Influence of seed health conditions on a following oat seed generation grown in organic farming

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Abstract

Our research has been aimed at an evaluation of the influence of seed health conditions on biological characteristics of seeds and a following seed generation (it was demonstrated on a model crop - oat). Exact small-plot trials were established on three different experimental certified organic parcels in the Czech Republic between 2010 and 2011. Two varieties of hulled oat and two varieties of naked oat were used. A rate of grain contamination with microscopic fungi was studied and assessed before seeding and after harvest of the seeds. A method of isolation of micromycetes on cultivation media was applied in order to assess the contamination rate. As for the biological characteristics, energy of germination, germination, contamination with microscopic fungi was studied and assessed before seeding and after harvest of the seeds. A method of isolation of micromycetes on cultivation media was applied in order to assess the contamination rate. As for the biological characteristics, energy of germination, germination, energy of emergence and emergence were studied and evaluated in the framework of the research. The results showed that the seed origin has no influence neither on the health conditions of the emerged plants nor on the rate of the microscopic fungi contamination of the following seed generation. The hulled oat caryopses were more seriously affected by Fusarium spp., Alternaria spp. and Penicillium spp. Such a less serious affection of the naked oat caryopses might be explained by a harvest of the caryopses rid of hulls, which are inclined more often to contamination with pathogens. The influence of the seed health conditions on the seed’s biological characteristics has not been proved via correlation analysis. However, Penicillium spp. usually contributes to a reduction of the germination ability. Farm saved seeds might be recommended to farmers in case of a deficiency of certified organic seeds and a ban of application of conventional untreated seeds. However, the use of farm saved seeds has to be done carefully and meet strict requirements.

Keywords: Organic farming, seed, contamination with fungi, biological traits of seed, naked oat, hulled oat.

Introduction

The area of organic land has been gradually extending worldwide. As for the European Union (EU 27), 7,500,000 ha were managed organically in 2007. The surface area of organic farming land has also extended within Central and Eastern Europe. For example, 448,000 ha of organic fields are registered in the Czech Republic nowadays. In 2010, the proportion of the arable land in the total organic land represented 12% (55,000 ha)2.

Council Regulation (EC) No. 834/2007 and Commission Regulation (EC) No. 889/2008 stipulate that certified organic seeds must be the only allowed seed types within the European Union organic farming system. In practice, seeds have to come from a plant which has been grown in accordance with the organic farming principles for at least one growing period. However, there has been a longtime deficiency of certified organic seeds provoked by difficulties connected with seed reproduction processes in the organic farming system. The reproduction crop stands have to meet all the obligatory legislative requirements put on the reproductive seeds and meet all the conditions on organic farming (there are not any supportive measures of conventional farming allowed). If organic seeds are not available, farmers are allowed to ask the administration for permission to use the conventional untreated seeds. Such a possibility has been discussed recently and a possible absolute ban of the application of conventional untreated seeds within the organic farming system is being considered. Otherwise, farmers are allowed to use their own (farm saved) seeds16.

Cereals are among the most important crops of the organic farming system. They contribute to the economic profit of farms to a large extent. Therefore, good quality certified seeds should be used in the certified organic system as they contribute to a stable yield rate formation. Uncertified seeds might transmit and distribute pathogens, having a negative effect on the crop stand yield rate and the quality of the following seed generation. Oat has been chosen as a model cereal crop for the research and evaluation of the seed health conditions on the quality of seeds. Oat is a cereal species suitable for the organic farming system. At the same time, oat farm saved seeds are frequently used. Neither organic nor conventional farming systems treat the seeds too often. Oat may be easily grown almost all over Europe, except for the warmest and driest regions. It is a universal crop; the naked oat is mostly used as a foodstuff.
The common oat is mostly used as a fodder crop. There has been a long-time deficiency of good-quality certified organic seeds in most of the European Union countries. Uncontrolled own (farm saved) seeds are usually used, therefore. However, they might be characterised by problematic health conditions. The farm saved seeds will probably be used more frequently in the future because of the European Union pressure to reduce untreated conventional seed application. Therefore, our research was aimed at the evaluation of the influence of seed quality (i.e. health conditions, biological traits) on the following seed generation. Differences in the health conditions between individual seed categories, which are usually applied within the framework of the organic farming system (the certified organic seeds, the conventional untreated seeds, the organic farm saved seeds), have also been tested, studied and evaluated.

**Materials and Methods**

**Varieties and seeds:** Three categories of seeds were collected in the Czech Republic: certified organic seeds, conventional untreated seeds and organic farm saved seeds. Two varieties of hulled oat (*Avena sativa* L.) (Neklan, Vok) and two varieties of naked oat (*Avena muda* L.) (Izak, Saul) were used in the experiments.

**Field trials:** Varieties were sown during the experimental years 2010 and 2011 in a randomized, complete block design on organic certified trial parcels in two locations in Prague (Czech University of Life Sciences Prague; Crop Research Institute in Prague) and Ceske Budejovice (University of South Bohemia in Ceske Budějovice). The seeding rate was adjusted for a density of 350 germinable grains per m². Rows were 125 mm wide. The plots were treated in compliance with European legislation - European Council Regulation (EC) No. 834/2007 and European Commission Regulation (EC) No. 889/2008.

**Characteristics of the trial stations:** The Czech University of Life Sciences Prague (50°04´N,14°62´E): warm and mid-dry climate, soil type - brown soil, kind of soil - loamy clay soil, altitude of 295 m. The Crop Research Institute in Prague - Ruzyně (50°08´N,14°30´E): warm mid-dry climate, soil type - degraded chernozem, kind of soil - clay and loamy soil, altitude of 340 m. The University of South Bohemia in Ceske Budejovice (48°98´N,14°45´E): mild warm climate, soil type - pseudogley cambisols, kind of soil - loamy sand soil, altitude of 388 m.

**Analyses of seed contamination with fungi before seeding and after harvest:** The method of isolation of micromycetes on cultivation media was applied in order to evaluate the rate of grain contamination with microspherical fungi. An universal nutritious soil - PDA (Potato Dextrose Agar - HiMedia) was used in the experiments. Incubation lasted from seven to ten days and it was run in a dark room and in a temperature of 20°C. Each sample was repeated five times, there were ten grains included in each repetition. Mixed colonies were cleaned and sorted before the determination, clean isolates of fungi were determined, therefore. The number of isolated colonies was visually determined. The determination of micromycetes was executed with microscopes based on the morphological traits.

Laboratory germination and energy of germination were determined before seeding and after harvest. Hundred caryopses of each sample were put into plastic bowls with perforated caps on wet folded filtration paper in four repetitions. The bowls were placed into a ventilated air-conditioned box where 20°C was the inside temperature. The energy of germination was assessed four days later (by counting of usual germinated caryopses). Laboratory germination was assessed by the same procedure eight days later.

Laboratory emergence and energy of emergence were determined before seeding and after harvest. Hundred caryopses of each sample were put in coarse sand, 3 cm deep, four times. A 1 cm wide wet sand layer (characterised by 60% humidity) was placed at the bottom of the bowl. The caryopses were put onto the sand layer, they were slightly pressed and covered with dry sand. The laboratory emergence was determined at the temperature of 15°C. Seven days later, the energy of emergence was assessed, and 14 days later, the laboratory emergence was determined by counting of the emerged caryopses.

**Statistical data analysis:** The analyses were provided by the Statistica 9.0 (StatSoft. Inc., USA). Regression and correlation analyses provided the evaluation of interdependence. The comparison of varieties and their division into statistically different categories were provided by the Tukey’s HSD test.

**Results and Discussion**

Results of the evaluation of the microscopic fungi occurrence on seeds, found out by isolation and cultivation of colonies on cultivation media, are shown in Table 1. The seeds were most seriously affected by *Penicillium* spp. colonies. The average number of colonies (*Fusarium* spp., *Alternaria* spp., *Penicillium* spp.) was 6.3 colonies per 10 grains occurring on the seeds before direct seeding. The hulled oat was more seriously affected than the naked oat. The particular varieties were affected similarly. Neklan was the most seriously affected variety. There were negligible differences among the seed categories (certified organic seeds, conventional untreated seeds, organic farm saved seeds) seen from the seed origin point of view. Such results are also shown in Table 1.

The occurrence of *Fusarium* spp. and *Alternaria* spp. colonies was influenced only by the year factor (Table 2). Differences in *Alternaria* spp. occurrence rate between the individual oat species were detected (*P* < 0.05, Tukey’s HSD test). The common oat caryopses affection was double to the naked oat caryopses. The analysis of variance (Table 2) also confirmed the above mentioned findings (*P* < 0.05). Adler *et al.* give a possible explanation. The microscopic fungi occurrence is stronger on a surface of hulls. The hulled oat is harvested despite the affected hulls, whereas the naked oat caryopses lose their hulls during the harvest; therefore, the harvested grains are less contaminated with fungi. Both oat species were characterised by a similar rate of contamination with the other microscopic fungi species (e.g. *Penicillium* spp.). *Rhizopus nigricans* was also detected in most of the evaluated samples. Results of the correlation analysis (Table 3) show a strong relationship between the individual biological traits. We have also detected a positive middle correlation between the occurrence of *Alternaria* spp. fungi, germination and emergence rate.

The research was aimed at the detection of a correlation between the microscopic fungi contamination of grains and the biological
traits of grains; it also was aimed at the detection of the transmission of grain micromycetes onto the following seed generation. When studying and evaluating the initial materials, we found out that the seed contamination rate was not influenced by the growing technology applied on the parent seed crop stands (Table 1). Neither the grain contamination with the individual species of colonies, nor the contamination with the total number of colonies, nor the contamination with the specific fungi, was influenced by the seed category (certified organic seeds, conventional untreated seeds, organic farm saved seeds). Such a finding is, nevertheless, surprising, as these fungi are considered as waste disposal pathogens.

The influence of seed health conditions on an expansion of diseases throughout the growing period was not ascertained. No varieties or localities were affected by any diseases being caused by the pathogens determined on the seeds. They were not affected by any other pathogens being transmitted by seeds either. The total rate of contamination of the caryopses with microscopic fungi was influenced by weather conditions during vegetation period. The year of 2010 was wetter, which caused a higher rate of grain contamination. The hulled oat was more seriously contaminated than the naked oat; it was caused by a fact that the hulled oat caryopses get less dry, that makes ideal conditions for fungal contamination rate and the biological traits of seeds (Table 2).

As for the following seed generation, a difference in the occurrence rate of Fusarium spp. colonies between the oat species was found out. The hulled oat was more seriously affected because of the harvest of grains covered with the contaminated hulls. The analysis of variance showed the soil factor (25%) and the growing locality (42%) influenced (P < 0.01) the rate of grain contamination with Fusarium spp. As oat is very sensitive to Fusarium spp. As oat is very sensitive to Fusarium spp. The influence of seed health conditions on an expansion of diseases throughout the growing period was not ascertained. No varieties or localities were affected by any diseases being caused by the pathogens determined on the seeds. They were not affected by any other pathogens being transmitted by seeds either. The total rate of contamination of the caryopses with microscopic fungi was influenced by weather conditions during vegetation period. The year of 2010 was wetter, which caused a higher rate of grain contamination. The hulled oat was more seriously contaminated than the naked oat; it was caused by a fact that the hulled oat caryopses get less dry, that makes ideal conditions for an expansion of the fungi pathogens. The strong rate of caryopses contamination with Penicillium spp. colonies was surprising, as these fungi are considered as waste disposal pathogens.

Our research has not ascertained any transmission of micromycetes or pathogens onto the emerged plants or the following seed generation either. Such a finding is, nevertheless, relevant to oat which is extensive and less bred than the other cereal species. The contamination of seeds with Penicillium spp. colonies usually leads to a reduction of germination and emergence. The contamination of caryopses with Fusarium spp. colonies did not cause any serious reduction of germination or emergence during the field trials. The Czech legislation on the marketing of cereal seeds (Regulation No. 369/2009), based on the European Union legislation, does not stipulate any limits of the rate of occurrence of Fusarium for oat grains. As for the other

### Table 1. Contamination of seed by microscopic fungi and biological traits - Seed before seeding (mean ± SD).

<table>
<thead>
<tr>
<th>Factor</th>
<th>Parameter</th>
<th>Fusarium spp. (no./10 grains)</th>
<th>Alternaria spp. (no./10 grains)</th>
<th>Penicillium spp. (no./10 grains)</th>
<th>Energy of Germination (%)</th>
<th>Germination (%)</th>
<th>Energy of Emergence (%)</th>
<th>Emergence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oat</td>
<td>Hullled</td>
<td>0.7±0.6e</td>
<td>2.0±0.7e</td>
<td>4.3±2.4e</td>
<td>77±24e</td>
<td>85±13e</td>
<td>69±12e</td>
<td>78±11e</td>
</tr>
<tr>
<td></td>
<td>Naked</td>
<td>0.4±0.3e</td>
<td>1.1±0.7e</td>
<td>4.1±3.4e</td>
<td>78±28e</td>
<td>82±25e</td>
<td>65±28e</td>
<td>71±28e</td>
</tr>
<tr>
<td>Variety</td>
<td>Izak</td>
<td>0.5±0.4e</td>
<td>1.1±0.7e</td>
<td>3.7±2.2e</td>
<td>93±7e</td>
<td>96±26e</td>
<td>84±4e</td>
<td>87±3e</td>
</tr>
<tr>
<td></td>
<td>Saul</td>
<td>0.3±0.2e</td>
<td>1.2±0.8e</td>
<td>4.5±4.5e</td>
<td>63±33e</td>
<td>68±29e</td>
<td>46±30e</td>
<td>55±3e</td>
</tr>
<tr>
<td></td>
<td>Vok</td>
<td>0.5±0.6e</td>
<td>2.0±1.0e</td>
<td>2.9±1.4e</td>
<td>69±30e</td>
<td>81±16e</td>
<td>65±12e</td>
<td>73±13e</td>
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<tr>
<td></td>
<td>Neklan</td>
<td>0.8±0.6e</td>
<td>2.0±3.0e</td>
<td>5.7±2.4e</td>
<td>85±14e</td>
<td>90±8e</td>
<td>74±10e</td>
<td>82±8e</td>
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<tr>
<td>Seed</td>
<td>Organic</td>
<td>0.5±0.6e</td>
<td>1.7±1.1e</td>
<td>4.8±3.6e</td>
<td>75±30e</td>
<td>8418e</td>
<td>67±21e</td>
<td>74±21e</td>
</tr>
<tr>
<td></td>
<td>Conventional</td>
<td>0.6±0.5e</td>
<td>1.6±0.8e</td>
<td>4.1±2.0e</td>
<td>86±25e</td>
<td>88±23e</td>
<td>73±25e</td>
<td>79±24e</td>
</tr>
<tr>
<td></td>
<td>Farm seed</td>
<td>0.5±0.4e</td>
<td>1.4±0.6e</td>
<td>3.7±3.2e</td>
<td>71±21e</td>
<td>79±17e</td>
<td>62±19e</td>
<td>70±18e</td>
</tr>
<tr>
<td>Year</td>
<td>2010</td>
<td>0.3±0.5e</td>
<td>2.0±0.7e</td>
<td>5.1±3.3e</td>
<td>92±8e</td>
<td>93±7e</td>
<td>73±7e</td>
<td>82±6e</td>
</tr>
<tr>
<td></td>
<td>2011</td>
<td>0.8±0.4e</td>
<td>1.2±0.8e</td>
<td>3.3±2.2e</td>
<td>63±29e</td>
<td>75±23e</td>
<td>61±28e</td>
<td>66±27e</td>
</tr>
<tr>
<td>Total</td>
<td>0.5±0.5</td>
<td>1.6±0.8e</td>
<td>4.2±2.9e</td>
<td>78±25e</td>
<td>84±19e</td>
<td>67±21e</td>
<td>74±21e</td>
<td></td>
</tr>
</tbody>
</table>

Remark: * Different letters show the statistical differences in Tukey’s HSD test between varieties, P < 0.05.

### Table 2. Influence of factors on health and biological traits - Seed before seeding (ANOVA).

<table>
<thead>
<tr>
<th>Factor</th>
<th>df</th>
<th>Fusarium spp.</th>
<th>Alternaria spp.</th>
<th>Penicillium spp.</th>
<th>EG (%)</th>
<th>G (%)</th>
<th>EE (%)</th>
<th>E (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variety</td>
<td>3</td>
<td>0.24**</td>
<td>1.66**</td>
<td>26</td>
<td>8.20**</td>
<td>22</td>
<td>1117.9</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.18**</td>
<td>3</td>
<td>2.68**</td>
<td>7</td>
<td>506.8**</td>
<td>7</td>
<td>175.6**</td>
</tr>
<tr>
<td>Year</td>
<td>1</td>
<td>1.22**</td>
<td>72</td>
<td>4.13**</td>
<td>65</td>
<td>17.85**</td>
<td>48</td>
<td>4818.1**</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0.70</td>
<td>12</td>
<td>0.41</td>
<td>6</td>
<td>8.52</td>
<td>23</td>
<td>322.2</td>
</tr>
<tr>
<td>Error</td>
<td>17</td>
<td>0.20</td>
<td>12</td>
<td>0.41</td>
<td>6</td>
<td>8.52</td>
<td>23</td>
<td>322.2</td>
</tr>
</tbody>
</table>

Remark: * P < 0.05; ** P < 0.01; * not significant; EG - Energy of Germination; G - Germination; EE - Energy of Emergence; E - Emergence.
### Conclusions

The two-year research focused on the evaluation of the contamination rate of grains with the microscopic fungi showed the fact that the rate of contamination of the individual seed categories (i.e., the certified organic seeds, the conventional untreated seeds, the own organic farm saved seeds) did not have any negative effect on the rate of contamination of the following seed generation. Generally said, the naked oat grains demonstrated a better health condition than the common oat grains. The caryopses of the naked oat were losing hulls during the harvest, leaving some of the micromycets and pathogens outside the grains. The hulled oat was the most affected species of all by *Fusarium* spp., *Alternaria* spp. and *Penicillium* spp. The land-climatic conditions played the role of the most important factor having an important effect on the rate of contamination of caryopses with the microscopic fungi. There was a significant competitive relationship detected between the rate of occurrence of the most frequent parasitic fungi (i.e., *Fusarium* spp.) and the contaminated and the non-contaminated grains. The hulled oat was the most affected species of all by *Fusarium* spp., *Alternaria* spp. and *Penicillium* spp. The land-climatic conditions played the role of the most important factor having an important effect on the rate of contamination of caryopses with the microscopic fungi. There was a significant competitive relationship detected between the rate of occurrence of the most frequent parasitic fungi (i.e., *Fusarium* spp.) and the contaminated and the non-contaminated grains. The hulled oat was the most affected species of all by *Fusarium* spp., *Alternaria* spp. and *Penicillium* spp. The land-climatic conditions played the role of the most important factor having an important effect on the rate of contamination of caryopses with the microscopic fungi. There was a significant competitive relationship detected between the rate of occurrence of the most frequent parasitic fungi (i.e., *Fusarium* spp.) and the contaminated and the non-contaminated grains. The hulled oat was the most affected species of all by *Fusarium* spp., *Alternaria* spp. and *Penicillium* spp. The land-climatic conditions played the role of the most important factor having an important effect on the rate of contamination of caryopses with the microscopic fungi. There was a significant competitive relationship detected between the rate of occurrence of the most frequent parasitic fungi (i.e., *Fusarium* spp.) and the contaminated and the non-contaminated grains. The hulled oat was the most affected species of all by *Fusarium* spp., *Alternaria* spp. and *Penicillium* spp. The land-climatic conditions played the role of the most important factor having an important effect on the rate of contamination of caryopses with the microscopic fungi. There was a significant competitive relationship detected between the rate of occurrence of the most frequent parasitic fungi (i.e., *Fusarium* spp.) and the contaminated and the non-contaminated grains. The hulled oat was the most affected species of all by *Fusarium* spp., **Alternaria** spp. and *Penicillium* spp. The land-climatic conditions played the role of the most important factor having an important effect on the rate of contamination of caryopses with the microscopic fungi. There was a significant competitive relationship detected between the rate of occurrence of the most frequent parasitic fungi (i.e., *Fusarium* spp., *Alternaria* spp. and *Penicillium* spp.) and the other species. It meant a certain autoregulative competence of the colonies of microscopic fungi being provoked by the competitive relationships and making a balance between them. Such a competition may play an important role for the organic reproduction.
of seeds. At the same time, a global ban of the application of conventional untreated seeds has been discussed throughout the European Union. However, we have been noticing a longtime deficiency of the certified organic seeds in some countries. If they are not available in a satisfactory amount, organic farmers are recommended to use their own organic farm saved seeds but they have to use them very carefully.

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References