Evaluation Seed-borne Fungi of Rice [Oryza sativa L.] and that Effect on Seed Quality

Salar Monajjem1,*, Ebrahim Zainali2, Farshid Ghaderi-Far3, Elias Soltani2, Maryam Hosseini Chaleshtari4 and Maryam Khoshkdaman5

1Ph.D Student of Seed Science and Technology
2Assistant Prof., Dept. of Agronomy, Gorgan University of Agricultural Sciences and Natural Resources
3Assistant Prof., Dept. of Agronomy, University of Tehran
4Assistant Prof., Rice Research Institute of Iran
5Scholar of Rice Research Institute of Iran

Abstract

Poor seedling establishment in rice is one of the problems in Guilan province as the second most important rice-growing locations in Iran. The aim of this study was to evaluate the contamination occurrence of rice seed in five locations of Guilan province to seed-borne fungi and their effects on germination characteristics. Five seed sample of Hashemi variety obtained from leading farmers from each location, and their germination characteristics and the rate of contamination to Fusarium moniliforme, Bipolaris oryzae, Aspergillus niger, A. flavus, Penicillium sp., Alternaria padwickii was evaluated using the PDA and standard blitter methods. The assessment results showed that among the seed-borne fungi, two species A. niger and A. flavus exhibited the highest severity in both methods. Samples from Rashid and Zeybaknar locations showed the most contamination to A. flavus and A. niger. A positive and significant linear relationship was observed between daily precipitation and relative humidity with severity of A. flavus and A. niger fungus. A. niger, A. padwickii; daily precipitation and average minimum temperature had the most influence on germination characteristics. Among the studied factors, A. niger had high negative impact compared to other factors on all rice seed germination characteristics. Among the study locations, quality of seeds in Rostam-Abad in terms of germination percentage, germination rate, germination uniformity and electrical conductivity had the best state. The results of this study showed that the low precipitation and low daily average humidity along with higher number of sunshine hours in the Rostam-Abad caused reduction in activity and abundance of fungi, led to improve the quality of produced seed.

Keywords: Seed-borne fungi; Rice; Seed quality; Climatic conditions

Introduction

Seed is the primary basis of crop production and is the most important available input factor for smallholder farmers [1]. In most parts of the world, smallholder farmers use their produced seed for next year planting, consequently, they attempt to stock their own produced seed for several months to several years. These seeds are often of poor quality, impure and contaminated with pathogens [2]. Seed contamination of pathogens during storage could reduce seed vigor, germination, and cause negative effect on appearance and chemical composition of seeds in addition to accelerate seed deterioration, it can also inhibit germination, transmission of the pathogen from seed to seedling or main plant leading to reduction in crop yield and threatened food security [3].

Food security of the world depends on sufficient production of small seed cereals as the cheapest source that provided about 70 of absorbable energy [4]. Based on seed production, rice is the second small seed cereals, with area under cultivation about 154 million hectares, with a global production of 720 million tons of paddy [5].

Rice is very important in Iran and it provides substantial part of the diet, especially in the three Northern provinces; Guilan, Mazandaran and Golestan. Total rice cultivation area in the country is approximately 600 thousand hectares. Guilan province with 230 thousand hectares of rice fields with an average of 0.8 hectares of land owned by each farmer has the second place in rice production. In this province, from total rice seeds which are used by farmers only about 5 percent are considered as certified seed and the other 95 percent is produced by farmers and keep maintained in On-farm storages until sowing [6].

Different research studies have stated that in poor storage conditions, pathogens are the most important factors which not only cause the seed aging and deterioration during storage, but also seed and seedling rotting or abnormal production of seedlings in nursery [7,8]. Several reports indicated that the majority of these pathogens that lead to the production of abnormal seedlings are seed-borne fungi [9]. The rate of damage of these fungi depends on their genus and species, rate of density, fungi invaded, environmental conditions, cultivar susceptibility and interaction of these factors on cultural practice [10].

More than 100 species of fungi have been identified on rice seeds so far. However, their severity depends on the time of sampling, location and varieties are different [11-13]. Through an assessment of rice seed contamination to different seed-borne fungi, 8 genera including 12 species of fungii were identified which among them Bipolaris oryzae with 59% and Alternaria padwickii with 53% had the highest severity [13]. Ahmed et al. [9] in their study on rice seed contamination identified 9 species of seed-borne fungi including: Fusarium oxysporum, F. moniliforme, Bipolaris oryzae, Alternaria padwickii, Curvularia lunata, Aspergillus flavus, A. niger, Penicillium sp. and Nigrospora oryzae. They
stated that the most common fungal contamination in examined seed samples was related to Bipolaris oryzae and Alternaria padwickii. Uma and Wesely [14] by studying on 5 seed varieties after ending storage period in India, identified seeds contamination to Aspergillus flavus, A. niger, Penicillium citrinum, Alternaria padwickii and Rhizopus oryzae in which, A. flavus with 18% and A. niger with 17.6% had the highest severity. Van Du et al. [15] studied the seed-borne fungi which were identified from samples of rice varieties in different locations in Vietnam and reported that there was a significant difference for fungus severity among the cultivars, but not for different locations of seed production. In their study, contamination to seed-born fungi in improved varieties was more than local varieties causing reduction in germination and seedling height percentage in these varieties. Among seed-borne fungi, the most severity in different varieties was related to A. padwickii. A. padwickii has led to reduction of germination stronger than others fungi. Karami et al. [16] studied the effect of Fusarium spp. and brown spot [Bipolaris oryzae] on seed germination of high yield rice varieties and reported that germination percentage and seedling growth on studied cultivars has declined due to fungal contamination.

The quality of used seeds in the establishment of normal seedlings is important. The contamination of seeds to seed-borne fungi during storage by reducing seed quality affects on seed germination and establishment of seedling. By considering the self-consumption of rice seed in the rice seed production system in Guilan, and inappropriate condition during on-farm storage, it seems that performing targeted basic-applied research in this field is necessary. Hence, the present study was carried out to evaluate the contamination of rice seed for Hashemi variety, which is commonly used by farmers in different locations of Guilan province, to seed-borne fungi and its effect on germination characteristics.

Methods and Materials

Guilan province located between 38˚-27˚-7˝ to 36˚-36˚3˝ north latitude and 50˚-26˚-42˝ to 48˚-34˚-25˝ east of the Greenwich meridian, between the heights of the Alborz Mountains and humidity resource of the Caspian Sea. However, among various locations of rice production in Guilan, in terms of the rate of precipitation, temperature, relative humidity and sunshine hours are different [17]. Hence, this evaluation was carried out in the spring of 2013 by using of seed samples collected from 5 different locations of Guilan including Amlash, Zeybakna, Talesh, Rašt and Rostam-Abad. Meteorological data in the studied locations of Guilan province during six months of plant growth period [2012/03/01 to 2012/09/01] and the seed development is presented in Table 1. From each location after the end of seed harvesting, five seed samples of Hashemi which is the local dominant variety in Guilan province randomly received from the leading farmers. All samples stored in similar condition in cold storage at 5°C for 6 months.

Seeds germination characteristics were evaluated by using standard germination test in a completely randomized design with four replications in Petri-dishes with 9 cm diameter. For this reason, the first seed surface dis contaminated for the purpose of determining the presence of internal fungi in seed with sodium hypochlorite [5%] for 1 min and then washed 3 to 5 times with distilled water [18]. Then, after laying one Whatman filter paper at the bottom of each Petri-dish, 25 seeds of each sample were placed on filter paper and after adding 5 ml of distilled water, to retain moisture Petri dish lid were placed on them. Then Petri-dishes were transferred to growth chamber at 25°C, with normal light and relative humidity of 70 ± 5 percent [19]. During the experiment [7 days] once in every 8 hours germination seeds were counted, based on root let criteria in size of 2 mm or more [20]. Using of obtained data, germination characteristics including germination percentage, germination rate, germination uniformity, D10, D50 and D95 [in order of time that it takes to cumulative germination percentage reach its maximum 10, 50 and 95] were calculated by Germin program [21]. In order to perform the electrical conductivity test [electrical conductivity which represented the amount of material was leakage from seed], the seeds washed with deionized water to remove contaminated surface of seeds, then 5 g of seeds immerse in 50 ml of distilled water at 25°C and after 24 hours electrical conductivity of solution measured by conductivity meter device model LF 90 SER-NA31245385 [22].

In vitro potato dextrose agar method [PDA] and standard blotter method were employed to identify the seed-borne fungi of Fusarium moniliforme, Bipolaris oryzae, Aspergillus niger, Aspergillus flavus, Penicillium sp., Alternaria padwickii and to determine their contamination percentage. In both methods, seeds were soaked for 5 minute at sodium hypochlorite [1%] solution and immediately washed with distilled water 3 to 5 times in order to prevent fungal pathogens infection [23]. In PDA method for each sample was performed with four replications, in each Petri dish poured some prepared of PDA then with sterile forceps under the hood 10 seeds were placed on the in PDA [23] (Figure 1). After six days Petri dishes were placed at a temperature of 22°C incubator, seed born fungi were identified and contamination rate of seeds to these factors were evaluated [24]. The standard Blotter method for each sample was carried out with 400 seeds, in each Petri dishes, three layers of Whatmann filter papers soaked with distilled water and were placed with 25 seeds. Petri dishes [16 Petri dishes for per sample] for incubating placed in temperature of 22°C then 6 days in alternating cycles of 12 hours near

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed develop. period</td>
<td>Seed develop. period</td>
<td>Seed develop. period</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012/03/01 to 2012/09/01</td>
<td>31.15</td>
<td>27.02</td>
<td>21.03</td>
<td>16.85</td>
<td>7.75</td>
</tr>
<tr>
<td>2012/03/01 to 2012/09/01</td>
<td>29.88</td>
<td>26.34</td>
<td>21.75</td>
<td>18.48</td>
<td>7.95</td>
</tr>
<tr>
<td>2012/03/01 to 2012/09/01</td>
<td>30.34</td>
<td>27.29</td>
<td>21.43</td>
<td>17.99</td>
<td>7.95</td>
</tr>
<tr>
<td>2012/03/01 to 2012/09/01</td>
<td>30.54</td>
<td>25.89</td>
<td>22.17</td>
<td>17.83</td>
<td>7.36</td>
</tr>
<tr>
<td>2012/03/01 to 2012/09/01</td>
<td>30.05</td>
<td>28.79</td>
<td>22</td>
<td>19.43</td>
<td>8.30</td>
</tr>
<tr>
<td>2012/03/01 to 2012/09/01</td>
<td>31.15</td>
<td>27.02</td>
<td>21.03</td>
<td>16.85</td>
<td>7.75</td>
</tr>
<tr>
<td>2012/03/01 to 2012/09/01</td>
<td>29.88</td>
<td>26.34</td>
<td>21.75</td>
<td>18.48</td>
<td>7.95</td>
</tr>
<tr>
<td>2012/03/01 to 2012/09/01</td>
<td>30.34</td>
<td>27.29</td>
<td>21.43</td>
<td>17.99</td>
<td>7.95</td>
</tr>
<tr>
<td>2012/03/01 to 2012/09/01</td>
<td>30.54</td>
<td>25.89</td>
<td>22.17</td>
<td>17.83</td>
<td>7.36</td>
</tr>
<tr>
<td>2012/03/01 to 2012/09/01</td>
<td>30.05</td>
<td>28.79</td>
<td>22</td>
<td>19.43</td>
<td>8.30</td>
</tr>
</tbody>
</table>

Table 1: Meteorological information for different locations of seed production of Guilan province during seed development period and six months of year in 2012.
ultraviolet light and 12 hours in darkness. At the seventh day grown fungi on seeds germination were identified by using of a stereo microscope and number of infected seeds in each seed sample marked and calculation was performed as contamination percentage [24] (Figure 2).

Data analysis conducted by stepwise regression, ANOVA and multiple comparison using LSD test was performed by using of SAS [25] software.

<table>
<thead>
<tr>
<th>DF</th>
<th>Fusarium moniliforme</th>
<th>Pyricularia oryzae</th>
<th>Bipolaris oryzae</th>
<th>Aspergillus niger</th>
<th>Aspergillus flavus</th>
<th>Penicillium sp.</th>
<th>Alternaria padwickii</th>
<th>% total infection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method</td>
<td>1</td>
<td>33.40**</td>
<td>143.41**</td>
<td>138.44**</td>
<td>2892.18**</td>
<td>442.50ns</td>
<td>367.90**</td>
<td>6.59ns</td>
</tr>
<tr>
<td>Location</td>
<td>4</td>
<td>142.33**</td>
<td>42.80**</td>
<td>176.32**</td>
<td>11491.03**</td>
<td>868.48**</td>
<td>221.06**</td>
<td>156.27**</td>
</tr>
<tr>
<td>Location × Method</td>
<td>4</td>
<td>46.96**</td>
<td>38.09**</td>
<td>16.28**</td>
<td>244.76**</td>
<td>139.65**</td>
<td>188.09**</td>
<td>30.45**</td>
</tr>
<tr>
<td>Rep[Method × Location]</td>
<td>30</td>
<td>0.94</td>
<td>0.41</td>
<td>3.01</td>
<td>62.44</td>
<td>18.76</td>
<td>2.38</td>
<td>0.73</td>
</tr>
<tr>
<td>Error</td>
<td>160</td>
<td>31.23</td>
<td>6.65</td>
<td>33.18</td>
<td>626.53</td>
<td>275.62</td>
<td>19.42</td>
<td>10.14</td>
</tr>
<tr>
<td>Coefficient Variance</td>
<td>6.67</td>
<td>8.63</td>
<td>6.61</td>
<td>7.85</td>
<td>7.76</td>
<td>6.66</td>
<td>6.95</td>
<td>3.37</td>
</tr>
</tbody>
</table>

ns: non-significant, * and **: Significant at 5% and 1% probability levels, respectively.

Table 2: Analysis of variance for seed-born fungi in rice seed samples in different locations of seed production of Guilan province.

Results and Discussion

The results showed differences between evaluated locations from contaminated rate point of view to seed-borne fungi and also different severity of contaminated seeds to various fungi included Fusarium moniliforme, Bipolaris oryzae, Aspergillus niger, Aspergillus flavus, Penicillium sp., Alternaria padwickii (Table 2). In examined seed samples, among rice seeds borne fungi, Aspergillus niger and Aspergillus flavus in both evaluated methods [Standard blotter method and PDA method] had the most severity than the other fungi species (Table 3), these data confirms the results reported by Uma and Wesely [14] which they stated that A. flavus and A. niger fungi as the most important storage fungi could be active in seed moisture content below 20 percent. Trung et al. [26] by examination on the 25 seed samples of rice in Vietnam mentioned that genus of fungus Aspergillus, Fusarium and Penicillium were the most common fungi. Reddy et al. [27] in their study on stored rice for more than a year from 18 different ecosystems in India were stated that Aspergillus is the most important fungal contamination on rice seeds.

Among the five different evaluated locations, samples from Rasht and Zeybakenar had the most contamination to rice seed-borne fungi, and the most severity fungi were A. flavus and A. niger (Table 3). Reddy et al. [27] stated that weather conditions before harvesting could be the most important factors that led to invasion of fungal species. Mosa-Nejad et al. [28] reported that the rate of precipitation, daily minimum humidity, daily maximum temperature and sunshine hours could be the most important factors affecting the distribution of rice blast in Guilan province so that suitable climatic conditions could considerably help to spore population of blast fungi and occurrence of blast disease in farm during seven to ten days after occurrence of suitable conditions. Aghili et al. [29] by study on the rice fungal contamination in Mazandaran province stated that increasing average humidity in the west of Mazandaran could be the reason for the severity of fungal contamination of the seeds. Also, the results showed that under high humidity conditions, fungi of genus Aspergillus had the most severity which corresponded with the obtained results in this research.

In the present study with regard to fungal contamination rate as a dependent variable, and climatic factors including; daily relative humidity, number of daily sunny hours, daily precipitation and minimum average temperature were entered to the regression model, respectively. Stepwise regression analysis showed that the daily humidity, the amount of daily sunshine hours, daily precipitation and minimum average temperature are the most important climatic factors that affected the distribution of different types of the evaluated seed-borne fungi except Fusarium moniliforme and Bipolaris oryzae (Table 4). The stepwise regression analysis on climatic factors affecting severity of fungi A. flavus and A. niger determined that precipitation and daily humidity could be the most influential factors in distribution of rice fungi.
seeds to this fungi. Regression analysis showed that there is linear relationship and positive significant difference between precipitation and daily humidity rate with severity of fungi. Obtained functions explain 95% and 85% changing percentage amount of daily sunshine hours and severity of Alternaria fungi and for standard blotter method for every per unit increase of daily humidity severity of fungi will be increase 9.54% and 8.65%, respectively. Furthermore, obtained regression function for Alternaria fungus by standard blotter method, for every per unit increase in daily humidity, the severity of fungi in PDA method, for every per unit reduction of daily sunshine hours EC will decrease at a rate of 9.54 micro Siemens per gram. Effect of minimum temperature on seed aging before harvest [30] or the influence of precipitation and daily average temperature had the most impact on the characteristic of studied germinating seed samples. These effects could probably be due to the influence of precipitation and daily minimum average temperature on seed aging before harvest [30] or the influence of Alternaria padwickii, on seed deterioration with various changes including the loss of membrane integrity, reduced energy metabolism, impairment of RNA and protein synthesis, and DNA degradation during storage [31].

### Table 3: Mean comparison of seed-born fungi at rice seed samples in different locations of seed production of Guilan province based on PDA and Blotter methods.

<table>
<thead>
<tr>
<th>Seed production location</th>
<th>Method</th>
<th>Number of Sample</th>
<th>Fusariumomoniliforme</th>
<th>Pycyricularoryzae</th>
<th>Bipolarisoryzae</th>
<th>Aspergillusniger</th>
<th>Aspergillusflavus</th>
<th>Penicillium sp.</th>
<th>Alternaria padwickii</th>
<th>% total infection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amlash</td>
<td>PDA</td>
<td>5</td>
<td>0g*</td>
<td>2.51b</td>
<td>6.2b</td>
<td>5.14f</td>
<td>16.33ab</td>
<td>2.06e</td>
<td>0g</td>
<td>19.40d</td>
</tr>
<tr>
<td></td>
<td>Blotter</td>
<td>5</td>
<td>0.25f</td>
<td>0e</td>
<td>4.68bc</td>
<td>3.32f</td>
<td>11.94dc</td>
<td>1.31f</td>
<td>0.90e</td>
<td>17.79d</td>
</tr>
<tr>
<td>Zeybakenar</td>
<td>PDA</td>
<td>5</td>
<td>2.06d</td>
<td>0e</td>
<td>6.15c</td>
<td>35.14c</td>
<td>17.29a</td>
<td>3.12bc</td>
<td>0g</td>
<td>39.17b</td>
</tr>
<tr>
<td></td>
<td>Blotter</td>
<td>5</td>
<td>0.85e</td>
<td>0.45d</td>
<td>3.73d</td>
<td>23.99d</td>
<td>15.52ab</td>
<td>2.57bc</td>
<td>1.31d</td>
<td>30.90c</td>
</tr>
<tr>
<td>Raat</td>
<td>PDA</td>
<td>5</td>
<td>7.1a</td>
<td>2.47c</td>
<td>1.05f</td>
<td>50.62a</td>
<td>14.26bc</td>
<td>1.05f</td>
<td>6.15a</td>
<td>56.67a</td>
</tr>
<tr>
<td></td>
<td>Blotter</td>
<td>5</td>
<td>2.72bc</td>
<td>0e</td>
<td>1.56e</td>
<td>41.79b</td>
<td>17.19a</td>
<td>1.76d</td>
<td>3.78b</td>
<td>61.80a</td>
</tr>
<tr>
<td>Talesh</td>
<td>PDA</td>
<td>5</td>
<td>0g</td>
<td>4.78a</td>
<td>8.21a</td>
<td>14.26e</td>
<td>11.24de</td>
<td>12.3a</td>
<td>2.11c</td>
<td>28.48bc</td>
</tr>
<tr>
<td></td>
<td>Blotter</td>
<td>5</td>
<td>1.15d</td>
<td>0.45d</td>
<td>5.79bc</td>
<td>11.14e</td>
<td>6.25f</td>
<td>2.16dc</td>
<td>0g</td>
<td>20.21d</td>
</tr>
<tr>
<td>Rostam-Abad</td>
<td>PDA</td>
<td>5</td>
<td>2.11c</td>
<td>0e</td>
<td>5.39bc</td>
<td>18.04e</td>
<td>9.12e</td>
<td>4.13b</td>
<td>0g</td>
<td>32.46bc</td>
</tr>
<tr>
<td></td>
<td>Blotter</td>
<td>5</td>
<td>2.21b</td>
<td>0e</td>
<td>2.92d</td>
<td>4.94f</td>
<td>2.47g</td>
<td>1.31ef</td>
<td>0.45f</td>
<td>12.35e</td>
</tr>
</tbody>
</table>

*Mean in each column followed by similar letters are not significantly different at 5% level, according to LSD Test.

### Table 4: Analysis of stepwise regression with consideration of seed-born fungi as dependent variables and climatic factor as independent variables.

<table>
<thead>
<tr>
<th>Method</th>
<th>independent variables</th>
<th>MS</th>
<th>a ± Es</th>
<th>b ± Es</th>
<th>R²</th>
<th>Pr-F</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDA</td>
<td>A. niger daily precipitation</td>
<td>4161.44</td>
<td>9.69 ± 7.16</td>
<td>4.26 ± 9.53</td>
<td>0.87</td>
<td>0.035</td>
</tr>
<tr>
<td></td>
<td>daily relative humidity</td>
<td>3430.59</td>
<td>6.97 ± 9.92</td>
<td>3.06 ± 8.65</td>
<td>0.95</td>
<td>0.009</td>
</tr>
<tr>
<td>Blotter</td>
<td>A. flavus daily precipitation</td>
<td>585.53</td>
<td>3.94 ± 3.87</td>
<td>1.73 ± 3.57</td>
<td>0.91</td>
<td>0.051</td>
</tr>
<tr>
<td></td>
<td>daily relative humidity</td>
<td>110.06</td>
<td>12.09 ± 35.25</td>
<td>1.57 ± 4.39</td>
<td>0.95</td>
<td>0.010</td>
</tr>
<tr>
<td>PDA</td>
<td>Alternaria daily precipitation</td>
<td>16.92</td>
<td>6.53 ± 14.39</td>
<td>0.85 ± 1.72</td>
<td>0.85</td>
<td>0.054</td>
</tr>
<tr>
<td></td>
<td>daily relative humidity</td>
<td>37.93</td>
<td>11.05 ± 21.55</td>
<td>1.44 ± 2.58</td>
<td>0.92</td>
<td>0.086</td>
</tr>
<tr>
<td>Blotter</td>
<td>Blast daily precipitation</td>
<td>209.68</td>
<td>62.92 ± 149.46</td>
<td>2.9 ± 7.09</td>
<td>0.90</td>
<td>0.022</td>
</tr>
<tr>
<td></td>
<td>daily relative humidity</td>
<td>2176.18</td>
<td>69.44 ± 95.47</td>
<td>0.95 ± 1.80</td>
<td>0.93</td>
<td>0.009</td>
</tr>
</tbody>
</table>

Intercept [a], the values of the slope of the regression line [b], mean squares (MS), coefficient of determination (R²), The level of significance (Pr-F).
is negative and significant correlation \( R = -0.97\% \) between rate of fungal 
with the results of the present study, Islam et al. [41] stated that there 
model. As a negative impact, fungi affects on all rice seed 
A. niger 
for other studied traits only 
percentage, Alternaria and 
were entered into models and 
the seed germination and seed vigor. 
This difference could due to seedling dry weight, normal seedling 
condition caused difference in seed vigor between seed lots of soybean. 
Moreover, the data showed clear dispersal of these two species \[ T. \text{leavis} \] and among provinces and towns with respect to 
in cold climatic zone of Iran reported a significant difference between 
period, seed quality reduced by increasing fungi activities. Mobasser et 
grain amylase content, but due to the prolonging period of grain filling 
in the reproductive phase and grain filling phase resulted to increase in 
minimum temperature and amylose content leads to reduced grain and seed 
to grain chalkiness, specification changes in viscosity, gelatinization 
have also stated that unfavorable climatic factors during grain filling, 
Similar studies have also reported the similar results [43-46]. According to their 
contaminations and germination percentage in different rice cultivars. 
Ijaz et al. [42] reported \( A. \text{niger} \) as the most damageable storage fungi 
among fungal pathogens which were introduced, leads to lower quality and seed germination. 

The results of ANOVA (Table 6) showed significant differences among different seed germination characteristics in the different 
locations of rice seed production in Guilan province. Based on 
germination percentage, germination rate, germination uniformity and electrical conductivity among the studied locations, Rostam-Abad 
location had highest seed quality and Rasht and Zeybaknar locations had the lowest quality of seed production (Table 7). According to the 
findings of this study, it could be stated that climatic conditions such 
as the lowest precipitation rate, daily humidity average and number of 
daily sunshine hours in Rostam-Abad reduce the activity and severity of seed-borne fungi, leading to an improvement in seed quality. Several 
studies have also reported the similar results [43–46]. According to their 
students, diversity and difference in severity of pathogenic fungi in the 
rice seed in various locations were attributed to the climatic conditions and crop management. Also, they stated that during seed development, 
severity of farm fungi [different species of Aspergillus, Fusarium and Penicillium] influenced by certain factors such as high relative 
humidity and environments temperature as well as high levels of seed 
development harvest which could increase the contamination to 
these fungi and reduce seed quality during Storage. 

### Conclusions 
The results showed that there was large variation in the diversity and
severity of fungal contamination to seed-borne fungi in seed samples. Among seed-borne fungi, Aspergillus niger and Aspergillus flavus had the most severity rate compared to others. Among the climatic factors, daily humidity, daily sunshine hours, daily precipitation and daily minimum average temperature were the most important factors that affected the distribution of studied seed-borne fungi types except Fusarium moniliforme and Bipolaris oryzae. Evaluation of germination characteristics of rice seeds under the influence of climatic factors on seed development stage and seed-borne fungi showed that there was a significant negative linear relationship between the average of daily precipitation amount with D10 and the average of minimum temperature with EC. Also among studied seed-borne fungi, for germination percentage, Alternaria and A. niger fungus and for other germination traits only A. niger were significant. From negative impact A. niger fungi compared with others fungus implied all characteristics were significant. From negative impact A. niger was a significant negative linear relationship between the average of cumulative germination percentage reach its maximum 10, 50 and 95% and electrical conductivity [micro Siemens. cm⁻¹. g⁻¹] in different locations of seed production of Guilan province.

Acknowledgements

The authors are thankful to the Department of Agronomy, Gorgan University of Agricultural Sciences and Natural Resources for financial support of this research and the Rice Research Institute of Iran, Rasht for permission to use laboratory facilities.

References


Table 7: Mean comparison for percent of germination [Gmax], germination rate [R50], uniformity of germination [GU], D10, D50 and 95% [in order of time that it takes to cumulative germination percentage reach its maximum 10, 50 and 95%] and electrical conductivity [micro Siemens. cm⁻¹. g⁻¹.] in different locations of seed production of Guilan province.

<table>
<thead>
<tr>
<th>Seed production Location</th>
<th>Gmax</th>
<th>R50</th>
<th>GU</th>
<th>D10</th>
<th>D50</th>
<th>D95</th>
<th>EC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amlash</td>
<td>98a*</td>
<td>0.0148ab</td>
<td>25.95ab</td>
<td>53.92c</td>
<td>67.43c</td>
<td>87.84b</td>
<td>47.38a</td>
</tr>
<tr>
<td>Zeybakenar</td>
<td>93.4b</td>
<td>0.0145b</td>
<td>41.09a</td>
<td>53.18c</td>
<td>70.46b</td>
<td>103.52a</td>
<td>38.72d</td>
</tr>
<tr>
<td>Rasht</td>
<td>90.6c</td>
<td>0.0139c</td>
<td>38.39b</td>
<td>57.74b</td>
<td>73.36a</td>
<td>100.44a</td>
<td>43.68b</td>
</tr>
<tr>
<td>Talesh</td>
<td>91.6bc</td>
<td>0.0136c</td>
<td>33.03c</td>
<td>62.27a</td>
<td>74.64a</td>
<td>102.9a</td>
<td>39.85c</td>
</tr>
<tr>
<td>Rostam-Abad</td>
<td>97.8a</td>
<td>0.015a</td>
<td>24.29e</td>
<td>55.94b</td>
<td>66.55c</td>
<td>85.29b</td>
<td>33.51e</td>
</tr>
</tbody>
</table>

*Mean in each column followed by similar letters are not significantly different at 5% level, according to LSD Test.


Submit your next manuscript and get advantages of OMICS Group submissions

Unique features:
• User friendly/feasible website-translation of your paper to 50 world's leading languages
• Audio Version of published paper
• Digital articles to share and explore

Special features:
• 400 Open Access Journals
• 30,000 editorial team
• 21 days rapid review process
• Quality and quick editorial, review and publication processing
• Indexing on PubMed (partial), Scopus, IBISSCI, Index Copernicus and Google Scholar etc
• Sharing Option: Social Networking Enabled
• Authors, Reviewers and Editors rewarded with online Scientific Credits
• Better discount for your subsequent articles

Submit your manuscript at: www.editorialmanager.com/