Organic oat seed quality

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Abstract

It is extremely difficult to get high-quality certified organic seeds. However, organic farmers are not allowed to use any other seeds than the certified organic seeds. Certified organic seeds are rare and organic farmers usually have to use conventional untreated seeds or farm seeds in order to establish their crop stands. For this reason, we studied and evaluated health and biological characteristics of four varieties of common oat (the hulled form) and naked oat within the three-year trial. The experimental crop stands were established in three different localities within the Czech Republic. Results of the trial have shown the sufficient quality of all the tested seeds. However, they must come from the farms applying high-quality agrotechnologies. There were minimum differences in the level of seed contamination with colonies of the most frequent pathogens (e.g. *Fusarium* spp., *Alternaria* spp.).

Key words: *Fusarium* spp., health and biological characteristics, seed, organic farming, oat

Introduction

At least 1.8 million hectares of main cereal species are under organic management (including in-conversion areas). As some of the world's largest cereal producers (such as India, China and the Russian Federation) do not provide land use details, it can be assumed that the area is larger than shown here (Willer and Kilcher, 2009). Comparing this figure with the FAO's figure for the world's harvested cereal area of 384 million hectares (FAOSTAT, 2011), 0.5 percent of the total cereal area is under organic management.

Oat is one of the most suitable cereal species for organic farming (Lockeretz *et al*. 1981). As it has low requirements on growing conditions, it is a suitable crop for organic farming in Central

Europe (Leistrumaite *et al*. 2009). There is a relatively wide range of use of oat. Naked oat is a suitable food crop (Batalova *et al*. 2010). Common oat is mostly used as a fodder crop (Stevens *et al*. 2004). It is the second most frequent crop (just after bread wheat) in the Czech organic farming system. The common oat growing area represents 5,000 hectares and its average yield rate represents 2.5 t/ha (Hrabalová, 2011).

The organic seeds used in order to establish organic crop stands must originate from plants being grown in compliance with the organic farming rules for at least one generation. Seed multiplication is an extremely difficult process. The reproduction crop stand and seed must meet the requirements of the seed certification and authorization procedure as conventional plants and seed do, but organic farming does not allow the use of any pesticides or mineral nitrogenous fertilizers, etc. Organic farmers may use certified organic seeds or farm seeds in order to establish the crop stand. They may also apply for an exception (derogation) and use the conventional untreated seed.

The paragraph above indicates a lower productivity of the organically grown cereal crop stands. A deficiency of certified organic seeds and a serious necessity of an application of own farm saved seed are the factors that might provoke it. For this reason, a question of quality in various provenances of seed is to be answered in this paper.

Material and methods

Tested varieties: We studied and evaluated quality of hulled oat varieties and naked oat varieties (see a list of the tested varieties in Table 1). We used various seeds to establish our exact field trials – certified organic seeds, farm organic seeds and conventional untreated seeds. The certified organic seeds and the farm organic seeds were provided by the PRO-BIO company. The conventional untreated seeds were usually provided by breeding companies.

Table 1: List of tested oat varieties

Crop	Variety	Seed origin
Naked oat	Saul	certified organic seeds (E) farm organic seeds (F) conventional untreated seeds (C)
	Izak	
Hulled oat	Vok	
	Neklan	

Establishment of trials: We used the above mentioned seeds to establish the exact field trials which were carried out in three different localities between 2010 and 2012: the Research

Institute of Crop Production in Prague, the University of South Bohemia in České Budějovice and the Prague Life Science University (the research station in Prague-Uhříněves). The exact field trials were based on a method of randomized blocs. We used the seeding rate of 350 germinable (viable) seeds per square meter and the rows were in a distance of 125 mm from each other. Mixture of peas and field beans was used as a forgoing crop in the location of the Prague Life Science University (the research station in Prague-Uhříněves). Oat was used as a forgoing crop in the location of the Research Institute of Crop Production in Prague. Leguminous plants were used as forgoing crops in the location of the University of South Bohemia in České Budějovice. The field trials complied with the European legislation, the Council Regulation (EC) No. 834/2007 and the Commission Regulation (EC) No. 889/2008. Characteristics of the trial localities are specified in the following table (Table 2).

Table 2: Characteristics of trial localities

Production locality	Soil type	Soil kind	Altitude (metres above sea level)	Average annual temperature (°C)	Average precipitation rate (mm)
Prague Life Science University, Prague - Uhříněves					
beet	brown earth	clay loam	295	8.3	575
Research Institute of Crop Production, Prague - Ruzyně					
beet	degraded black earth	clay loam	340	7.8	472
University of South Bohemia, České Budějovice					
potato	pseudogley cambisol	loam sand	388	8.2	620

Laboratory analyses of seed health: Before sowing trial seeds, we studied health of those seeds by a method of isolation of micromycetes on the artificial nutrient substance. We used a universal nutrient substance – PDA (Potato Dextrose Agar). We repeated every seed sample test five times. There were 10 seeds in every sample test. Incubation lasted 7 – 10 days (in absolute dark, at 20°C). We evaluated the number of isolated colonies visually. We determined genera of micromycetes with microscopes, on the basis of their microscopic morphological features. After harvesting the exact field trials from three trial locations, we tested and evaluated health of grown seeds by the same method.

Laboratory analyses of seed biological characteristics: We determined the laboratory germination capacity and the energy of emergence. We accepted the following ČSN requirements No. 46 0610 – Testing of seed corns. One hundred caryopses of every sample (every sample repeated itself four times in the trial) were put on wet folded filtration paper into plastic bowls with a perforated cover. The bowls were put into an air-conditioning box where temperature was 20°C. Energy of emergence was counted four days later. Germinated caryopses which were developed normally were subtracted. Laboratory germination capacity was counted eight days later by the same method. Laboratory emergence and energy of emergence were determined in another stage of the trial. One hundred caryopses of every sample (every sample repeated itself four times in the trial) were put into coarse sand, 3 cm deep into the sand. Sand layer which was 1 cm high was put onto the bowl bottom. Sand was wet (moisture of 60 %). The caryopses were put onto the sand layer, they were pushed slightly into the sand and covered with dry sand. The bowls were put into the air-conditioning box and left there (in 15°C). Energy of emergence was counted seven days later and laboratory emergence was counted 14 days later by subtracting the emerged caryopses.

Statistical data analysis: Results of the study of seed health, biological characteristics, as well as results of yield, were assessed statistically. We applied a method of polyfactorial analysis of variance. Statistically significant differences in mean values was verified by Tukey HSD test.

Results and discussion

Results of seed health, which was studied before sowing seeds in the field trials, can be found in Table 3. We determined the number of colonies of genera of pathogens which were found in the caryopses most frequently – *Fusarium* spp., *Cladosporium* spp., *Alternaria* spp. and *Penicillium* spp.; *Fusarium* spp. colonies were not too frequent. There was less than one colony per 10 caryopses on average in every variety. There were 2.5 colonies of *Alternaria* spp. per 10 caryopses on average. And we found 1.66 colonies of *Cladosporium* spp. per 10 caryopses on average. There were negligible differences between the studied varieties. They were mostly statistically non-significant. Seed origin did not influence the number of colonies of micromycetes either. Differences between the years of seeds were a little bit more visible.

There was the highest number of colonies of *Penicillium* genus in the studied caryopses, 3.27 colonies per 10 caryopses on average. The naked oat caryopses contained more colonies of *Penicillium* spp. than the hulled oat caryopses, which also influenced the individual varieties. Two naked oat varieties, Saul and Izak, contained 1 colony (per 10 caryopses) more (on average) than two hulled oat varieties, Vok and Neklan. The seed origin did not influence it a lot. Neither did the year.

Table 3: Evaluation of health of seeds of oat (before they were sown in the exact field trials) (isolation of colonies on artificial nutrient substance)

Factor / Parameter		*Fusarium* spp. (number of colonies per 10 caryopses)	*Alternaria* spp. (number of colonies per 10 caryopses)	*Penicillium* spp. (number of colonies per 10 caryopses)	*Cladosporium* spp. (number of colonies per 10 caryopses)
Oat	Hulled	0.69±0.48[a]	2.50±0.93[a]	2.79±0.62[a]	2.12±0.90[b]
	Naked	0.69±0.49[a]	2.49±0.77[a]	3.75±0.37[b]	1.19±0.96[a]
Variety	Izak	0.67±0.51[a]	2.67±0.91[a]	3.79±0.39[b]	1.52±1.18[ab]
	Saul	0.71±0.50[a]	2.32±0.66[a]	3.71±0.37[a]	0.87±0.87[a]
	Vok	0.45±0.38[a]	2.81±0.72[a]	2.67±0.39[b]	2.41±0.91[b]
	Neklan	0.94±0.46[a]	2.19±1.06[a]	2.92±0.79[ab]	1.83±0.83[ab]
Seed origin	E	0.42±0.39[a]	2.60±0.92[a]	3.19±0.60[a]	1.68±1.05[a]
	C	0.83±0.51[a]	2.59±0.69[a]	3.41±0.50[a]	1.78±1.01[a]
	F	0.82±0.48[a]	2.31±0.95[a]	3.24±0.44[a]	1.52±0.76[a]
Year	2010	0.35±0.49[a]	1.84±0.76[a]	3.15±0.58[a]	1.19±0.75[a]
	2011	0.92±0.48[a]	2.91±0.85[b]	3.45±0.55[a]	2.12±0.86[b]
	2012	0.81±0.42[a]	2.75±0.92[ab]	3.21±0.46[a]	1.67±1.20[ab]
Total		0.69±0.48	2.50±0.85	3.27±0.50	1.66±0.93

Letters indicate the statistically significant differences between the studied data files. The significance level is $P \leq 0.05$.

Results of seed biological characteristics, which were studied before sowing seeds in the field trials, can be found in Table 4. The naked oat variety Izak had got the best biological characteristics of all the studied varieties. The hulled oat variety Neklan was on the second place and the naked oat variety Saul was on the third place. On the other hand, the hulled oat variety Vok had got the worst biological characteristics of all the studied varieties. We also wanted to find out if the seed origin influenced the studied parameters or not. We have found out that the seed origin plays a little bit more important role in the conventional seeds than in the certified organic seed or the organic farm seeds. The year influenced the energy of germination and the laboratory germination capacity a lot.

Table 4: Evaluation of biological characteristics of seeds of oat (before they were sown in the exact field trials)

Factor / Parameter		Energy of germination (%)	Laboratory germination capacity (%)	Energy of emergence (%)	Laboratory emergence (%)
Oat	Hulled	80.35±12.44[a]	87.29±10.45[a]	70.93±11.54[a]	81.42±9.87[a]
	Naked	88.41±12.21[b]	90.21±10.19[a]	79.28±9.68[b]	84.45±8.99[a]
Variety	Izak	93.71±9.40[a]	96.12±8.91[b]	84.92±8.70[b]	88.43±8.74[b]
	Saul	83.10±14.97[b]	84.31±11.82[a]	73.64±10.66[a]	80.47±11.24a
	Vok	75.49±15.96[c]	83.49±12.91[a]	67.38±12.39[a]	77.41±11.62[a]
	Neklan	85.21±8.98[b]	91.10±7.61[b]	74.48±10.07[a]	85.42±6.00[ab]
Seed origin	E	82.98±14.16[a]	88.37±11.24[ab]	74.38±10.79[ab]	81.60±9.78[a]
	C	88.30±12.17[b]	93.28±8.39[b]	79.03±9.94[b]	86.48±6.64[a]
	F	81.85±10.89[a]	84.63±11.48[a]	71.93±10.86[a]	80.73±11.71[a]
Year	2010	90.80±9.11[a]	91.74±7.10[b]	74.13±7.83[a]	82.29±6.15[ab]
	2011	77.80±14.94[b]	83.15±13.06[a]	73.57±13.55[a]	78.12±12.43[a]
	2012	83.58±12.66[ab]	92.31±11.12[b]	77.63±10.16[a]	88.39±10.41[b]
Total		84.38±12.33	88.75±10.32	75.11±10.61	82.94±9.43

Letters indicate the statistically significant differences between the studied data files.
The significance level is P≤0.05.

Results of the study of health of the seeds which come from the exact field trials and from three different localities can be found in Table 5. We also studied the number of colonies of the most frequent genera of micromycetes in this case – *Fusarium* spp., *Cladosporium* spp., *Alternaria* spp. and *Penicillium* spp. Beside these genera of micromycetes, we also found a low number of the other genera of micromycetes on the caryopses, e.g. *Epicoccum*, *Ulocladium*, *Bipolaris*, *Aspergillus* and *Nigrospora*. They might have a negative impact on the seed germination capacity (Mathre, 1991; Bhat and Fazal, 2011).

There was also quite a low number of *Fusarium* spp. micromycetes in the seeds coming from the exact field trials. There were 1.03 colonies of micromycetes per 10 caryopses on average. There were slightly more micromycetes in the hulled oat seeds. The seed origin had a minimum impact on the number of *Fusarium* spp. colonies. In fact, its impact was non-significant. The

year and the trial locality impact was a little bit more important impact on it. The highest average number of micromycetes was found in the ČZU locality, Prague in 2010.

Table 5: Evaluation of health of oat seeds (after harvest) (isolation of colonies on artificial nutrient substance)

Factor / Parameter		Fusarium spp. (number of colonies per 10 caryopses)	Alternaria spp. (number of colonies per 10 caryopses)	Penicillium spp. (number of colonies per 10 caryopses)	Cladosporium spp. (number of colonies per 10 caryopses)
Oat	Hulled	1.28±0.81^{b}	4.08±2.13^{b}	2.55±1.51^{a}	6.13±5.00^{b}
	Naked	0.77±0.60^{a}	2.27±1.50^{a}	5.43±2.67^{b}	4.84±3.48^{a}
Variety	Izak	0.83±0.40^{a}	2.31±1.31^{a}	5.51±2.68^{b}	5.19±3.27^{a}
	Saul	0.71±0.65^{a}	2.24±1.69^{a}	5.33±2.61^{b}	4.48±3.70^{a}
	Vok	1.41±0.82^{b}	4.29±2.10^{b}	2.56±1.66^{a}	7.03±5.14^{b}
	Neklan	1.15±0.80^{ab}	3.88±2.19^{b}	2.54±1.39^{a}	5.23±4.78^{a}
Seed origin	E	1.07±0.75^{a}	2.98±1.72^{a}	3.86±2.02^{a}	5.14±4.40^{a}
	C	1.14±0.92^{a}	3.15±1.73^{a}	4.28±2.09^{a}	5.92±3.82^{a}
	F	0.87±0.54^{a}	3.41±2.16^{a}	3.83±2.13^{a}	5.40±4.62^{a}
Year	2010	1.53±0.78^{b}	3.25±2.68^{ab}	3.80±2.13^{a}	9.23±4.22^{b}
	2011	0.97±0.80^{a}	3.88±1.93^{b}	4.25±2.97^{a}	3.19±1.60^{a}
	2012	0.96±0.55^{a}	2.40±0.89^{a}	3.92±2.67^{a}	4.03±2.36^{a}
Location	ČZU	1.44±0.95^{b}	3.00±1.85^{a}	3.70±2.08^{a}	6.30±4.64^{b}
	JU	0.88±0.58^{ab}	3.34±1.76^{a}	4.01±2.01^{a}	4.06±2.80^{a}
	VÚRV	0.75±0.57^{a}	3.20±1.80^{a}	4.25±2.39^{a}	6.10±5.19^{b}
Total		1.03±0.72	3.18±1.82	3.99±2.09	5.49±4.24

Letters indicate the statistically significant differences between the studied data files. The significance level is P≤0.05.

Concerning *Alternaria* spp., there was a trend of higher number of micromycetes being found in the hulled oat seeds. The number of colonies was twice as high as the number of colonies in the

naked oat seeds. The naked oat varieties were very different from the hulled oat ones. There was a statistically significant difference between them. The seed origin had a statistically non-significant impact on the micromycetes colonies. The farm seeds contained a little bit more micromycetes than the other seed types. The locality impact was statistically non-significant.

Concerning *Penicillium* spp. micromycetes colonies, there were almost four colonies per 10 caryopses on average. There was quite an important difference between the hulled oat seeds and the naked oat ones. The naked oat seeds contained twice as many micromycetes colonies as the hulled oat seeds. There were a little bit more colonies of *Penicillium* spp. micromycetes in the conventional seeds, whereas there was no difference between the certified organic seeds and the farm seeds. The year and the locality impact was statistically non-significant.

There was the highest number of *Cladosporium* spp. micromycetes colonies in the studied seeds. There were more micromycetes in the hulled oat seeds. Concerning the individual hulled oat varieties, Vok was the most contaminated variety of all the hulled oat varieties. Neklan hulled oat variety was very similar to Izak naked oat variety in the number of micromycetes found in the seeds. Saul naked oat variety was the least contaminated variety of all the studied varieties. The seed origin impact was statistically non-significant there too. On the other hand, the year impact was considerable. And the locality impact was not negligible either.

There are biological characteristics and yield rate of the grown trial seeds in Table 6. All the parameters we had been studying (energy of germination, laboratory germination capacity, energy of emergence and laboratory emergence) achieved very high values. Except for the year impact on the energy of emergence, there were statistically non-significant differences in the average values between the individual characteristics and varieties. It means, besides other things, the seed contamination with the studied micromycetes colonies and the differences in the contamination level between the studied varieties have not had any considerable impact on the biological characteristics of seeds. The naked oat varieties might be less germinable, if the seeds are damaged mechanically (Peltonen-Sainio *et al*. 2001). We noticed no difference between the naked and the hulled oat seeds.

There were several statistically significant differences in the seed yield rate between the tested varieties. These were the differences between the hulled and the naked oat varieties (in favour of the hulled oat varieties). There was a difference between the individual years. And, last but not least, there was a difference between the three trial localities. The yield rate in the ČZU locality, Prague-Uhříněves, was twice as high as the yield rates in the other two trial localities. It was influenced by favourable land and climatic conditions in the ČZU locality, Prague-Uhříněves, and stability of that trial locality. It had been certified as an organic locality since 1996. It means it has been the certified organic locality for a long time, much longer than the other two trial localities. An improving forgoing crop (a mixture of peas and field beans) was

used there, which also played an important role and has had a positive impact on it. Such mixture is better than a cereal as a forgoing crop; cereals were used as forgoing crops in the Research Institute of Crop Production.

High-quality uncontrolled farm seeds were surprising to us. The reproductive effort mechanism might explain it (Renno and Winkel, 1996). A plant grown from the worst quality caryopses provided a lower yield rate but good quality production. Therefore, the farm seeds may be applied to grow extensive (Thorsted *et al*. 2002; Erol *et al*. 2009) and less bred (Lynch and Frey, 1993) crops (e.g. oat). However, such growing has to be done very carefully. Minimum negative impacts on the crop stand yield rate can be expected.

Table 6: Evaluation of biological characteristics of oat seeds (after harvest)

Factor / Parameter		Energy of germination (%)	Laboratory germination (%)	Energy of emergence (%)	Laboratory emergence (%)	Yield rate ($t.ha^{-1}$)
Oat	Hulled	91.93±5.48^{a}	94.09±4.34^{a}	83.55±6.34^{a}	88.11±4.16^{a}	3.98±1.50^{b}
	Naked	92.47±4.29^{a}	94.14±3.30^{a}	81.47±10.57^{a}	87.29±7.44^{a}	2.49±1.17^{a}
Variety	Izak	93.52±3.97^{a}	95.00±2.99^{a}	83.21±8.06^{a}	89.32±4.12^{a}	2.71±1.10^{a}
	Saul	91.43±4.75^{a}	93.27±3.74^{a}	79.73±12.80^{a}	85.27±9.91^{a}	2.27±1.21^{a}
	Vok	90.21±4.99^{a}	92.93±4.40^{a}	82.73±5.88^{a}	86.89±3.90^{a}	3.91±1.46^{b}
	Neklan	93.64±5.50^{a}	95.23±4.05^{a}	84.37±6.79^{a}	89.34±4.99^{a}	4.04±1.56^{b}
Seed origin	E	92.42±5.51^{a}	94.28±4.08^{a}	83.38±7.53^{a}	88.37±4.54^{a}	3.21±1.28^{a}
	C	91.95±5.14^{a}	93.82±4.18^{a}	81.04±11.62^{a}	87.11±8.00^{a}	3.36±1.39^{a}
	F	92.23±4.10^{a}	94.24±3.29^{a}	83.10±6.19^{a}	87.64±5.01^{a}	3.13±1.35^{a}
Year	2010	92.82±4.42^{a}	94.88±3.29^{a}	77.24±7.89^{a}	85.89±6.88^{a}	2.67±1.25^{a}
	2011	89.77±6.44^{a}	91.76±4.69^{a}	81.65±9.55^{ab}	86.46±6.82^{a}	3.78±1.35^{b}
	2012	94.00±3.75^{a}	95.70±2.96^{a}	88.63±8.12^{b}	90.77±3.42^{a}	3.25±1.42^{ab}
Locality	ČZU	92.46±4.35^{a}	94.25±3.99^{a}	83.57±9.00^{a}	87.81±6.62^{a}	4.60±1.48^{b}
	JU	93.16±3.91^{a}	94.78±2.84^{a}	82.98±6.45^{a}	87.71±3.92^{a}	2.84±1.33^{a}
	VÚRV	90.99±6.20^{a}	93.30±4.59^{a}	80.98±10.08^{a}	87.60±6.87^{a}	2.26±1.22^{a}
Total		92.20±4.89	94.11±3.82	82.51±8.45	87.71±5.80	3.23±1.34

Letters indicate the statistically significant differences between the studied data files. The significance level is P≤0.05.

Conclusions

We studied the quality of hulled and naked oat seeds of various origin for three years – the certified organic seeds, the farm organic seeds and the conventional untreated seeds. Results of our research have shown the farm seeds are not of inferior quality or worse health to the certified organic seeds of the conventional seeds. Seeds of the above-mentioned cereal varieties were little contaminated with the studied and evaluated micromycetes. The contamination rate is mostly determined by the year and the trial locality conditions. The studied biological characteristics of seeds were mostly good. In that case, the year and the trial locality conditions have had a negligible impact on them.

Working on the assumption of the results of our research, we can say that a well-arranged cropping, a good forgoing crop and a respect of agrotechnological principles lead to a production of high quality organic farm seeds. The quality of such organic farm seeds is similar to the quality of certified organic seeds. There might be some problems in the localities where certain pathogens and microorganisms live (e.g. *Fusarium* spp.), or in certain years when the pathogens and microorganisms emerge.

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