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Original scientific paper

ANALYSIS OF SPELT VARIABILITY (*Triticum spelta* L.) GROWN IN DIFFERENT CONDITIONS OF SERBIA BY ORGANIC CONDITIONS

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Ugrenović V., M. Bodroža Solarov, L. Pezo, J. Đisalov, V. Popović, B. Marić, V. Filipović (2018): *Analysis of spelt variability (Triticum spelta L.) grown in different conditions of Serbia by organic conditions*.- Genetika, Vol 50, No.2, 635-646.
The objective of this study was to examine the effect of the variety, locality and year on the morphological and productive parameters of the spelt wheat obtained in the organic production system. Four spelt varieties were grown at three agroecological environment (Pančevo, Bogdanica and Zlatar), in southeast Europe, Serbia. They are used in order to determine general adaptability in different environment in three years trial (2014-2016). Analysis of the selected production parameters of spelt wheat, according to variety, locality and year, were conducted by the Principal Component Analysis (PCA). The PCA of the presented data explained that the first two components accounted 86.02% of the total multivariance in the eleven variable factor space. The results showed that the highest values of a number of plants, number of stems, number of spikes, plant height,the number of grains in the spikes, weight of grains per spike, yield of above ground biomass, harvest index and yield of hulled grain were observed for the crops grown in Pančevo, regardless of the spelt wheat variety and year. The samples grown in Bogdanica showed to be very sensitive to the spelt wheat variety, in terms of hull index value. The highest value of mortality stems has been found in Zlatar, regardless of the spelt wheat variety, or the year.
Keywords: Mathematical modelling, morphological and productive traits, *Triticum spelta,* varieties, year.

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INTRODUCTION

Spelt wheat (*Triticum spelta* L.) belongs to the hexaploid group of cultivated *Triticum* wheat with fragile spikes and hulled kernels (UGRENOVIĆ *et al*., 2012; GLAMOČLIJA *et al*., 2015). This ancient cereal was created 7,000 years ago, most likely by the spontaneous crossing of wild grass species (NESBITT, 2001). By the mid-twentieth century, the spelt wheat had an important role in the diet of humans. Afterwards it has been gradually replaced by yielding soft wheat (*Triticum aestivum* L.) (ALVAREZ, 2007) and cultivated marginally mostly as fodder crop at altitudes where other cereals failed. Since seveties of the last century spelt is enjoying a resurgence in popularity mainly in mountain areas of Central Europe and North America and demand for this alternative cereals crop is continuously growing (ZIELINSKI *et al*., 2008). This could be connected with the development of organic agriculture and high nutritional value of this crop with benefits to human health (MAJEWSKA *et al*., 2007; SULEWSKA *et al*., 2008).

The morphological and producive characteristics of spelt wheat were the subjects of investigation of many scientists in worldwide (RÜEGGER and WINZELER,1993; TROCCOLI and CODIANNI, 2005; NEESON *et al*., 2008; KOUTROUBAS *et al*., 2012; POSPIŠIL *et al*., 2011; KONVALINA *et al*., 2014; LONGIN *et al*., 2014).However, the seasonal character of crop production, effected by the local agro-ecological conditions, indicates that there is no unique solution to maximize the genetic potential of the variety.

In Serbia, extensive surveys were carried out on the quality of spelt wheat kernels, (VUČKOVIĆ *et al*., 2013; FILIPČEV *et al*., 2013; BODROŽA SOLAROV *et al*., 2014; KRULJ *et al.*, 2016), while there is less data on the agronomic properties of this crop (UGRENOVIĆ, 2013; JANKOVIĆ *et al.*, 2015).

For these reasons, the main goal of this research was to examine the influence of variety (V), locality (L) and year (Y) on the morphological and productive characteristics of spelt wheat varieties produced in Serbia.

MATERIALS AND METHODS

Field trials

The experiments were carried out at three different locations in Serbia: in Pančevo (77 m above sea level - masl), in Bogdanica (485 masl) and on Zlatar (1038 masl), on different soil types: chernozem, eutric cambisol („gajnjača“) and gray forest land respectively The four winter wheat varieties: Ebners Rotkorn and Ostro (Austria), Nirvana (Serbia) and Ekö-10 (Hungary) were used. The field microtrials were set up in 2013/14, 2014/15 and 2015/16 as three-factorial trial in four repetitions, in the random block system.

The main plot was 5 m^2, 4 m long and 1.25 m wide, with ten rows of 12.5 cm interval distance. In all three years of research, methods of organic production were applied, with the potatoes as previous crop. Sowing was done manually in the first decade of October, with a seedling rate of 500 germinated hulled seeds per m^2 (UGRENOVIĆ, 2013). No direct application of fertilizers and plant protection measures were used.

During the vegetation season, monitoring of the growth stages was carried out according to the BBCH scale (HACK *et al*., 2001), with the following analysis: number of plants per m^2 (NP), number of stems per m^2 (NS), number of spikes per m^2 (NSP), plant height in cm (PH), mortality of stems in percent (Mort) which is calculated according to the EHSANZADEH (1999).

On the full maturity stage (BBCH 89), 30 spikes were randomly taken from the each plot in order to determinate the number of grains per spike (NGS) and the weight of grains per spike in g (WGS). After the harvest, biomass yield in t ha^{-1} was determined (YOB).

The total yield of hulled kernels was determined after the threshing. Re Pietro Spelt Huller MDF1 was used for dehullling and the yield of dehulled kernels in t ha^{-1} was measured (YHG).

By comparing the yield of dehulled kernels with the biomass yield from each plot, the harvest index in percent (HI), (KOUTROUBAS *et al*., 2012) was obtained. Additionally, the share of hulls in the total weight of kernels, was expressed by the hull index in percent (HLI), (UGRENOVIĆ *et al*., 2015).

Agroecological conditions

Meteorological conditions. For the analysis of the amount and distribution of precipitation and thermal conditions during the vegetation session of spelt wheat for all localities and in all three years of research the data of the Meteorological Institute of Serbia were used (Figure 1).

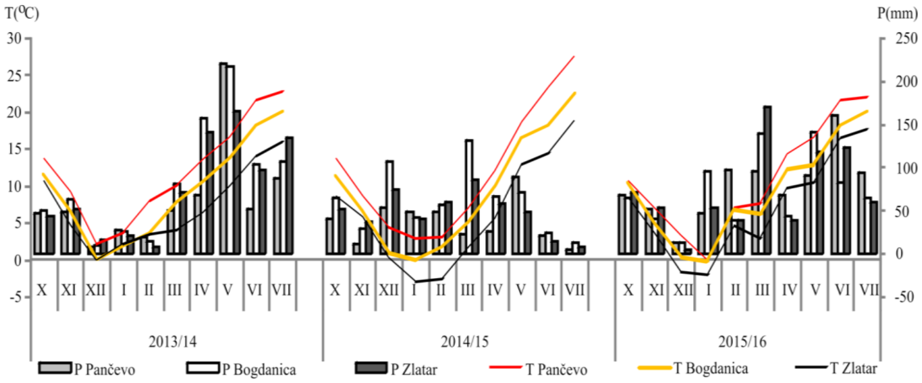

Figure 1. Precipitation (mm) andaverage air temperatures (˚C), Pančevo, Bogdanica and Zlatar

The average amount of precipitation in all locations was very similar in the third (774.4 mm) and the first year of research (732.8 mm), and significantly lower in the second year (473.6 mm). The highest rainfall locality, on average, was Bogdanica (716.4 mm), followed by Zlatar (651.1) and Pančevo (584 mm).

Variations by the years in Pančevo were detected in the range of 339.1 mm (2014/15), 627.0 mm (2013/14), to 785.7 mm (2015/16), in Zlatar from 477.1 mm (2014/15), 729.7 mm (2015/16) to 746 mm (2013/14), and in Bogdanica from 604.4 mm (2014/15), 717.9 mm (2015/16), to 825.3 mm (2013/14). Despite significant differences, the monthly water regime across all years and agroecological environments were favorable, with sufficient water in the periods with the highest demand. However, due to the later beginning of the vegetation period on Zlatar, the lack of water was detected in June and July 2015 (Figure 1).

The heat sum during the vegetation period was the highest in Pančevo (350.4 ˚C), followed by Bogdanica (277.2 ˚C) and the lowest at Zlatar (202.6 ˚C). The average air temperature, was the lowest in 2015/16 in Pančevo (10.9 ˚C) and in Bogdanica (9.1 ˚C), while in 2014/15 the lowest air temperature was detected at Zlatar (6.2 ˚C). The analysis of the monthly distribution of heat showed that the winter on Zlatar was extremely cold followed with the spring with low average air temperatures (Figure 1), which causes the later beginning of the vegetation period at that site.

Soil conditions. The chemical analysis of the soil presented in Table 1, were performed by the methods described by BOGDANOVIĆ *et al*. (1966).

*Table 1. Agrochemical properties of soil**

Locality - Soil type	pH		$CaCO_3$	Humus	Total N	Available	
	nKCl	H_2O	%	%	%	P_2O_5 mg/100 g	K_2O mg/100 g
Pančevo - Chernozem	7.4	8.3	16.2	4.4	0.23	22.5	26.9
Bogdanica - Eutric cambisol	5.3	6.0	1.3	2.6	0.10	6.2	10.9
Zlatar - Grey forest soil	4.5	5.6	1.7	2.1	0.10	1.1	6.7

* Agrochemical analyses of soil samples from the experimental fields were performed in the laboratory of Institute Tamiš in Pančevo, in year 2013.

Statistical analysis

Principal component analysis (PCA) was applied to classify the spelt wheat samples. PCA decomposes the original matrix into several products of multiplication into loading (different spelt samples cultivated under different conditions) and score matrices (NP, NS, Mort, NSP, PH, NGS, WGS, YOB, HI, YHG and HLI).

The significance of this research, in which the second order polynomial model covers a number of indicators, is that the obtained results can be applied to optimize the production of spelt wheat in organic cropping system in different soil type of Serbia.

The collected data were subjected to analysis of variance (ANOVA), for the comparison of means and separated using post-hoc Tukey's LSD test to consider significantly different means at $p<0.05$ level. The second order polynomial models (SOP) were fitted to the observed experimental data. Eleven mathematical models of the following form were developed to relate eleven responses (*Y*) and three process variables (*X*):

$$Y_k = \beta_{k0} + \sum_{i=1}^{3}\beta_{ki}\cdot X_i + \sum_{i=1}^{3}\beta_{kii}\cdot X_i^2 + \sum_{i=1,\, j=i+1}^{3}\beta_{kij}\cdot X_i\cdot X_j,\ \text{k=1-11}, \qquad (1)$$

where: β_{k0} (intercepts), β_{ki} (the linear coefficients), β_{kii} (the quadratic coefficients), β_{kij} (the interchange coefficients) are constant regression coefficients; Y_k represents the predicted response variables, either NP, NS, Mort, NSP, PH, NGS, WGS, YOB, HI, YHG and HLIwhile X_k the independent variables affecting the responses.

The adequacy of the developed models was tested using coefficient of determination (r^2), reduced chi-square (χ^2), mean bias error (MBE), root mean square error (RMSE), and mean percentage error (MPE). These commonly used parameters can be calculated as follows:

$$\chi^2 = \frac{\sum_{i=1}^{N}(x_{\exp,i} - x_{pre,i})^2}{N-n}, \; RMSE = \left[\frac{1}{N}\cdot\sum_{i=1}^{N}(x_{pre,i} - x_{\exp,i})^2\right]^{1/2},$$

$$MBE = \frac{1}{N}\cdot\sum_{i=1}^{N}(x_{pre,i} - x_{\exp,i}), \; MPE = \frac{100}{N}\cdot\sum_{i=1}^{N}\left(\frac{|x_{pre,i} - x_{\exp,i}|}{x_{\exp,i}}\right) \qquad (2)$$

where: $x_{exp,i}$ stands for the experimental values and $x_{pre,i}$ are the predicted values obtained by calculating from the model for these measurements. *N* and *n* are the numbers of observations and constants, respectively.

RESULTS AND DISCUSSION

The results of this research indicate that the highest influence on the yield of the dehulled spelt wheat kernels had locality of cultivation. The highest yield was achieved in Pančevo on chernozem (3.35 t ha^{-1}), followed by Bogdanica on eutric cambisol (2.94 t ha^{-1}), and on Zlatar, on the gray forest land, the yield was the lowest (2.33 t ha^{-1}), Fig. 1.

This trend was recorded for all varieties and across three years during the research. Similar results were obtained JANKOVIĆ *et al.* (2015) and GLAMOČLIJA *et al.* (2013). The results achieved on naturally less fertile soils of the hilly and mountainous regions of Serbia showed that the spelt wheat can be successfully cultivated even under unfavorable agroecological conditions (GLAMOČLIJA *et al*., 2013).

The highest average yield was measured at the Ebners Rotkorn variety (3.07 t ha^{-1}) while Ostro, Ekö-10 and Nirvana had less yields by 4.6%, 7.8% and 13.4% respectively, indicating the significant genotypic variability. A variation of the values of the observed parameters by years indicate the significance of the meteorological conditions on yield parameters, which is consistent with the research UGRENOVIĆ *et al*. (2013).

In the third year (2015/16), the highest average yield of dehulled kernels (3.06 t ha^{-1}) was obtained, which is the result of the smallest degree of mortality of the stems, as well as the optimal ratio of the number of spikes and the number and weight of kernels per spikes, which is consistent with the research UGRENOVIĆ *et al*. (2013).

In the first year (2013/14) the yield was lower by 5.2%, and in the second (2014/15) by 13.1%. Using the mathematical models for processing the obtained results, the effects of the analyzed factors (variety, locality and year) on the morphological and productive properties of the spelt wheat were shown.

The PCA of the presented data explained that first two components explained 86.02% of the total variance (73.01% and 13.01%, respectively) in the eleven variable factor space (which describe the specific productive parameters of the Spelt samples). Considering the map of the PCA performed on the data (Fig. 2), variable Mort (which contributed 9.3% of total variance, based on correlations) exhibited the most pronounced positive scores according to first principal component, whereas NP (9.9%), NS (8.8%), NSP (12.2%), PH (8.4%), NGS (11.1%), WGS (10.4%), YOB (11.9%) and YHG (12.2%) showed a negative score according to first principal component (Figure 2). The positive contribution to the second principal component calculation was observed for HI (9.0% of total variance, based on correlations), while the most intense negative influence on the second factor coordinate was observed by NS (10.6%), Mort (9.1%), PH (14.4%) and HLI (49.4%).The points shown in the PCA graphics, which are geometrically close to each other indicate the similarity of patterns that represent these points.

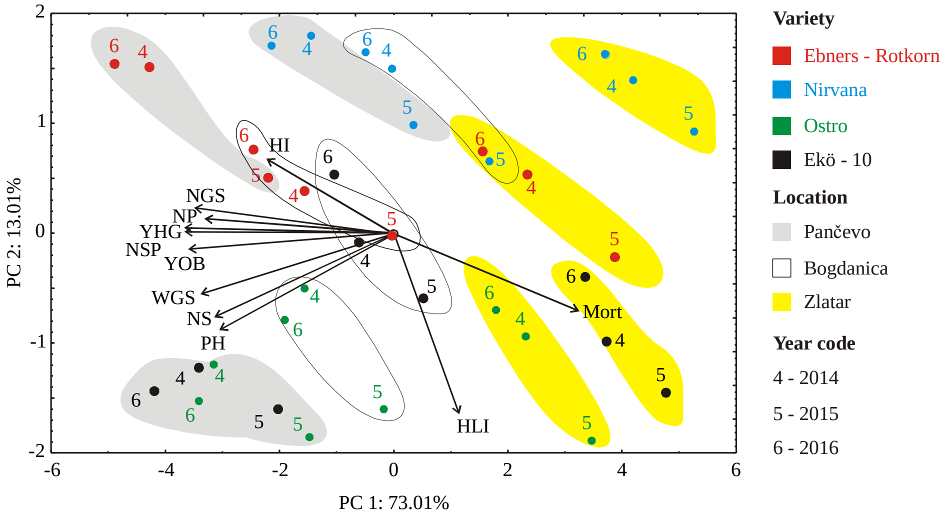

Figure 2. PCA ordination of variables based on component correlations

The orientation of the vector describing the variable in factor space indicates an increasing trend of these variables, and the length of the vector is proportional to the square of the correlation values between the fitting value for the variable and the variable itself (WESTERLUND *et al*. 1991; KRULJ *et al*., 2016). According to Fig. 2, the differentiation between the Spelt wheat variety is more evident on the second factor coordinate (PC2) (samples of Ebners Rotkorn and Nirvana varieties are located in the upper part, while the samples of Ostroand Ekö-10 are located at the bottom of the graph). The position of samples, obtained by the different location of the grown is more evident in the direction of the first factor coordinate (PC1) (*Spelt*) samples cultivated in Pančevo are located at the left side of the graphic, the samples from Bogdanica are located at the middle of the graphic, and the samples from Zlatar are located at the right side of the graphic). The angles between corresponding variables indicate the degree of their correlations (small angles corresponding to high correlations) (WESTERLUND *et al*. 1991; JACOBSON *et al*. 2005; KRULJ *et al*., 2016). The position of Spelt samples in groups (determined by the location of production), according to the year of production is affected by both PC axes. The samples from year 2016 are located at the upper left part of each location group, samples from 2014 are located to the central part of each group, while the samples form year 2015 are located in the bottom - right of each location group.

The differentiation among samples grown under different agro-ecological circumstances could be realized from the PCA graphic, where the highest values of NP, NS, NSP, PH, NGS, WGS, YOB, HI and YHG were observed for the crops grown in Pančevo, regardless of the Spelt wheat variety, or the environment. The samples of Ostro variety, grown in Bogdanica showed the highest HLI, the samples of Ebners Rotkorn and Ekö-10 were, grown in Bogdanica were spotted for the medium HLI value, and the lower HLI value were found for Nirvana variety. The highest value of Mort is found in Zlatar, regardless of the Spelt wheat variety, or the environment. Similar results were obtained JANKOVIĆ *et al*. (2015) and GLAMOČLIJA *et al*. (2013). Which is also in consistent to the research UGRENOVIĆ *et al*. (2013).

SOP MODEL

The effects of V (Ebners Rotkorn, Nirvana, Ostro and Ekö-10), L (Pančevo, Bogdanica and Zlatar), and Y (2013/14, 2014/15, 2015/16) NP, NS, Mort, NSP, PH, NGS, WGS, YOB, HI, YHG and HLI, were fitted to the SOP models.

As can be seen from the data in Table 2, the linear term of L in SOP model, was the most influential in the SOP model for NP, NS, Mort, NSP, PH, NGS, WGS, YOB, HI and YHG evaluation (statistically significant at $p<0.01$ level) and for HLI ($p<0.05$). The influence of the second order term of L was also observed for NP, Mort and NSP calculation ($p<0.01$) and for the evaluation of NS ($p<0.05$). It is apparent that the linear term of V significantly contributed to the prediction of NS, Mort, PH and NGS ($p<0.01$) and also for the calculation of HI and HLI ($p<0.05$). The quadratic term of V in SOP model contributed to the calculation of NS and HI ($p<0.01$), and also the evaluation of NSP, NGS and YHG ($p<0.05$). Further analysis showed that the second order term of Y affected NS, NSP, NGS, WGS, YOB, HI, YHG and HLI calculation ($p<0.01$), and also for the prediction of NP and PH ($p<0.05$). ANOVA also revealed that the nonlinear synergy effect of V × L was influential in the SOP model for HLI assessment ($p<0.05$).

Table 2 ANOVA of the fitted SOP models for NP, NS, Mort, NSP, PH, NGS, WGS, YOB, HI, YHG and HLI calculation

	df	NP	NS	Mort	NSP	PH	NGS	WGS	YOB	HI	YHG	HLI
V	1	293.9**	6046.5^{+}	378.3^{+}	86.1	155.46^{+}	23.58^{+}	0.00	0.09	5.05*	0.09	11.62*
V^2	1	253.3**	1042.8^{+}	0.0	702.2*	52.55**	13.97*	0.01	0.24	10.72^{+}	0.21*	0.50
L	1	48218.3^{+}	17469.0	$^{+}$1094.8^{+}	40961.3^{+}	781.75^{+}	265.70^{+}	0.22^{+}	44.72^{+}	11.07^{+}	6.22^{+}	11.54*
L^2	1	10052.4^{+}	520.0*	86.2^{+}	1730.7^{+}	1.09	1.85	0.01	0.53	1.59	0.09	0.32
Y	1	30.9	72.6	4.4	173.3	11.92	3.27	0.00	0.93	1.41	0.18*	0.37
Y^2	1	305.3*	775.2^{+}	56.5	1995.0^{+}	66.28*	63.73^{+}	0.05^{+}	2.34^{+}	19.32^{+}	0.80^{+}	21.83^{+}
V × L	1	31.8	92.8	6.9	22.1	11.24	0.97	0.01	0.01	3.17	0.02	12.61*
V × Y	1	2.6	0.1	0.1	1.9	0.00	0.31	0.00	0.00	0.00	0.00	0.00
L × Y	1	11.0	15.5	1.2	0.0	2.39	0.04	0.00	0.00	0.06	0.00	0.16
Error	26	1869.1	2331.6	77.9	2718.0	373.96	59.59	0.13	7.56	23.57	0.84	42.74

$^{+}$Significant at $p<0.01$ level, *Significant at $p<0.05$, **Significant at $p<0.10$, df– degrees of freedom, V – the Spelt wheat variety, L – the location of breeding, Y – the year of production.

NP - number of plants per m^2, NS - number of stems per m^2, NSP - number of spikes per m^2, PH - plant height (cm), Mort - mortality stems (%), NGS - number of grains in the spikes,WGS - weight of grains per spike(g), YOB - yield of overhead above ground biomass (t ha^{-1}), HI - harvest index (%), YHG - yield of hulled grain (t ha^{-1}), HLI - hull index (%).

In the cases where interaction between factors was statistically significant, complete information regarding the effect of the factors on the responses can be perceived on the basis of the three-dimensional contour plots. The plots of Mort, NSP, NGS, WGS, YOB and YHG (Fig. 3a) were plotted to show the dependence of these response variables to year of production (Y) and the location (L). The observed three-dimensional contour plot of Mort surface showed a 'rising ridge' pattern, with the augment in the Mort value could be found in Zlatar, regardless of the production year, or the Spelt variety (Fig. 3a). The higher values of NSP, NGS, WGS, YOB and YHG (Fig. 3b, 3c, 3d, 3e and 3f, respectively), could be observed in Pančevo, nevertheless the production year, or the Spelt variety. These results coincide very well to PCA analysis.

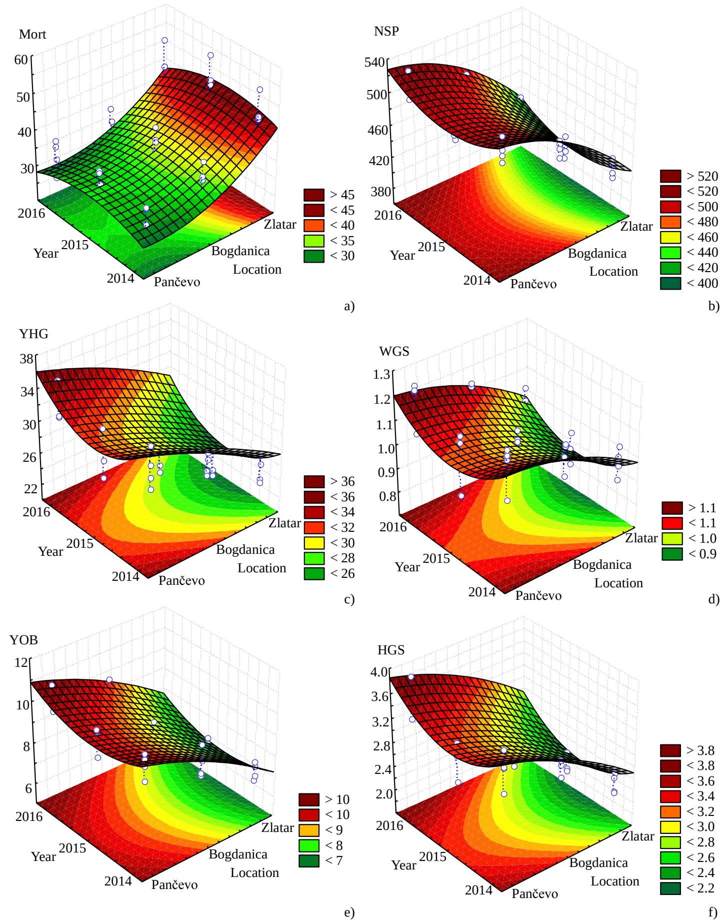

Figure 3. Three-dimensional contour plot of Mort, NSP, NGS, WGS, YOB and YHG responses, affected by the location of breeding and the year of production.

RESIDUAL ANALYSIS

Much useful data can be obtained using the statistical analysis of the residuals of the modelling. Many authors (DEVLIEGHERE *et al*.; 2000; WEI *et al*., 2001; OSCAR, 2002) reported that this analysis could show whether there are any larger differences in any particular area of the model or whether the scatter is random. Because of the above mentioned facts, the residual analysis of the developed models was also performed. Skewness measures the deviation of the distribution from normal symmetry. If skewness is clearly different from 0, then the distribution is asymmetrical, while normal distributions are perfectly symmetrical. Kurtosis measures the 'peakedness' of a distribution. If kurtosis is clearly different than 0, then the distribution is either flatter or more peaked than normal; the kurtosis of the normal distribution is 0.

The analyzed mean values, standard deviations (SD), and the variance of the residuals are shown in Table 3. All SOP models had an insignificant lack of fit tests, which means that all the models represented the data satisfactorily.

Table 3 The 'goodness of fit' tests of the developed mathematical models

	χ^2	RMSE	MBE	MPE	r^2	Skew.	Kurt.	Mean	SD	Var.
NP	72.535	7.053	0.722	1.446	0.963	-0.405	-0.815	0.843	7.700	59.294
NS	90.523	7.879	0.858	1.024	0.918	-0.179	-1.101	1.001	8.595	73.879
Mort	2.787	1.382	-0.114	3.014	0.936	-0.427	-1.254	-0.133	1.513	2.288
NSP	100.961	8.320	1.010	1.326	0.940	0.287	-0.693	1.178	9.062	82.117
PH	13.612	3.055	0.246	2.043	0.777	-0.554	-0.397	0.287	3.344	11.180
NGS	2.183	1.223	0.169	3.353	0.842	0.083	-0.695	0.197	1.329	1.766
WGS	0.005	0.059	0.006	4.336	0.676	-0.561	-0.539	0.007	0.064	0.004
YOB	0.279	0.438	0.060	3.689	0.857	0.184	-0.603	0.071	0.475	0.226
HI	0.749	0.717	-0.036	1.650	0.704	-0.307	-0.383	-0.042	0.786	0.618
YHG	0.032	0.148	0.017	3.723	0.889	-0.574	0.275	0.020	0.161	0.026
HLI	1.671	1.070	0.092	2.532	0.592	-0.276	-0.761	0.107	1.171	1.371

Wheat is grown on 220 million hectares throughout the world producing approximately 729 million tons of grain. Grain yield of wheat has increased noticeably since the beginning of the twentieth century. Understanding agronomical, phenological, and physiological traits associated with grain yield can help wheat breeders to accelerate genetic improvement in grain yield potential. Grain yield in wheat has been divided into its components, namely, grain number and grain weight (JOUDI, 2017; RUKAVINA *et al*., 2017). Breeding effort on increasing grain yield of wheat will incessantly continue because it is an indispensable product (KUTLU *et al.,* 2017).

CONCLUSIONS

The obtained relationship between the independent extrinsic factors (V, L and Y) and the dependent responses (targeted productive parameters of the Spelt wheat) could be a useful tool to assess and manage the optimal production parameters. Quantification of these relations through mathematical models represents a great benefit for agricultural technologists since it allows making predictions of the agronomic indicators as the potential productive parameters of the Spelt wheat. The SOP models developed to investigate the effect of the locality, the year and the variety on the observed productive parameters of the Spelt wheat, showed a good fit to the experimental data for NP, NS, Mort, NSP, PH, NGS, WGS, YOB, HI, YHG and HLI. The results showed that the highest values of NP, NS, NSP, PH, NGS, WGS, YOB, HI and YHG which were observed for the crops grown in Pančevo, regardless of the Spelt wheat variety and year. The samples grown in Bogdanica showed to be very sensitive to the Spelt wheat variety, when considering the HLI value. The highest value of Mort is found in Zlatar, regardless of the Spelt wheat variety, or the year.

In general, the developed empirical models gave a reasonable fit to experimental data and predicted the targeted productive parameters of the Spelt wheat a satisfactory level, and could be successfully implemented to optimize the production of Spelt wheat.

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ANALIZA VARJABILNOSTI KRUPNIKA (*Triticum spelta* L) GAJENOG U RAZLIČITIM USLOVIMA SRBIJE, PO ORGANSKIM METODAMA

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Izvod

Cilj ovog istraživanja bio je proučavanje uticaja sorte, lokaliteta i godine na morfološke i produktivne osobine pšenice krupnik, dobijenih u sistemu organske proizvodnje. Četiri sorte su gajene na tri različita lokaliteta Srbije (Pančevo, Bogdanica i Zlatar), da bi se utvrdila njihova opšta prilagodljivost u različitim uslovima životne sredine u tri godine istraživanja (2014-2016). Analiza odabranih osobina krupnika, u odnosu na proučavane faktore, izvedena pomoću glavnih komponenti (engl. Principal Component Analysis - PCA), ukazala je da su prve dve komponente predstavljale 86,02% od ukupne varijanse u faktorskom prostoru od jedanaest promenljivih. Rezultati isrživanja su pokazali da su vrednosti promenljivih: broj biljaka, broj stabljika, broj klasova, visina biljke, broj zrna u klasu, masa zrna u klasu, prinos nadzemne biomase, žetveni indeks i prinos oljuštenog zrna bile najveće u Pančevu, bez obzira na sortu i godinu. Uzorci gajani u Bogdanici pokazali su se veoma osetljivim na sortu, uzimajući u obzir vrednost žetvenog indeksa, dok je vrednost mortaliteta stabala bila najveća na Zlataru, bez obzira na sortu krupnika ili godinu.

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