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THE EFFECT OF SUNN PEST INFESTED GRAINS ON WHEAT QUALITY IN DIFFERENT FIELD CONDITIONS

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ABSTRACT

In order to determine the effect of the number of grains infested with sunn pest (*Eurygaster austriaca* Schrk. and *Eurygaster maura* L.) on the quality of wheat (*Triticum aestivum* L.), we analyzed five commercial varieties of bread wheat grown in field conditions in 2003/2004 on ten localities in Vojvodina, Republic of Serbia. A range from 0.8% to 8.26% of infested grains was registered on the analyzed sites. Reduction of quality traits (protein content – PC, sedimentation value – SV1, modified sedimentation value – SV2, wet gluten content – WG and energy test – E) was observed in accordance to the number of infested grains (damaged grain – DG). Statistically significant differences were determined in the number of damaged grains and analyzed quality traits between localities, varieties and their interaction (locality x variety). Although there was significant variation for the PC, WG and SV1 between localities, it was not as high as for SV2 and E. Obtained by modified Zeleny test, SV2 is considered to be an objective parameter for determining the infested grains. Results of this study indicated a different intensity of bug attack in researched localities. In addition, there was a different reaction of varieties to the wheat bugs bite, which may be used in plant breeding programs for the improvement of bread wheat resistance against attack of bugs.

Key words: wheat variety, sunn pest, infested grains, wheat quality, localities.

INTRODUCTION

Wheat bugs are very significant pests of small grains, especially wheat, in several countries. They are the most prominent problem in the countries of the Middle East (Turkey, Iraq, Iran, Syria, Jordan, and Lebanon) and in Russia, Ukraine, Moldova, Romania and Bulgaria. In former Yugoslavia wheat bugs were a significant problem in recent period of time. In the mid sixties and early seventies they were the leading pests on small grains, when chemical methods were used against them. Normally, they are present wherever wheat is grown, but the main areal of their distribution and harmfulness is an area of Vojvodina. There are several species belonging to the genera *Eurygaster austriaca* and *E. maura*. There is a lot of data of their harmfulness, methods and forms of damage (Stamenković and Protić, 1995; Stamenković, 2004). The data on infested grains has been expressed as a percentage of infested grains, and the percentage of infested grains has been most commonly used to classify the quality of wheat (Popov et al., 1996). It is difficult to visually detect internal infection of the grain after wheat bug bites. Different opinions have been expressed about the appearance of the grains on the device for illumination, that show weak or strong opacities in the endosperm, yellow-brown areas of varying shapes and sizes that are not well defined and, most importantly, without any visible evidence of bite (Stamenković, 2004).

In 2004 production year, there were significant differences of wheat bug attacks between localities. In the population of wheat bugs in Vojvodina, the most frequent type was *Eurygaster austriaca* Schrk. (67.8%), followed by *E. maura* L. (30.2%), while the other species of the genus *Eurygaster*, as well as those of the genus *Aelia*, were represented with 2% (Stamenković, 2004). There was an apparent decrease of the technological quality and problems in processing wheat flour from the harvest 2004 at some localities with a

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significant share of infested grains (Bodroža et al., 2004; Torbica et al., 2004; Šimurina et al., 2004).

However, it could not precisely be determined whether the grain was damaged or not, just based on the number of wheat-bugged grains. Wheat grains, infected at the milk stage of maturity had similar values of quality traits with tested non-infected grains (Every et al., 1990). Wheat bitten by these bugs contains proteases that degrade gluten structure, primarily glutenin, which results in formation of soft, incompact and difficultly kneadable dough, and therefore of low bread volume and inferior crumb structure (Kretovich, 1944; Salis et al., 2007).

The main objective of this study was to describe the methods and determine the parameters based on which the effect of infested grains on the quality of domestic wheat varieties grown under field conditions in different localities could be estimated.

MATERIAL AND METHODS

Number of bug-bitten grains was determined by visual inspection (5 x 100 grains in three repetitions) on the device for illumination, by Paikina method. A total of 50 samples of five wheat varieties (NSR-5, Renesansa, Pesma, Evropa 90 and Pobeda) grown under field conditions in 2003/2004 at ten localities were examined. Samples (20 kg) were obtained from the producers of the most representative, most common commercial varieties in Vojvodina.

The following qualitative parameters were analyzed; protein content (PC), sedimentation value (SV), wet gluten content (WG) and energy of the dough made from wheat flour on Brabender extensograph (E).

PC (N x 5.7) was determined by the ICC 105/2 method. For evaluation of infested proteins Zeleny sedimentation was used (SV1) (ICC 116/1) or modified (SV2) Zeleny test (Greenway et al. 1965). Wheat samples were milled on a laboratory pneumatic mill (Bühler, MSU 202). The resulting flour was used to determine the content of wet gluten (WG) by ICC method 106/2 and the energy of the dough (E) – area (cm^2) under the curve of Brabender exstenograf (Brabender OHG, Duisburg, Germany) in accordance with the ICC method 114/1.

A combined analysis of variance (ANOVA) was carried out using SAS statistical software (SAS Institute Inc. 2007). Correlations between pairs of traits were assessed through Pearson's correlation coefficients. Only correlations significant at all localities were used for the Principal Component Analysis (PCA) and were presented in two-dimensional biplot (Gabriel, 1971). PCA was performed using the software package Statistics v. 7.

RESULTS AND DISCUSSION

Combined analysis of variance (ANOVA) for multiple localities and varieties showed that there were statistically significant differences in the percentage of damaged grains between localities, varieties and interactions of locality x variety and their qualitative parameters (Table 1).

Table 1. Analysis of variance of qualitative parameters average values and main sources of their variation during the growing season 2004

Source of variation	df	DG	PC	WG	SV1	SV2	E
Rep.	2	0.03	0.28	1.06	1.09	15.39	80.69
Localities (L)	9	81.78**	1.60**	16.35**	95.69**	405.72**	8874.55**
Variety (V)	4	14.28**	3.68**	50.20**	947.38**	1487.27**	6377.21**
L x V	36	6.30**	1.61**	19.05**	39.05**	80.06**	641.20**
Error	98	0.34	0.08	1.36	3.13	10.90	21.68

DG (damaged grain), PC (protein content), WG (wet gluten), SV1 (sedimentation value Zeleny), SV2 (sedimentation value - Zeleny modified) and E (dough energy)

In accordance with the ANOVA (Table 1), although there was significant variation of PC between varieties, it was not as high as the variation of damage between varieties.

The percentage of infested wheat grains (DG) per variety ranged from 2.57% for Pesma to 4.31% for Renesansa variety (Table 2). Different percentages of infested grains for different varieties meant that some varieties were less and some more resistant to bug bites (Kinaci and Kinaci, 2007). Renesansa variety was significantly more damaged by bugs than the other four varieties that had less than 3% of infested grains. With the exception of Pesma variety, between the other varieties there were no statistically significant differences. Generally, it is considered that flour obtained from wheat with less than 3% damaged grains does not have significantly reduced quality of the dough and of the final product (Tsen, 1965).

According to Sanaey and Mirak (2012) more tolerant cultivars to wheat bag attack are characterized by high quality, soft grain, full grain, large starch grains, late heading and early maturing etc. In our study, medium early varieties (NSR-5 and Renesansa) compared to the medium late varieties (Pesma, Evropa 90, Pobeda), have not shown a higher tolerance to wheat bag attack. In contrast, early-maturing variety Renesansa had the highest number of damaged kernels, which may indicate some other cause of sensitivity, given that this cultivar has almost all other characteristics of tolerant cultivars.

Table 2. Quality traits of wheat grain samples grown in 2004 production year

Variety/ Quality traits	DG (%)	SP (%/dm)	WG (%)	SV1 (ml)	SV2 (ml)	E (cm^2)
NSR 5	2.87	12.65	27.77	35.93	31.80	64.17
Renesansa	4.31	13.31	28.88	35.80	25.17	27.93
Pesma	2.57	13.47	31.10	47.30	43.87	58.73
Evropa 90	2.97	12.77	28.40	33.03	29.13	44.77
Pobeda	2.80	12.96	29.74	35.27	30.40	39.97
LSD 0.01	0.30	0.15	0.60	0.91	1.69	2.39

DG (damaged grain), PC (protein content), WG (wet gluten), SV1 (sedimentation value Zeleny), SV2 (sedimentation value - Zeleny modified) and E (dough energy).

The highest PC (13.31% and 13.47%) was found in varieties with highest 4.31%, and lowest 2.57% grain damage (Table 2), meaning that infested grains affected quality more than protein content. In other varieties PC was significantly lower, but as PC was more than 12.5% these differences in practice were not perceived to be significant.

Considered to be the most important parameter to evaluate the potential of flour for the product quality (Hoseney and Peña, 1997), protein content was not associated with the number of infested grains in the analyzed varieties (Every et al., 1998).

Wet gluten content

Wet gluten content (WG) depended on the variety and was in accordance with the protein content of the analyzed varieties. Although being significantly different in the number of infested grains, varieties Renesansa and Evropa 90 were not significantly different in WG content. Vaccino et al. (2004) determined a significant reduction of wet gluten content in some varieties with high level of damaged grains, but not at medium damage of the grains.

Sedimentation volume

Sedimentation volume (SV) is one of the most frequently discussed parameters that determine the quality of protein (Williams et al., 1988). Developed by Greenaway et al. (1965), the modified Zeleny sedimentation test was used to detect the activity of proteases in bug-damaged grains. In this experiment, SV value with 15 ml and less was considered weak, 16-24 ml medium, 25-36 ml strong and over 36 ml very strong (Uluöz, 1965). As we assumed, relatively high SV1, which are partly correlated with the protein content in the analyzed varieties, showed no clear reduction in the quality of gluten in infested grains.

In all analyzed varieties SV1 was higher than SV2 (Table 2). The greatest difference between the SV1 and SV2 was found in Renesansa variety (10.63 ml), with the highest percent (4.31%) of infested grains, and lowest in Pesma variety (3.43 ml) with the lowest percent (2.57%) of wheat-bugged grains. With NSR-5 and Pobeda varieties which had the same level of infested grains, there was no statistically significant difference between the SV2. However, generally, a high reduction of SV2, compared to SV1, does not show the highest degree of gluten degradation (Sivri et al., 1999). Reducing sedimentation value and wet gluten content may be the result of enzyme activity from secretion of grain bitten by bugs (Kretovich 1944; Every et al., 1998). Generally, it could be said that by extending the period of incubation after adding bromine-phenol blue solution (Greenaway et al., 1965) proteolytic activity in all samples was increased, which was confirmed by Sivri (1998) and Sivri et al. (1999). Secretion or saliva of the bug contains proteolytic enzymes that degrade proteins of wheat grain after the bite (Cressey, 1987; Sivri et al., 1999, Rosell et al., 2002). These proteolytic enzymes retain and degrade proteins of the endosperm and after grinding grains into flour and during dough formation (Hariri et al., 2000).

A significant reduction of the rheological properties of flour from infested wheat was at the first place detected in significant reduction in energy of dough by extensograph. After biting the grain, bugs salivate and this secretion contains proteases that in the process of mixing and fermentation degrade gluten network and form dough of weak rheological properties (Kara et al., 2005). The analyzed varieties (Table 2) had significantly different E of dough.

Renesansa had the lowest E of dough (27.93), associated with highest (4.31%) damage of the grain and NSR-5 had the highest E of dough. NSR-5 had higher energy than the most NS varieties with the lowest coefficient of variation in a few years (Mladenov et al., 2005). With a similar proportion of wheat bugged grains, Pobeda had significantly lower (39.97) dough energy than Pesma (58.73). A possible explanation for reduction of all the extensographic parameters is degradation and weakening of gluten structure. Sivri et al. (1999) and Aja et al. (2004) found that varieties responded differently to wheat bugs bite with a similar intensity of proteolytic activity. Table 3 shows the results of the quality traits of analyzed varieties in the same production year grown at ten different localities (L1-L10).

Table 3. Damaged grains and quality traits of five varieties at ten different localities from the same production year

Locality	Quality traits grains and flour					
	DG	PC	WG	SV-1	SV-2	E
L1	1.78	12.83	28.41	35.53	32.20	64.87
L2	3.36	12.61	28.13	34.87	31.13	35.60
L3	8.26	13.19	30.73	37.73	24.07	12.60
L4	2.01	13.11	28.33	36.20	35.00	60.93
L5	6.13	12.39	27.73	33.27	22.27	0.00
L6	0.89	13.31	30.20	38.87	36.07	72.40
L7	3.12	13.03	28.90	39.73	31.07	41.07
L8	2.37	13.19	29.47	38.00	34.93	61.27
L9	1.39	13.25	29.40	38.67	36.93	62.20
L10	1.71	13.42	30.47	41.80	37.07	60.20
LSD 0.01	0.42	0.21	0.84	1.28	2.39	3.37

DG (damaged grain), PC (protein content), WG (wet gluten), SV1 (sedimentation value Zeleny),
SV2 (sedimentation value - Zeleny modified) and E (dough energy).

Number of bug-damaged grains from ten locations ranged from 0.89 to 8.26%. Four (L2, L3, L5 and L7) of ten localities had more than 3% of infested grains. Except for localities L1, L2 and L5, there was no statistically significant difference between the PC compared to other localities.

The results in Table 3 show that between localities L3, L6 and L10, with the highest 8.26%, lower 1.71%, and the lowest 0.89% percentage of bugged wheat grains, there was no statistically significant difference in WG. The lowest SV2, as a result of enzymatic degradation of gluten, compared to SV1, was found at localities L3, L5 and L7 with the highest percentage (8.26, 6.13 and 3.12) of damaged grains. Varieties with more than 3% bug-damaged grains had statistically significant lower E of dough at localities L2, L3, L5 and L7. Analyzed varieties had the highest average E of dough (72.40) at L6, with the lowest percentage (0.89%) of infested grains. Among other localities there was no statistically significant difference between the E of dough of analyzed varieties. Samples from L3 and L5, with the highest percentage of bugged wheat grains (8.26% and 6.13%) had the lowest values of SV2 (24.07% and 22.27%) and E of dough (12.60% and 0.00%). The average content of WG in analyzed varieties at L3 and L5 was quantitatively satisfactory, but it was hard to rinse, and because of high moisture showed apparently high values.

Rheological properties of varieties determined by extensograph at these localities were reduced to the extent that the dough was impossible to process (Torbica and Mastilović, 2008).

Pearson's correlation coefficients between the number of bug-damaged grains and certain quality traits were determined at all localities (Table 4). The results showed that a significant correlation between the PC and the WG was established at half of studied localities, while the correlation between SV1 and SV2 was significant on six of the ten localities. Other significant correlations established at certain localities were probably developed under the influence of specific conditions. Thus at the L5 with many infested grains (6.13%) a significant effect on WG was determined. Significant correlation between DG and SV2 at L3 (r=-0.98**) and L7 (r=-0.91*) were found also at localities with high percentage of DG. The correlation between DG and E, found at L7 (r=-0.90*) and L9 (r=-0.89*), showing different levels of bug damage, probably resulted from the impact of several other factors.

Table 4. Pearson's correlation coefficients (r) between damaged grains and wheat quality traits at ten environments (L1 to L10)

	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10
DG-PC	0.02	-0.67	-0.11	0.1	0.33	0.11	0.76	0.75	-0.17	0.06
DG-WG	0.09	-0.64	-0.22	-0.04	**0.89***	0.34	0.83	0.23	-0.56	0.31
DG-SV1	0.01	-0.8	-0.51	-0.63	0.55	-0.22	-0.49	0.12	-0.15	-0.45
DG-SV2	-0.4	-0.81	**-0.98****	-0.5	0.51	-0.64	**-0.91***	-0.07	-0.24	-0.4
DG-E	-0.37	-0.81	-0.6	0.74		-0.68	**-0.9***	-0.11	**-0.89***	-0.83
DG-WG	**0.99****	**0.91***	**0.91***	**0.97****	0.56	**0.90***	0.52	0.43	0.55	0.79
PC-SV1	0.85	0.87	0.71	0.59	0.75	-0.02	-0.31	-0.07	0.68	0.75
PC-SV2	0.75	0.84	0.11	0.75	0.69	0.14	-0.7	-0.38	0.52	0.73
PC-E	-0.62	0.42	-0.61	-0.002		0.23	-0.49	-0.74	-0.25	0.2
WG-SV1	0.85	**0.93***	0.78	0.72	0.75	0.06	-0.39	0.34	0.46	0.52
WG-SV2	0.72	**0.95***	0.15	0.83	0.34	0.02	-0.64	0.05	0.56	0.73
WG-E	-0.68	0.47	-0.57	0.02		0.15	**-0.93**	-0.37	0.37	0.15
SV1-SV2	**0.91***	**0.98****	0.5	**0.96****	-0.36	0.85	0.77	**0.94***	**0.96****	**0.88***
SV1-E	-0.23	0.75	-0.02	-0.29		0.8	0.61	0.28	0.01	0.74
SV2-E	-0.01	0.69	0.65	-0.32		**0.97****	0.83	0.55	0.19	0.76

DG (damaged grain), PC (protein content), WG (wet gluten), SV1 (sedimentation value Zeleny), SV2 (sedimentation value - Zeleny modified) and E (dough energy).

Biplot (Figure 1) shows relations between localities and statistically significant correlations. Thus, the correlation between the PC and the WG, and between SV1 and SV2, which were significant at a certain number of localities are divided into a special group. These correlations may be considered relatively stable in different environments. Strong positive correlation between certain characteristics (SV2-E, DG-WG, WG-SV1, WG-SV2) that were established at one of the localities, appear in the biplot near these localities. In contrast, a strong negative correlation (WG-E, DG-E and DG-SV2) appears in the biplot in opposite quadrants, in relation to the localities where they were significant. All of these correlations, which occur on fewer sites, are considered unstable, as they are greatly affected by the external environment.

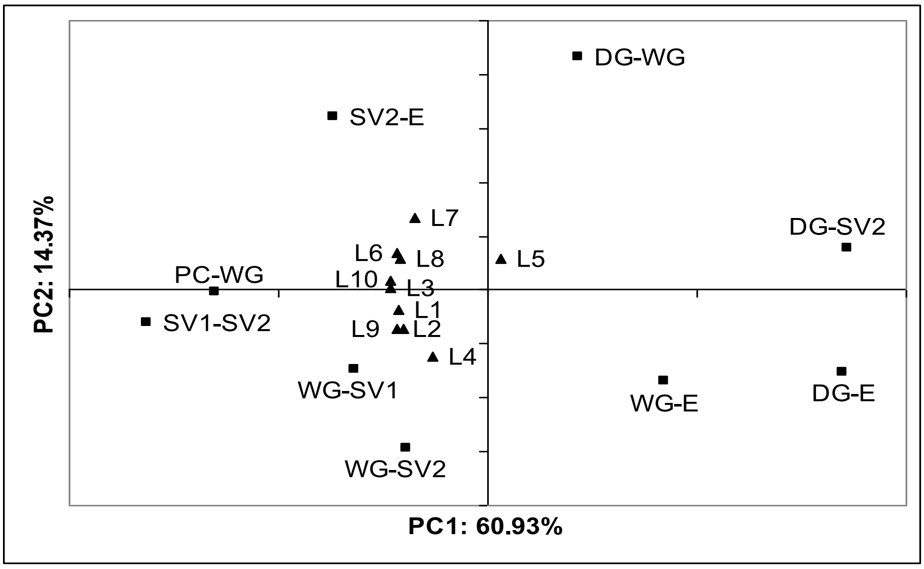

Figure 1. Interdependence between correlations and environments biplot, based on study with five wheat genotypes at ten localities (L1 to L10)
(DG – damaged grain, PC – protein content, WG – wet gluten, SV1 – sedimentation value – Zeleny, SV2 – sedimentation value - Zeleny modified, E – dough energy)

These results were consistent with the understanding that the correlation between the properties depends on the tested genotypes, and on the environment in which the testing was performed (Yan & Wallace, 1995). Similar conclusions, that environments might significantly alter the correlation relationships between the properties, were also reached by other authors (Yan et al., 2007; Dodig et al., 2008; Gorjanovic et al., 2010; Kondić-Špika et al., 2011).

CONCLUSIONS

Visual inspection of the samples on the device for illumination proved to be a reliable method for determining the number of bug-infested grains and their impact on reducing technological quality features.

The negative impact of infested grains was determined by a modified Zeleny method based on SV2, and by the extensograph based energy of dough.

The level of reduction of the quality features of wheat depended on the variety and the environment.

Correlations between the number of infested grains and quality traits were influenced by environment (locality) to a large extent.

Detailed laboratory analysis and results are required to verify the mechanism of action of wheat bugs bite on technological quality of wheat.

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