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# The Effect of the Genotype and Environment on Damage of Barley Grains (*Hordeum vulgare* L.)

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The occurrence of damaged grains was studied in 12 barley genotypes in a three-year period. The occurrence of grains with physiological split of lemma and endosperm was generally low. Split of palea and endosperm was mostly affected by the genotype (10%) and it was recorded most frequently in the genotype Heris. Incomplete overlapping of husks was also markedly affected by the genotype (10%) and it occurred most frequently in the genotype Scarlett. Sprouted grains and grains of green color occurred minimally. Black points were affected by year (21%) and genotype (15%). This damage was most frequently reported for the genotypes Camera and Jersey. Surprisingly, the occurrence of grains with apparently moldy husks was markedly affected by the genotype (25%), less substantially by the location (10%) and minimally by year (3%).

**Keywords:** barley, genotype, gape, grain damage, husk, skinned, split grain

## Introduction

Barley grain damages can involve a damage of appearance without pronounced economic or hygienic impacts but also more serious defects that cause economic losses to producers (e.g. gushing of beer) and can imperil health of people and livestock (mycotoxin content). For this reason, identification and monitoring of specific barley grain damages is the subject of various state or company standards and rules in consumer-supplier relations (ČSN 461100-5 2005; EBC 2005; EC 2000; USDA 2007). Malting industry in the effort to obtain homogeneous and for health suitable barley grains of varietal purity has paid constant attention to the damage of barley grain (Baumer et al., 1998; Grossmann et al. 2001; Hoad et al. 2003).

Grain can be damaged in many ways, e.g. by weathering before a delayed harvest (Thomas et al. 1987), by poorly set combine harvesters or during handling in stores. Pre-harvest damage can range from gape between the lemma and palea, splits in the pericarp/testa/aleurone, to germination before harvest (sprouting). When the crop is combine harvested, over-threshing can result in grain cracking, skinning (i.e. partial or complete stripping of the husk) or embryo damage. Skinning can also occur when the wetted

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grain is transported to the malt houses. Grain damage by preharvest weathering can directly reduce malting performance through sprouting and, as a result of fungal infection, it can introduce mycotoxins into the malt (D'Mello et al. 1993).

Rajasekaran et al. (2004) warned that selection for a thin husk, to maximize hot water extract, could result in (i) enhanced vulnerability to mechanical damage; (ii) curtail an essential period of post-harvest dormancy, and (iii) an increase in grain size might not correspond to the mechanical strength of the outer grain tissues.

The aim of the study was to determine the effect of the genotype, environment and year on the occurrence of the individual types of caryopses damages in the current spring barley varieties under the conditions of the Czech Republic.

## Materials and Methods

Following damages of barley grains were studied in the set of 12 barley genotypes (Psota and Jurečka 2001; Psota et al. 2001) (Table 1) in 2001–2003:

- Grains with a removed germ and grains with a germ damaged physically.
- Grains physically deformed.
- Broken grains regardless their size.
- Grains without husks (skinned grain), i.e. grains naked of husks from more than 25%.
- Grains with physiological split of lemma if extending to endosperm.
- Grains with physiological split of palea if extending to endosperm.
- Grains with gape between the lemma and palea incomplete overlapping of lemma and palea and split if extending to endosperm.
- Sprouted grains (grains with rootlets or a coleoptile and grains with broken rootlets or a coleoptile with apparent signs of growth).

*Table 1.* Basic description of the genotypes

| Genotypes | Spring Winter | 6/2 row | Malting quality index | Country of origin | Maintainer | Parentage |
|---|---|---|---|---|---|---|
| HERIS | S | 2 | 5 | CZ | Plant Select spol s r. o. | HE 4431/CE 431 |
| ORTHEG | S | 2 | 2 | D | Lochow-Petkus GmbH | Ceb.7931/Pompadour//S.77323/Gol |
| SCARLET | S | 2 | 6 | D | Saatzucht J. Breun GdbR | Amazone/Breun St. 2730 e//Kym |
| JERSEY | S | 2 | 7 | NL | Cebeco Zaden B. V. | Apex/Alexis |
| PRESTIG | S | 2 | 7 | GB | PBI Cambridge Ltd. | Cork/Chariot |
| TOLAR | S | 2 | 6 | CZ | Plant Select spol s r. o. | HE 4710/HWS 78267-83 |
| LURAN | W | 6 | 2 | CZ | Selgen, a. s. | LU 27/LU 16 |
| LUXOR | W | 6 | 2 | CZ | Selgen, a. s. | LU 27/LU 16 |
| NELLY | W | 6 | 3 | D | W.von Borries-Eckendorf GmbH&Co. | Tapir/76079/3/Birgit/Banteng//Gerb |
| CAMERA | W | 2 | 2 | GB | Nickerson Seeds Ltd. | NRPB 87-5685c*Stamm 41 |
| TIFFANY | W | 2 | 4 | D | Saatzucht J. Breun GdbR | Labea/Marinka |
| VILNA | W | 2 | 2 | NL | Plant Select spol s r. o. | Intro//Cebeco 87262/Tamara |

*Note:* MQI: 9 = the best quality; 1 = without malting quality.

- Unripe grains of green color.
- Grains with black points (grains of markedly brown or even dark color of husks round points).
- Grains with apparently moldy husks

Grain of genoptypes studied was acquired from the trial sites of the Central Institute for Supervising and Testing in Agriculture of the Czech Republic soon after harvest and it was not dried. Therefore, the samples did not contain grains damaged by drying (burnt, concaved) and inexpert storage (humidified).

Each harvest year samples, of the studied collection of genotypes (Table 1) were taken from three trial sites. Due to technical problems, the stations were not the same in all three years. Study was conducted in the three-year period (2001–2003).

Grains were sieved and from sieving fractions above 2.5 mm always two 100 g samples were taken as two repetitions. In the samples the studied types of damage were assessed visually. Share of individual damages was expressed in%.

It means that totally 216 samples (100 g each) were analyzed in the experiment (12 varieties × 3 localities × 3 years × 2 repetitions).

Results were statistically evaluated using the analysis of two-way variance. Least square difference for $\alpha = 0.05$ (LSD) was used for multiple comparison of mean values. The genotypes or sites that did not differ statistically significantly formed a homogeneous group and they are marked in the column with the letters "a – f".

## Results

### *1. Physical damage*

#### *1a. Grains with a removed germ and grains with a germ damaged physically*

Values of this damage in the studied set ranged from 0–9.35% (Table 2). The damage was caused mainly by rough handling with grain (20%) in the given trial site. The effect of the genotype (6%) and year on the variability of this trait was low (Table 3). The highest mean values of the occurrence of the grains with removed germs were found in the genotype Nelly, which differed statistically significantly from the other genotypes in the set (Table 4).

#### *1b. Grains physically deformed*

Physically deformed grain is a serious damage with the same consequences as the previous damage. However, the occurrence of this damage in the observed set was only 0–0.4% (Table 2).

#### *1c. Broken grains*

Broken grains in the samples occurred in the range of 0–6.6% (Table 2). Harvest and following treatment of the harvested grain affected the variability of this trait significantly (62%). The effect of the year (9%) and genotype was substantially lower (7%) (Table 3).

The grain fractions occurred in the samples of the genotypes Prestige and Vilna most frequently. On the contrary, the smallest amount of fractions was found in the samples of the genotypes Jersey, Nelly, and Luxor (Table 4).

*Table 2.* Basic statistical characteristics of the tested 216 barley samples

| | Grains with removed germ | Grains physically deformed | Broken grains regardless their size | Grains without husks | Grains with split of lemma | Grains with split of palea | Grains with incomplete overlapping of lemma and palea | Sprouted grains | Unripe grains of green colour | Grains with black points | Grains with apparently mouldy husk |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1a | 1b | 1c | 1d | 2a | 2b | 2c | 2d | 2e | 2f | 2g |
| Sample size | 216 | 216 | 216 | 216 | 216 | 216 | 216 | 216 | 216 | 216 | 216 |
| Average | 0.52 | 0.05 | 1.37 | 2.19 | 0.03 | 0.11 | 0.20 | 0.04 | 0.13 | 1.94 | 13.84 |
| Median | 0.23 | 0.00 | 0.60 | 1.52 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.33 | 10.67 |
| Mode | 0.00 | 0.00 | 0.19 | 2.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.14 |
| Variance | 1.00 | 7.09 | 2.55 | 5.38 | 9.18 | 0.15 | 0.54 | 0.03 | 0.06 | 3.77 | 147.69 |
| Standard deviation | 1.00 | 0.08 | 1.60 | 2.32 | 0.10 | 0.39 | 0.74 | 0.18 | 0.25 | 1.94 | 12.15 |
| Standard error | 0.07 | 5.73 | 0.11 | 0.16 | 6.52 | 0.03 | 0.05 | 0.01 | 0.02 | 0.13 | 0.83 |
| Minimum | 0.00 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.45 |
| Maximum | 9.35 | 0.40 | 6.62 | 11.30 | 0.70 | 3.67 | 6.77 | 1.24 | 1.30 | 10.62 | 60.62 |

*Table 3.* Analysis of variance of physically damaged grains

| Source of variation | Mean square | d.f. | F-ratio Value | | P | Estimated components of varience abs. | rel. (%) | Source of variation | Mean square | d.f. | F-ratio Value | | P | Estimated components of varience abs. | rel. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1a for grains with removed germ | | | | | | | | 1c for broken grains | | | | | | | |
| Year | 4.501 | 2 | 6.668 | ** | 0.002 | 0.09019 | 8.76 | Year | 14.276 | 2 | 23.082 | *** | 0.000 | 0.26128 | 9.25 |
| Locality | 7.808 | 4 | 11.566 | *** | 0.000 | 0.20594 | 20.01 | Locality | 3.953 | 4 | 89.117 | *** | 0.000 | 1.76102 | 62.32 |
| Genotype | 1.732 | 11 | 2.566 | ** | 0.005 | 0.05877 | 5.71 | Genotype | 0.619 | 11 | 6.392 | *** | 0.000 | 0.18527 | 6.55 |
| Residual | 0.675 | 198 | | | | 0.67431 | 65.52 | Residual | 0.026 | 198 | | | | 0.61838 | 21.88 |
| 1b for grains physically deformed | | | | | | | | 1d for grains without husks (naked) | | | | | | | |
| Year | 0.007 | 2 | 1.349 | NS | 0.262 | 0.00002 | 0.27 | Year | 44.333 | 2 | 26.261 | *** | 0.000 | 0.91974 | 15.30 |
| Locality | 0.064 | 4 | 11.763 | *** | 0.000 | 0.00152 | 20.65 | Locality | 99.898 | 4 | 59.176 | *** | 0.000 | 2.53165 | 42.09 |
| Genotype | 0.012 | 11 | 2.200 | * | 0.016 | 0.00036 | 4.89 | Genotype | 17.432 | 11 | 10.326 | *** | 0.000 | 0.87466 | 14.55 |
| Residual | 0.005 | 198 | | | | 0.00546 | 74.19 | Residual | 1.688 | 198 | | | | 1.68783 | 28.07 |

Value * P = 0.05 ** P = 0.01 *** P = 0.001 NS = not significant

*1d. Grains without husks (skinned), i.e. grains naked from more than 25% of the surface*

In the studied set, this damage varied in dependence on the genotype, site and year from ca 0 to 11% (Table 2). Quality of the harvest and manner of handling with the grain after harvest in the given trial site affected the damage from more than 40%. The effect of the genotype and year was substantially lower and moved around 15% (Table 3). The genotype Jersey suffered from this damage most; the genotypes Luran and Camera came the second. The lowest occurrence was detected in the genotypes Orthega, Heris and Vilna (Table 4).

*Table 4.* Multiple range analysis of physically damaged grains

| 1a for grains with removed germ | | | | 1b for grains physically deformed | | | 1c for broken grains | | | 1d for grains without husks (naked) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Genotype | n | mean | | Genotype | mean | | Genotype | mean | | Genotype | mean | |
| Heris | 18 | 0.14 | a | Tolar | 0.01 | a | Jersey | 0.86 | a | Orthega | 0.80 | a |
| Orthega | 18 | 0.24 | a b | Orthega | 0.02 | a b | Nelly | 0.93 | a | Heris | 1.35 | a b |
| Tolar | 18 | 0.31 | a b | Nelly | 0.02 | a b | Luxor | 0.94 | a | Vilna | 1.43 | a b |
| Luxor | 18 | 0.32 | a b | Scarlett | 0.02 | a b | Orthega | 1.06 | a b | Tiffany | 1.69 | b |
| Camera | 18 | 0.41 | a b | Jersey | 0.02 | a b c | Tolar | 1.10 | a b c | Prestige | 1.73 | b |
| Luran | 18 | 0.48 | a b | Luxor | 0.05 | a b c d | Luran | 1.34 | a b c d | Nelly | 1.82 | b |
| Scarlett | 18 | 0.53 | a b | Luran | 0.06 | a b c d | Tiffany | 1.56 | b c d e | Luxor | 1.91 | b |
| Prestige | 18 | 0.53 | a b | Vilna | 0.06 | b c d | Camera | 1.61 | c d e | Tolar | 1.95 | b |
| Jersey | 18 | 0.59 | a b | Prestige | 0.06 | b c d | Heris | 1.61 | c d e | Scarlett | 1.99 | b |
| Vilna | 18 | 0.67 | a b | Tiffany | 0.06 | b c d | Scarlett | 1.67 | d e | Luran | 2.85 | c |
| Tiffany | 18 | 0.74 | b | Camera | 0.07 | c d | Vilna | 1.97 | e f | Camera | 3.13 | c |
| Nelly | 18 | 1.33 | c | Heris | 0.09 | d | Prestige | 2.38 | f | Jersey | 4.52 | d |
| LSD(t) (0.05) = 0.54 | | | | LSD(t) (0.05) = 0.05 | | | LSD(t) (0.05) = 0.52 | | | LSD(t) (0.05) = 0.85 | | |

Comments: average values indicated by various letters are statisticantly different (P = 0.05)

## 2. Biological damage

*2a. Grains with physiological split of lemma extending to endosperm*

The occurrence of grains with physiological split of lemma was generally low and its range was 0–0.7% (Table 2).

*Table 5.* Analysis of variance of biologically damaged grains

| Source of variation | Mean square | d.f. | F-ratio Value | | P | Estimated components of varience abs. | rel. (%) |
|---|---|---|---|---|---|---|---|
| 2a for grains with physiological split of lemma | | | | | | | |
| Year | 0.001 | 2 | 0.082 | NS | 0.921 | 0.00000 | 0.00 |
| Locality | 0.027 | 4 | 3.112 | * | 0.016 | 0.00055 | 5.83 |
| Genotype | 0.014 | 11 | 1.598 | NS | 0.101 | 0.00029 | 3.07 |
| Residual | 0.009 | 198 | | | | 0.00860 | 91.10 |
| 2b for grains with physiological split of palea | | | | | | | |
| Year | 0.221 | 2 | 1.750 | NS | 0.176 | 0.00210 | 1.37 |
| Locality | 0.265 | 4 | 2.091 | NS | 0.083 | 0.00369 | 2.41 |
| Genotype | 0.506 | 11 | 4.001 | *** | 0.000 | 0.02112 | 13.79 |
| Residual | 0.126 | 198 | | | | 0.12622 | 82.43 |
| 2c for grains with incomplete overlapping of lemma and palea | | | | | | | |
| Year | 0.582 | 2 | 1.232 | NS | 0.294 | 0.00520 | 0.95 |
| Locality | 1.027 | 4 | 2.173 | * | 0.074 | 0.01878 | 3.41 |
| Genotype | 1.453 | 11 | 3.072 | *** | 0.001 | 0.05449 | 9.90 |
| Residual | 0.473 | 198 | | | | 0.47188 | 85.74 |
| 2d for sprouted grains | | | | | | | |
| Year | 0.205 | 2 | 7.768 | *** | 0.001 | 0.00332 | 9.30 |
| Locality | 0.198 | 4 | 7.477 | *** | 0.000 | 0.00462 | 12.94 |
| Genotype | 0.050 | 11 | 1.896 | * | 0.042 | 0.00131 | 3.67 |
| Residual | 0.026 | 198 | | | | 0.02645 | 74.09 |
| 2e for unripe grains of green colour | | | | | | | |
| Year | 1.238 | 2 | 26.271 | *** | 0.000 | 0.02580 | 30.29 |
| Locality | 0.220 | 4 | 4.674 | ** | 0.001 | 0.00639 | 7.50 |
| Genotype | 0.148 | 11 | 3.142 | *** | 0.001 | 0.00560 | 6.58 |
| Residual | 0.047 | 198 | | | | 0.04738 | 55.63 |
| 2f for grains with black points | | | | | | | |
| Year | 50.140 | 2 | 21.216 | *** | 0.000 | 0.91772 | 21.49 |
| Locality | 14.765 | 4 | 6.248 | *** | 0.000 | 0.34906 | 8.17 |
| Genotype | 13.891 | 11 | 5.878 | *** | 0.000 | 0.64047 | 15.00 |
| Residual | 2.363 | 198 | | | | 2.36295 | 55.34 |
| 2g for grains with apparently mouldy husks | | | | | | | |
| Year | 198.025 | 2 | 2.063 | NS | 0.130 | 3.84868 | 2.53 |
| Locality | 489.072 | 4 | 5.096 | *** | 0.001 | 14.52215 | 9.53 |
| Genotype | 784.619 | 11 | 8.176 | *** | 0.000 | 38.27529 | 25.13 |
| Residual | 95.972 | 198 | | | | 95.66333 | 62.81 |

Value
* P = 0.05 ** P = 0.01
*** P = 0.001 NS = not significant

The effect of the location (6%), genotype (3%) and year (0%) was significantly low (Table 5). Most frequently this damage occurred in the genotypes Nelly, Heris, Prestige and Orthega. The damage was not recorded in the genotypes Vilna, Luxor and Camera (Table 6).

*2b. Grains with physiological split of palea extending to endosperm*

The occurrence of grains with physiological split of palea and endosperm was a substantially more frequent damage. Distribution of this trait in the samples moved within 0–3.7% (Table 2). Variability of this trait was most affected by the genotype (14%), the effects of the location (2%) and year (1%) were not statistically significant (Table 5). In the studied set, the genotype Heris suffered most from this damage. Differences among the other genotypes were statistically non-significant (Table 6).

*2c. Grains with, incomplete overlapping of lemma and palea and with split extending to endosperm*

The quantity of grains with this type of damage in individual samples moved from 0–6.8%. Of all the studied factors, this damage was most affected by the genotype (10%) and location (3.5%). Year (1%) did not affect the variability of this trait statistically significantly (Table 5). The genotype Scarlett suffered most from this damage. The other genotypes did not differ statistically significantly (Table 6).

*Table 6.* Multiple range analysis of biologically damaged grains

2a for grains with physiological split of lemma

| Genotype | n | mean | |
|---|---|---|---|
| Vilna | 18 | 0.00 | a |
| Luxor | 18 | 0.00 | a b |
| Camera | 18 | 0.00 | a b |
| Tiffany | 18 | 0.01 | a b c |
| Luran | 18 | 0.01 | a b c |
| Scarlett | 18 | 0.02 | a b c d |
| Jersey | 18 | 0.03 | a b c d |
| Tolar | 18 | 0.03 | a b c d |
| Orthega | 18 | 0.06 | b c d |
| Prestige | 18 | 0.06 | b c d |
| Heris | 18 | 0.06 | c d |
| Nelly | 18 | 0.07 | d |
| LSD(t) (0.05) = 0.06 | | | |

2b for grains with physiological split of palea

| Genotype | mean | |
|---|---|---|
| Tiffany | 0.01 | a |
| Vilna | 0.01 | a |
| Luxor | 0.01 | a |
| Camera | 0.02 | a |
| Luran | 0.04 | a |
| Orthega | 0.05 | a |
| Scarlett | 0.07 | a |
| Nelly | 0.09 | a |
| Jersey | 0.10 | a |
| Prestige | 0.16 | a |
| Tolar | 0.22 | a |
| Heris | 0.61 | b |
| LSD(t) (0.05) = 0.23 | | |

2c for grains with incomplete overlapping of lemma and palea

| Genotype | mean | |
|---|---|---|
| Camera | 0.00 | a |
| Vilna | 0.00 | a |
| Luxor | 0.01 | a |
| Orthega | 0.02 | a |
| Nelly | 0.03 | a |
| Luran | 0.05 | a |
| Tiffany | 0.07 | a |
| Prestige | 0.14 | a |
| Tolar | 0.19 | a |
| Jersey | 0.37 | a |
| Heris | 0.38 | a |
| Scarlett | 0.96 | b |
| LSD(t) (0.05) = 0.45 | | |

2d for sprouted grains

| Genotype | mean | |
|---|---|---|
| Vilna | 0.00 | a |
| Tiffany | 0.00 | a |
| Luxor | 0.00 | a |
| Nelly | 0.00 | a |
| Camera | 0.00 | a |
| Heris | 0.00 | a |
| Luran | 0.00 | a |
| Tolar | 0.01 | a |
| Orthega | 0.05 | a b |
| Jersey | 0.07 | a b |
| Prestige | 0.12 | b |
| Scarlett | 0.13 | b |
| LSD(t) (0.05) = 0.11 | | |

2e for unripe grains of green colour

| Genotype | n | mean | |
|---|---|---|---|
| Luran | 18 | 0.00 | a |
| Vilna | 18 | 0.00 | a |
| Luxor | 18 | 0.01 | a b |
| Orthega | 18 | 0.05 | a b c |
| Tolar | 18 | 0.09 | a b c d |
| Nelly | 18 | 0.12 | a b c d |
| Tiffany | 18 | 0.14 | b c d |
| Prestige | 18 | 0.19 | c d |
| Jersey | 18 | 0.20 | d |
| Scarlett | 18 | 0.21 | d |
| Camera | 18 | 0.22 | d |
| Heris | 18 | 0.23 | d |
| LSD(t) (0.05) = 0.14 | | | |

2f for grains with black points

| Genotype | mean | |
|---|---|---|
| Luxor | 0.40 | a |
| Luran | 0.69 | a b |
| Nelly | 1.26 | a b c |
| Vilna | 1.30 | a b c |
| Prestige | 1.57 | b c d |
| Scarlett | 1.60 | b c d |
| Tiffany | 1.69 | b c d |
| Tolar | 2.15 | c d e |
| Orthega | 2.20 | c d e |
| Heris | 2.44 | d e |
| Jersey | 2.91 | e f |
| Camera | 3.45 | f |
| LSD(t) (0.05) = 1.01 | | |

2g for grains with apparently mouldy husks

| Genotype | mean | |
|---|---|---|
| Orthega | 6.80 | a |
| Luxor | 7.87 | a b |
| Luran | 8.61 | a b |
| Nelly | 10.18 | a b c |
| Jersey | 11.10 | a b c |
| Scarlett | 11.56 | a b c |
| Camera | 11.95 | a b c |
| Heris | 13.66 | b c d |
| Tolar | 15.80 | c d e |
| Prestige | 19.32 | d e |
| Tiffany | 20.66 | e |
| Vilna | 29.87 | f |
| LSD(t) (0.05) = 6.44 | | |

Comments:

average values indicated by various letters are statisticantly different (P = 0.05)

*2d. Sprouted grains*

Sprouted grains occurred only from 0–1.24% in the studied set (Table 2). In the set studied, the variability of occurrence of this damage was mostly affected by the location (13%) and course of weather before harvest (9%). The effect of the genotype on the variability of this trait was low (4%) (Table 5). Most frequently this damage was found in the spring barley genotypes, first of all in the genotypes Scarlett and Prestige. In the other, mainly winter genotypes, this damage was not detected at all or only to a limited extent (Table 6). According to Grossmann et al. (2001) and Baumer et al. (1998), the genotype Orthega belonged to the genotypes least susceptible to this damage. On the contrary, the genotype Annabell belonged to the genotypes with higher susceptibility to sprouting.

*2e. Unripe grains of green colour*

The occurrence of green grains in the studied set of genotypes was low and moved within 0–1.3% in the sample (Table 2). The variability of this trait was significantly affected by year (30%), substantially less by the location (8%) and genotype (7%) (Table 5). The differences among the genotypes were negligible. The green grains occurred most in the genotypes Heris, Camera, Scarlett and Jersey. The green grains were not detected in the genotypes Luran and Vilna (Table 6).

*2f. Grains with black points*

The occurrence of grains with black points in the particular samples ranged from 0–10.6% (Table 2). The variability of this damage was statistically significantly affected by all the followed factors: year (21%), location (8%) and genotype (15%) (Table 5). Weather conditions, especially amount of precipitations and high relative air humidity have a decisive effect on the occurrence of black points at the lactic-wax ripeness and mainly wax ripeness (Petr and Capouchová 2001; Sulman et al. 2001). This damage was most frequently detected in the genotypes Camera, Jersey, Heris, Orthega and Tolar (Table 6).

*2g. Grains with apparently moldy husks*

The amount of grains with moldy husk in the studied samples was considerable and varied in the range of 0.5–60.5% (Table 2). The variability of this damage was substantially affected by the genotype (25%), the effect of the year was less than 3%, the effect of the location reached 10% (Table 5). Such strong effect of the genotype on this type of damage was not expected. The genotypes Vilna, Tiffany, Prestige and Tolar suffered most from this damage. Significantly lower occurrence was recorded in the genotypes Orthega, Luxor and Luran (Table 6).

## Discussion

*1. Physical damage*

This group includes damages originating during the harvest (imperfect adjustment of threshing machines), transport of grain from a field, post-harvest treatment, grain storage and transport.

In addition, the occurrence of grains physically damaged is also affected by the physical characters of grains (Vejražka et al. 2008) and level of husk adhesion, which can be varietally conditioned characters. According to Fornal et al. (2000), mechanical properties of grain are related to a barley genotype. Grains of genotypes with glassy endosperm are characterized by higher mechanical resistance than those with floury endosperm. The number of damaged kernels correlates with the fracture resistance and is related both to the direction of compression force and water content of grain.

Results discussed in this study were to a certain extent affected by grading. During the sample preparation, part of physically damaged grains, mainly grains physically deformed and broken grains, fell through the sieve and did not get into the sample assessed.

Grain fraction with a removed germ is a serious damage resulting in complete destruction of the malting value. Grain fractions without an embryo do not germinate and become a nutrient substrate for fungi. Non-germinated grains or their parts increase the rate of glassy grains, reduce the friability value, increase $\beta$-glucan content in sweet wort and impair filtration. In the malt house, fractions of grains with the embryo germinate, but they germinate in a completely atypical manner. Broken grains without embryo behave similarly as the grains with a removed germ and have a similar impact on the quality of the produced malt. Broken grains without embryo and with embryo are a nutrient substrate for fungi, this increases risk of the enhanced mycotoxin content.

Grain without husks is a less significant damage because it does not degrade the basic character of malting barley, i.e. capacity to germinate. However, germination of the grains without lemmas is atypical as these grains take up water faster. The level of modification of malt from the naked grains is higher than in the malt made from the undamaged grains. The grains without husks thus contribute to non-homogeneity of the malt manufactured (Olkku et al. 2003). Baumer et al. (1998) suppose that a lot otherwise faultless should not contain more than 5% of grains without lemmas.

*2. Biological damage*

Extreme weather conditions during the period of grain ripening affect unfavorably the grain physiology; they affect the occurrence of morphological and anatomical changes of grain and grain microbial contamination.

Split of lemma, first of all palea and consequently testa, pericarp and endosperm, and also incomplete overlapping of lemma and palea are affected by characters of these tissues. The results below show a certain influence of the genotype on the occurrence of this type of the damage. Some genotypes seem to be more sensitive to this damage. For demonstration of varietal differences, it is necessary to induce these damages experimentally as their occurrence in field conditions is affected by numerous other factors.

Grains with physiological split of lemma and endosperm, palea and endosperm and grains with incomplete overlapping of lemma and palea and lateral split take water during steeping more rapidly. If they germinate, course of their germination is atypical, they overmodify proteolytically and thus they contribute to non-homogeneity of the malt produced. Non-germinating grains increase the rate of glassy grains, reduce the friability value, increase $\beta$-glucan content in sweet wort and affect filtration negatively. At the same time the grains with this damage are contaminated microbiologically which brings risk of enhanced mycotoxin content (Schwarz et al. 1995). Malts with the increased content of the biologically damaged grains can cause considerable problems during their processing in breweries (Olkku et al. 2003). According to Baumer et al. (1998), the maximum amount of the grains with this damage is 2% in the lot otherwise faultless.

The occurrence of grains with physiological split of palea and endosperm was substantially more frequent damage than split of lemma and endosperm. In Scotland, the cultivar 'Tankard' was added to the 'UK cereal recommended list for 1996' as a malting quality spring barley, it was given a good score for malting on the 1998 list, but was removed from the 1999 list because of a 'pronounced tendency for grain to split'. Grossmann et al. (2001) developed the method inducing conditions under which physiological split of lemma and palea occurs. They divided the studied genotypes into seven groups (1 = the lowest damage, 7 = the highest damage) according to susceptibility to split of lemma and palea. This method assigned the genotype Orthega to the first group and malting genotype Scarlett to the third group. Grossmann et al. (2001) and Baumer et al. (1998) published the Table showing the results of ten-year monitoring of this damage in a number of genotypes. It is evident from this Table that the genotype Orthega was the least susceptible and on the contrary the malting genotype Prestige suffered from this damage considerably. The genotype Scarlett was placed between these two genotypes. The genotypes Orthega, Scarlett and Prestige took the same position in our study, too.

The grains in which lemma overlaps palea incompletely often exhibit a lower germination power. In practice this leads to uneven germination and thus to production of non-homogeneously modified malt with low cytolytical activity. Baumer et al. (1998) stated that the occurrence of grains with physiological split of lemma and palea and with incomplete overlapping of lemma and palea had increased recently due to the extreme weather conditions in the crucial period of grain formation and maturation. Our results also show that the occurrence of these traits has been significantly affected by the susceptibility of the studied genotypes to the given damages.

Sprouting is a phenomenon when grains germinate already in the ear before harvest. If rootlets or a coleoptile are apparent, open sprouting is regarded. If a coleoptile remains under the lemma and rootlets are broken off, then hidden sprouting is regarded. Sprouting is also dangerous in its initial phases as only biochemical processes occur without an evident growth of rootlets or a coleoptile. Such sprouting is not visually detectable. Generally, sprouted grains do not germinate in the malt house. In addition, they are a cause of strong malt microbial loading (Baumer et al. 1998).

In tillers formed late and in open or beaten stands, grains in ears do not often ripe and are green or green-yellow. Green color of grain often develops more markedly only after steeping. Due to their size, these grains frequently get to the sieve portion above 2.5 mm. Damaged grains contain low active enzymatic apparatus. They usually contain higher percentage of nitrogenous substances. Malt produced from these grains is not sufficiently modified; it exhibits low friability and high $\beta$-glucan content in sweet wort, which subsequently affects lautering and filtration negatively (Baumer et al. 1998). According to the results of Grossmann et al. (2001) and Baumer et al. (1998), the green grains occurred most in the genotypes Annabell, Saloon and Orthega. The genotype Prestige had medium loading. The genotype Scarlett suffered the least from this damage.

Black points are a very often damage of barley grains mainly in years with a higher relative air humidity during the ripening time. Germination, a basic barley malting character, is not impaired in grains with black points. Some maltsters, however, describe different behavior of lots with an enhanced content of these grains in the course of malting. All changes of colors can indicate potential damage of a grain caused by moulds and due to the possible technological and hygienic problems, the damaged barley lots are refused by the processing industry.

Barley husk was also found out to change color in dependence on time and temperature of storage. The husk becomes yellow and dark during storage. With short time storage at high temperatures or long time storage at mild temperatures 5-hydroxymethyl-2-furaldehyde accumulates in husks (Reuss 2001).

Damage of barley grains with moulds (fibrous micromycetes) is the most serious damage of barley both from the hygienic (risk of mycotoxin content) (Perkowski et al. 1995) and technological point of view (overfoaming of beer – gushing, etc.) (Herrera and Axcell 1991; Schwarz et al. 1996). Also, the germination itself can be negatively affected by moulds in the course of malting and the produced malt is then non-homogeneous.

Significant differences among the genotypes in ergosterol levels (microbial contamination indicator) and fungal contamination of barley caryopses were also determined by Young and Lochman (2001).

A considerable quantity of barley is used for production of malt, an intermediate product for beer production. Variability of the occurrence of the most widespread damages, i.e. grains with black points and grains infested with moulds, was affected both by the weather conditions and genotype. Apparently, the occurrence of black points was lower in the winter barley genotypes. In grains infested with moulds, the effect of the genotype was significant both in winter and spring barley varieties. It is suggested that chemical composition of lemma and palea of some barley genotypes reduces the microflora development on their surface. This finding is important from the breeding point of view and for selection of genotypes.

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