_{0.05}</td>
<td>0.003</td>
<td>4.2</td>
<td>0.2</td>
<td>26</td>
<td>1.4</td>
<td>2.8</td>
<td>224</td>
<td>403</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Means comparison of cultivars on measured traits.

<table>
<thead>
<tr>
<th>Wheat Cultivars</th>
<th>No Tiller/Plant</th>
<th>No Spike/m²</th>
<th>No Grain/Spikelet</th>
<th>No Grain/Spike</th>
<th>1000 Grains Weight (g)</th>
<th>Grain Yield (kg/ha)</th>
<th>Biological Yield (kg/ha)</th>
<th>Harvest index (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Azar 2</td>
<td>2.8</td>
<td>343</td>
<td>2.05</td>
<td>23.5</td>
<td>31.1</td>
<td>1774</td>
<td>6512</td>
<td>27.4</td>
</tr>
<tr>
<td>Sardari</td>
<td>3.1</td>
<td>338</td>
<td>1.59</td>
<td>19.4</td>
<td>33.4</td>
<td>1936</td>
<td>7705</td>
<td>25.8</td>
</tr>
<tr>
<td>Sardari 39</td>
<td>3.0</td>
<td>338</td>
<td>1.75</td>
<td>18.6</td>
<td>40.3</td>
<td>2011</td>
<td>6810</td>
<td>29.9</td>
</tr>
<tr>
<td>LSD_{0.05}</td>
<td>0.2</td>
<td>34</td>
<td>0.26</td>
<td>0.7</td>
<td>2.1</td>
<td>146</td>
<td>274</td>
<td>2.7</td>
</tr>
</tbody>
</table>

Table 5: Means comparison of priming and cultivar interactions on number of spikelet per spike (LSD_{0.05}=0.76)

<table>
<thead>
<tr>
<th>Priming Treatments</th>
<th>Wheat Cultivars</th>
<th>Azar 2</th>
<th>Sardari</th>
<th>Sardari 39</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc sulfate</td>
<td>12.45</td>
<td>12.08</td>
<td>11.07</td>
<td></td>
</tr>
<tr>
<td>Urea</td>
<td>11.62</td>
<td>12.46</td>
<td>11.31</td>
<td></td>
</tr>
<tr>
<td>Tap water</td>
<td>10.91</td>
<td>13.10</td>
<td>10.02</td>
<td></td>
</tr>
<tr>
<td>Compound (zinc + urea)</td>
<td>11.92</td>
<td>12.00</td>
<td>12.11</td>
<td></td>
</tr>
<tr>
<td>Control (no primed)</td>
<td>10.44</td>
<td>13.00</td>
<td>9.51</td>
<td></td>
</tr>
</tbody>
</table>

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Seed priming can increase the yield of harvested wheat, corn and cotton in the subtropical regions. This increasing is function of plant type, cultivar, environmental conditions and type of used priming treatment [34].

Sardari 39 cultivar without significant difference with Sardari cultivar had maximum grain yield (2011 kg/ha) and Azar 2 with 1774 kg/ha grain yield was the last (Table 4).

**Biological yield and harvest index**

According to results of analysis of variance (Table 2) both priming and cultivar were significant at 1% on biological yield and harvest index only affected by cultivar at 1%. Means comparison for priming effect on biological yield shows that priming with zinc sulfate, urea, compound solutions and tap water increased it by 23.7, 13.1, 16.4 and 10.5 percent respectively compared with control (Table 3). These results are similar to the results of grain yield however there is a significant difference between control and tap water treatments.

Despite the biological yield of Sardari 39 is less than Sardari but its grain yield is even more but not significant (Table 4). The answer is that Sardari 39 cultivar has a significant greater harvest index (Table 4).

In this study harvest index was not affected by priming treatment (Table 2). Harris et al. (2008) also reported wheat seed priming with water and zinc sulfate increased grain yield and total dry matter however harvest index did not have any increasing but Bakht et al. (2010) reported that harvest index was increased by priming.

**CONCLUSION**

In general, on-farm seed priming of rainfed wheat cultivars with zinc sulfate particularly in the zinc- deficient soils can increase grain yields by increasing emergence speed and percentage and improving tillering ability with the lowest possible cost.

**REFERENCES**