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Wheat cultivars grain yield and quality traits variability under conditions of southern Pannonian plain

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Summary: In order to meet milling industry and grain producers' requirements, wheat grain needs to possess good technological quality, and high and stable grain production. This study analyzed 30 varieties of winter wheat over four growing seasons (2015/16, 2016/17, 2017/18, and 2018/19) at the location Rimski Šančevi, Serbia. The studied traits were under the control of genotype, environment, and their interaction. The analysis of variance (ANOVA) revealed that the influence of the factors varied depending on the studied trait. Thousand grain weight showed the highest variability depending on genotype influence, protein content and sedimentation value that were mostly affected by environmental conditions, while the genotype and environment interaction had the greatest impact on hectoliter weight and grain yield. Using principal component analysis significant positive relationship was observed between protein content and sedimentation value, and between thousand grain weight and hectoliter weight. It was also shown that yield and thousand grain weight, sedimentation value and hectoliter weight are positively related. A strong negative association was noted between grain yield and protein content. The protein content and hectoliter weight did not show any dependency. All analyzed traits are significant for breeding programs, emphasizing the importance of developing high-quality varieties with high yield potential and tolerance to adverse environmental conditions.
Key words: hectoliter weight, protein, *Triticum aestivum* L., variety, wheat, yield

Introduction

Cereal crops are the most important agricultural crops worldwide, and wheat is particularly significant due to its extensive use in human and livestock nutrition. Wheat is one of the most widespread crops in the world including Europe and as well as domestically (Jocković et al., 2023). Global wheat production in 2022 accounted for approximately 808 million tons on 219 million hectares, with an average yield of 3.69 t ha^{-1} (FAOSTAT, 2023). Over the past 70 years, there has been an increase in the average yield from 1.00 t ha^{-1} to approximately 3.45 t ha^{-1}. Considering the expected increase in the world population and food demand, predictions indicate that by 2050, an increase in the average wheat yield to about 5 t ha^{-1} will be necessary (Rosegrant & Agcaoili, 2010). In recent years, the Republic of Serbia has seen an increase in the average yield from 4.2 t ha^{-1} to 5.2 t ha^{-1}. In addition to high and stable yields, achieving high grain quality is also crucial for wheat production. High grain quality is essential to meet the requirements of local mills and the processing sector, as well as export standards (Živančev et al., 2022).

Wheat grain contains approximately 60-80% carbohydrates, 8-15% protein, essential amino acids, fats, minerals, and vitamins (Hussain & Qamar, 2007). Despite its relatively low protein content, in regions where bread and other bakery products are a staple part of the diet, wheat plays a crucial role in providing essential nutrients (Shewry, 2000) and is considered a major source of energy, supplying 19% of global daily calorie needs (D'Odorico et al., 2014). On average, wheat protein intake per capita ranges from 16% to 19% of their total daily intake globally (Erenstein et al., 2022). Extremely high temperatures, insufficient and unevenly distributed rainfall during the grain formation and filling stage are characteristics of the agroecological conditions in Serbia. These weather factors negatively impact grain yield and quality, particularly protein content. Predictions indicate an expected increase in average temperatures by 2 °C to 4 °C by the end of this century (Asseng et al., 2015), and the Pannonian Plain region is likely to experience the most significant negative consequences of climate change (Olsen et al., 2011). During flowering stage, wheat is sensitive to high temperatures and drought, which can reduce grain yield through decreased grain number and weight per plant (Akter et al., 2017). Additionally, pre-harvest rainfall can cause vivipary, grain sprouting in the spike, significantly reducing the quality of wheat flour (Barbeau et al., 2006).

Developing high-yielding and quality varieties in breeding programs can contribute to mitigating the negative impact of these agroecological factors to achieve production stability. The primary breeders focus during the past century has been on improving yield, while enhancing quality-determining traits has been a secondary goal. Maintaining high-quality wheat varieties is important throughout various growing seasons from the perspective of breeders, producers, and the processing sector. The aim of this study is to analyze the impact of growing seasons and genotype on the variability of technological quality indicators (hectoliter weight, thousand kernel weight, protein content, sedimentation value), and grain yield in wheat. The obtained results can contribute to the selection process improvement, as well as providing detailed recommendations for specific varieties cultivation in suitable regions.

Materials and Methods

Field trial and experimental setup

The research was conducted at the experimental field of the Institute of Field and Vegetable Crops, Novi Sad, Rimski Šančevi (45°20'N and 19°51'E) during four growing seasons (2015/16, 2016/17, 2017/18, and 2018/19). The thirty wheat varieties developed in Serbia or surrounding countries were included in field trials. The location is characterized by chernozem soil type. The experimental field was characterized by a three-year crop rotation system involving cereals, maize, and legumes. Basic fertilization with nitrogen (N), phosphorus (P), and potassium (K) was applied in the fall during all four growing seasons, using quantities recommended based on soil agrochemical analysis. The trial was arranged in a completely randomized block design with three replications, and the size of the basic plot was 5 m^2. The plots were 1 m wide and 5 m long with a spacing of 0.1 m between rows. To prevent nitrogen deficiency during the intensive plant growth, nitrogen fertilization (NH_4NO_3) was applied, with quantities determined based on N-min analysis (Wehrmann & Scharpf, 1979) during early spring. Crops were sown within the optimal sowing period for wheat: 16 October 2015, 20 October 2016, 17 October 2017, and 23 October 2018. The seeding rate was 500 germinated seeds per m^2, which is recommended for the agroecological conditions of the Republic of Serbia. Appropriate pesticides were applied during the vegetation period.

Quality traits and data analysis

The harvest was conducted at the end of June at the physiological maturity stage using the experimental Wintersteiger Delta combine harvester, with grain yield (YLD) calculated to 13% moisture content and expressed in t ha^{-1}. Thousand grain weight (TGW) was determined from the combined sample by measuring two samples of 500 grains each, and their average value was reported. Using a Dickey John analyzer (Model GAC2100), hectoliter weight (HW) was measured and expressed in kg hL^{-1}. The total nitrogen content in the grain was determined using the standard Kjeldahl method (AACC, 2000), where multiplying the nitrogen content percentage by a factor of 5.7 yielded the total protein content (GPC) expressed as % on a dry matter basis. Sedimentation value (SED) of the samples was determined using the Zeleny method, based on the sedimentation of wheat flour fractions suspended in a lactic acid solution over a specified period (Shewry et al., 2000).

Statistical analysis included calculating the mean values of the examined varieties for defined quality parameters during four growing seasons. The data obtained in this research were statistically processed using the analysis of variance (ANOVA) method with the INFOSTAT program (Di Rienzo et al., 2011). Principal component analysis (PCA) was used to determine the relationships among the examined traits using R package.

Weather conditions

Weather data on temperature and precipitation a meteorological station located near the experimental field (Figures 1 and 2). The data cover the period from October to June during the examined seasons of 2015/16, 2016/17, 2017/18, and 2018/19. Weather conditions during May and June (flowering and grain filling stages) were most important for achieving good wheat grain quality.

Average daily air temperatures (Fig. 1) during the fall, specifically in October and November, did not significantly vary during the studied growing seasons. On the other hand, precipitation amounts (Fig. 2) varied cross the growing seasons. The lowest average temperatures during the winter were recorded in 2016/17, while precipitation amounts were lowest in 2015/16. February and March were drier during 2016/17 and 2018/19 compared to others. In April, plants were in the stem elongation stage, and throughout all seasons, a significant amount of rainfall was recorded along with moderate temperatures. An exception is the 2017/18 season, which was characterized by relatively higher temperatures. May was characterized by high rainfall amounts during 2018/19, while higher rainfall amounts in June were observed during the 2015/16 and 2017/18 growing seasons. Temperatures during May and June did not exceed 25 °C, which is favorable to grain dry matter accumulation.

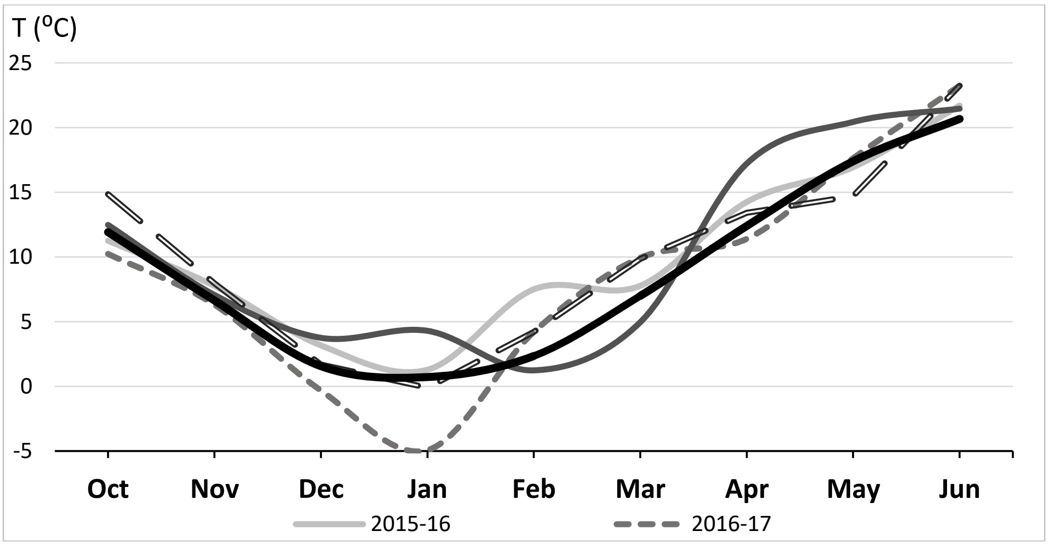

Figure 1. Average monthly temperature during four growing seasons and long-term average (1989-2018)

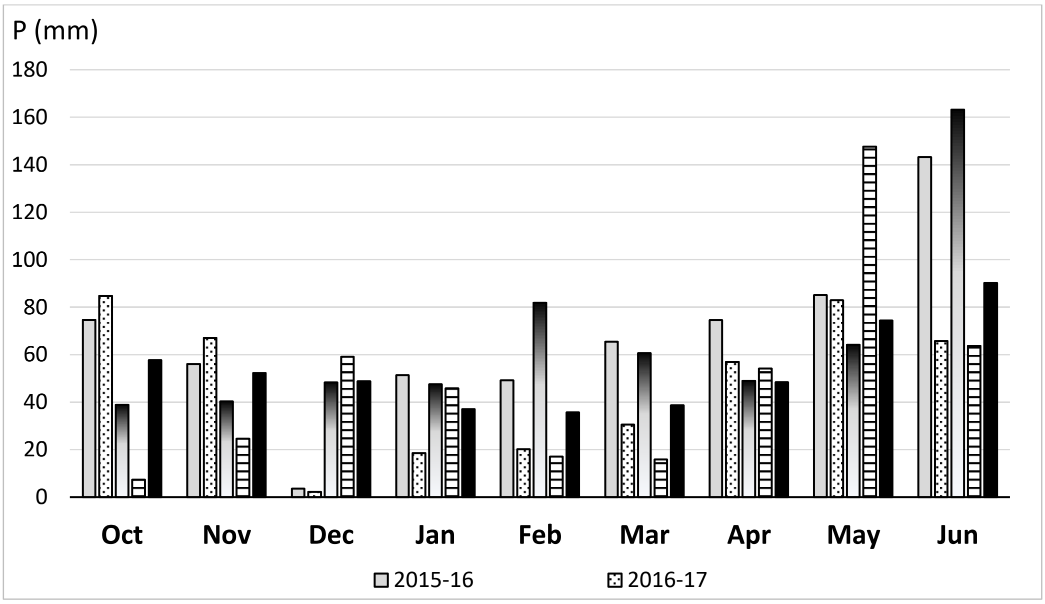

Figure 2. Average monthly rainfall during four growing seasons and long-term average (1989-2018)

Results and Discussion

The results of this study indicate a significant influence of the growing season, variety, and their interaction on wheat yield and the examined quality traits (Table 1). The significance of the studied factors varied across the examined traits. The variability of protein content (GPC) and sedimentation value (SED) was mostly influenced by climatic conditions, specifically, the growing season (Y). More than half of the variation in GPC (60.1%) and one third of variation in SED (34.1%) was attributed to the effect of Y. The genotype × year interaction effect (G × Y) explained the most variability in wheat yield (YLD) and hectoliter weight (HW), while the genotype (G) showed the greatest influence on the value of thousand grain weight (TGW).

HW is a commonly analyzed trait and one of the most important indicators of wheat quality. Its value can vary depending on agronomic conditions, moisture content, and seed health. It is significant for the milling process as it represents a measure of grain volume and indicates its health status. Also, it is an indicator of expected flour yield, making this trait significant for the milling industry. Wheat with higher HW generally has a higher flour yield (Okuyama et al., 2020). The HW value depends on G but also on Y. The variability of this trait was mostly influenced by the interaction of G × Y, indicating that the studied varieties changed their ranking during different seasons. Additionally, the results of the study by Luković et al. (2016) indicate a significant influence of the G × Y interaction on the variability of this trait. On the other hand, research conducted in Croatia (Svecnjak et al., 2007) suggests that the variability of HW was most influenced by Y. Nutrient deficiency, temperature stress, lodging, and other unfavorable weather conditions negatively affect HW (Isleib et al., 2012). The results (Table 2) show that the highest average value of 80.24 kg hL^{-1} was recorded during 2016/17, with the variety Zvezda standing out at 81.00 kg hL^{-1}. The lowest HW of the tested genotypes was recorded during the 2017/18 season. The variety GK Zugoly had the lowest values at 72.85 kg hl^{-1}, while studies in Turkey show the lowest value around 65.2 kg hL^{-1} (Mut et al., 2010). The value of this parameter in Romania was around 79 kg hL^{-1} (Golea et al., 2023), which is approximately the HW value achieved during the 2016/17 season.

In addition to HW, TGW is considered a physical parameter of grain quality and represents grain size. It is one of the key components of wheat yield, and under favorable agroecological conditions during the grain filling period, larger grains are filled better, resulting in higher TGW and higher YLD (Jocković et al., 2010). A high TGW value can improve flour yield and positively affect the milling quality of wheat grains. It should be noted that TGW is primarily variety specific, and there is considerably greater variation between different genotypes than between applied treatments or environmental factors (Đurić et al., 2012). Consistent with this, the results of this study revealed that the TGW was most influenced by G (36.9%). Average values ranged from 30.43 g for the GK Garaboly variety to 45.85 g recorded for the Balkan variety. High values were also obtained for the Ilirija, Jugoslavija, and MV Suba varieties. However, in addition to genotype-related variations, average values also changed depending on environmental factors, with the highest average value recorded during the 2016/17 (42.74 g), while the lowest value was achieved in the 2018/19 season (34.84 g). Mladenov & Milošević (2011) highlighted that the variability of TGW was affected by the G × Y interaction, with the average value of the tested varieties being 38.6 g, slightly higher than the value for the 2015/16 season in this study (37.58 g).

Table 1. Sum of squares (type III) and percent of variance explained to the total sum of squares of the analysis of variance for the studied parameters across the treatments

Source of variation	SS*					%SS*				
	HW	TGW	GPC	SED	YLD	HW	TGW	GPC	SED	YLD
Genotype	1187	5030	172	4390	289	17.3	36.9	17.6	28.6	29.4
Year	1151	3047	588	5245	170	16.8	22.4	60.1	34.1	17.3
Genotype × Year	1784	4870	137	5137	472	26.0	35.8	13.9	33.4	48.0
Error	2730	675	82	596	52					
Total	6851	13622	979	15368	983					

*SS- sum of squares

The primary significance of wheat lies in its ability to be milled into flour, which constitutes the basic ingredient of for bread making and other bakery products. The quality of flour and its rheological characteristics, as well as the functional properties of dough, often depend on GPC, which typically ranges from 6% to values high as 19.8% (Caporaso et al., 2018). The variation in protein content and other technological traits is influenced by the gene action, agroecological factors, and the interaction of genotype, agronomic practices and environment (Banjac et al., 2022). In the Republic of Serbia, the flowering and grain filling stage are the most significant periods, requiring favorable weather conditions to achieve good wheat grain quality. The variability of GPC in this study was mostly influenced by Y. Microclimatic conditions, particularly temperature and moisture are crucial for the growth, development and GPC in wheat (Đurić & Kobiljski, 2006). Across the growing seasons, the average GPC ranged from 11.31% in 2015/16 to 14.71% in 2016/17. Significant variations in GPC during different growing seasons have been observed in Central Europe (Hlisnikovský et al., 2020) as well as in the Mediterranean region (Kaya & Akcura, 2014). The presented results (Tab. 2) show that the old Hungarian variety Bankut 1205 had the highest average GPC of 15.11%, making it of high quality. Research conducted in Hungary confirms that the GPC of this variety ranged from a minimum of 11.70% to a maximum of 15.20% (Juhász et al., 2003). In our study, the lowest average GPC was 12.26% for the Lucija variety. Similar results showed GPC ranging from 12.0% to 16.4% in Croatian wheat varieties (Horvat et al., 2012).

The quality of wheat grain, besides GPC, is also determined by the sedimentation value (SED), which can be used as a criterion in breeding programs. The highest percentage of variation in this parameter was influenced by Y and amounted to 34.1%. However, the data showed that besides the influence of the season, the interaction G × Y significantly affects this parameter (33.4%) (Tab. 1). Unlike GPC, the quality of wheat expressed through SED depends more on weather conditions (Đurić & Kobiljski, 2006). However, Laidig et al. (2017) stated that SED was mostly influenced by G, accounting for as much as 69%. Similar results were recorded by Živančev et al. (2022), who indicated that more than half of the variation in SED is influenced by G. The highest average value of SED was observed in 2016/17, while the lowest was achieved in 2015/16 (Tab. 2). The Renata variety achieved the highest average value of 43.25 mL, while the lowest value among all tested genotypes was recorded by the GK Zugoly variety (29.75 mL). Hristov & Mladenov (2005) found slightly lower SED values ranging from 26.4 mL to 33.0 mL, with an average value of 31.0 mL.

The adjustment of genetics and environmental factors is of essential importance for achieving high yields under specific agroecological conditions. Major priority in developing new varieties is yield and stability improvement, with emphasis on the importance of testing genotypes across different locations and over multiple seasons. Throughout the last century, increases in wheat yield have resulted from advancements in production technology as well as the development of new high-yielding varieties. The results of this study have shown that the variability in YLD was mostly influenced by the interaction effect of G × Y, accounting for almost half of the total variation (48.0%). The variability influenced by G was slightly lower at 29.4%. The significant influence of G × Y and G on grain yield variation in our study can be attributed to use of a wide range of varieties developed over a long period of time. This diversity profoundly impacts the complexity of genetic and environmental interactions, influencing agricultural and quality traits.

On the other hand, Mirosavljević et al. (2020) reported contrasting results, indicating that approximately half of the variability in YLD was influenced by genotype. Observing the growing seasons (Tab. 2), we can note that the highest average YLD was achieved during 2015/16 at 8.03 t ha^{-1}, while the lowest was recorded in 2016/17 (6.14 t ha^{-1}). The average yield values were similar during the growing seasons of 2017/18 and 2018/19. Varieties MV Magdalena (9.11 t ha^{-1}), BC Renata, MV Suba, and Lucija achieved the highest values, while the variety GK Garaboly recorded the lowest yield (5.32 t ha^{-1}). Similar results in terms of YLD were reported by Živančev et al. (2022), where the dominant influence of G was in accordance with the effect of G × Y interaction, accounting for 32.4% of the total variation. Conversely, the researchers in Croatia recorded a slightly wider range of average YLD values for tested varieties across different seasons, ranging from approximately 6 t ha^{-1} to 11 t ha^{-1} (Spanic et al., 2024).

To enable simultaneous analysis of multiple traits of the tested wheat varieties and assess their relationships, a biplot analysis of principal components (PCA) was conducted, averaging across all four growing seasons (Figure 3). The PCA1 explained 38.58%, and the second explained 28.37% of the variation, together constituting 66.95% of the total data variance. According to Fig. 3, PCA1 primarily relates to SED and GPC, while TGW and HW were mostly associated with PCA2.

Relationship among studied traits

Understanding the association of traits facilitates selection and achievement of the desired plant ideotype. YLD represents one of the most important and complex cereal traits, depending on several quantitative properties and their components. Observing Fig 3, we can conclude that YLD has a positive association with TGW, as well as with HW. Many authors have recorded similar results in their studies regarding these properties (Mirosavljević et al. 2020; Zhang et al. 2021; Jocković et al. 2022). On the other hand, Kaya & Akcura (2014) found a negative association between YLD and TGW during one of the examined growing seasons. PCA shows there has been established a negative relationship between GPC and YLD, making it consistent with the results of Da Silva et al. (2014). As expected, Fig 3 shows a high degree of dependence between GPC and SED properties. Similar results were obtained by Živančev et al. (2022). Cubbada et al. (2007) emphasize that the SED value is under the significant effect of GPC, with the degree of influence depending on the genotype, further indicating the negative relationship between YLD and SED confirmed in this study. The results of this study show a strong positive relationship between TGW and HW. A slightly weaker association is observed between TGW and SED, as well as between SED and HM, while on the other hand, Devesh et al. (2021) state a negative relationship between these traits. In Fig 3, HW and GPC were not related, contrary to the results of Khan et al. (2007), who reported a positive association between HM and GPC.

Table 2. Average values of hectoliter weight (HW), thousand grain weight (TGW), grain protein content (GPC), sedimentation value (SED) and yield (YLD)

Year	HW	TGW	GPC	SED	YLD
Aida	75.38^{bcd}	32.55^{no}	13.46^{defgh}	36.50^{efg}	7.63^{bc}
Balkan	77.18^{abcd}	45.85^{a}	13.67^{cdefg}	35.50^{fghij}	7.62^{bcd}
Bankut 1205	78.68^{abc}	38.28^{fghij}	15.11^{a}	34.25^{ghijk}	6.45^{hij}
BC Renata	77.88^{abcd}	35.73^{jklm}	$13.04^{efghijk}$	37.25^{def}	9.09^{a}
Feliks	79.13^{ab}c	37.90^{ghijk}	12.93^{fghijk}	38.50^{cde}	6.76^{fghi}
GK Garaboly	76.35^{abcd}	30.43^{o}	13.74^{cdef}	30.25^{o}	5.32^{k}
GK Kalasz	75.50^{bcd}	40.88^{cde}	14.22^{abcd}	34.50^{ghijk}	7.41^{bcdef}
GK Zugoly	72.85^{d}	32.43^{no}	14.48^{abc}	29.75^{o}	5.85^{jk}
Ilirija	79.40^{abc}	43.9^{5ab}	13.51^{defg}	40.25^{bc}	7.55^{bcde}
Jugoslavija	76.68^{abcd}	43.50^{ab}	13.89^{bcde}	31.50^{lmno}	7.69^{bc}
Lela	78.30^{abc}	32.35^{no}	13.22^{efghij}	40.50^{bc}	6.71^{fghi}
Lucija	77.40^{abcd}	35.33^{lm}	12.26^{k}	36.50^{efg}	8.59^{a}
MV Kolo	76.18^{abcd}	39.43^{defgh}	12.40^{jk}	39.25^{cd}	$7.06^{cdefghi}$
MV Kolompos	75.23^{bcd}	34.80^{lmn}	12.94^{fghijk}	31.13^{mno}	6.92^{defghi}
MV Lucilla	75.68^{bcd}	39.58^{defgh}	12.58^{hijk}	33.00^{klmn}	7.06^{cdefgh}
MV Magdalena	75.48^{bcd}	37.10^{hijkl}	14.13^{bcd}	33.25^{jklm}	9.11^{a}
MV Palma	76.70^{abcd}	39.78^{defg}	$13.01^{efghijk}$	34.75^{ghijk}	7.65^{bc}
MV Suba	74.50^{cd}	42.58^{bc}	$13.07^{efghijk}$	36.00^{fgh}i	8.96^{a}
NS Rana2	78.20^{abc}	39.90^{defg}	$13.03^{efghijk}$	30.75^{no}	6.35^{ij}
Partizanka	80.15^{ab}	39.40^{defgh}	$13.04^{efghijk}$	33.00^{klmn}	7.74^{bc}
Pipi	75.88^{abcd}	34.45^{mn}	12.42^{jk}	39.00^{cd}	7.12^{cdefgh}
Prima	77.53^{abcd}	40.53^{cdef}	12.54^{ijk}	34.00^{hijk}	7.87^{b}
Proteinka	78.80^{abc}	41.45^{bcd}	13.67c^{defg}	32.75^{klmn}	6.79^{fghi}
Renata	76.95^{abcd}	39.48^{defgh}	13.76^{cdef}	43.25^{a}	6.35^{ij}
Rodna	78.73^{abc}	39.55^{defgh}	12.95^{fghijk}	35.00^{fghijk}	6.68^{ghi}
Ružica	79.60^{abc}	32.65^{no}	12.81^{ghijk}	41.75^{ab}	7.59^{bcd}
Sava	77.25^{abcd}	36.78^{ijklm}	14.76^{ab}	34.50^{ghijk}	5.95^{jk}
Vesna	76.70^{abcd}	39.65^{defgh}	13.50^{defg}	40.50^{bc}	6.85^{efghi}
Zlatka	79.63^{abc}	35.38^{klm}	13.40^{defghi}	33.75^{ijkl}	7.38^{bcdefg}
Zvezda	81.00^{a}	38.85^{efghi}	12.87^{fghijk}	36.25^{efgh}	7.26^{bcdefg}
Year					
2015/16	76.99^{b}	37.58^{b}	11.31^{d}	30.57^{d}	8.03^{a}
2016/17	80.24^{a}	42.74^{a}	14.71^{a}	40.40^{a}	6.14^{c}
2017/18	75.47^{c}	36.90^{c}	13.30^{c}	33.43^{c}	7.44^{b}
2018/19	76.47^{bc}	34.84^{d}	14.07^{b}	37.88^{b}	7.38^{b}

Different letters indicate significant difference at $P < 0.05$ level

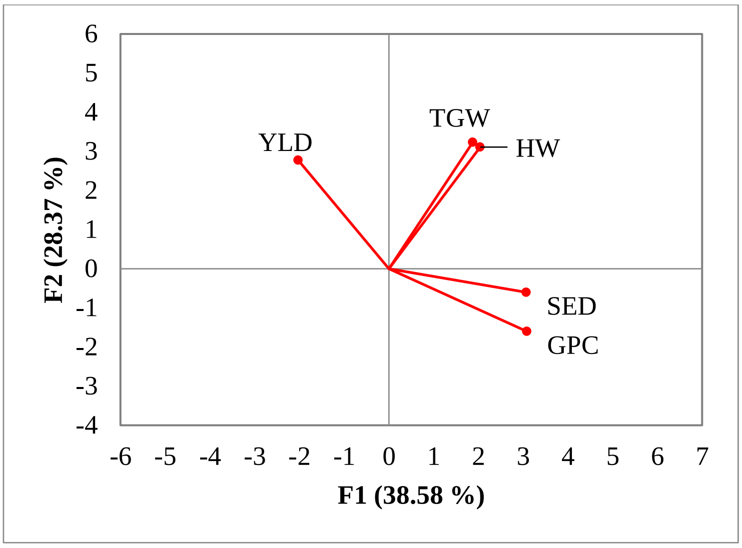

Figure 3. PC analysis of trait relationship (Hectoliter weight – HW, Thousand grain weight – TGW, grain protein content – GPC, Sedimentation value - SED and Grain yield - YLD) in winter wheat across four growing seasons

Conclusions

The results of this study have shown a significant effect of Y and G, as well as the interaction G × Y on YLD and the examined qualitative traits of wheat (HM, TGW, GPC, and SED). The effect of G was found to be the most important for TGW formation, while the influence of Y and G × Y was crucial for the variability of other parameters. PC analysis revealed a strong negative correlation between YLD and GPC. The examined traits were analyzed across different growing seasons and varieties with high average values were identified, which is significant for the development of new wheat varieties with desirable technological quality. The results of this study indicate that understanding the relationships between grain quality traits is crucial for efficient variety selection to meet the needs of agricultural producers and the industry. Further research should focus on studying the mechanisms underlying the interaction between genotype and environment to define varietal characteristics that will ensure stable yields of high quality in various agroecological conditions.

Author contributions: Jovana Timić: Conceptualization, Writing - original draft; Tanja Dražić: Visualization; Milan Mirosavljević: Formal analysis, Validation; Bojan Jocković: Methodology; Vladimir Aćin: Data curation; Sanja Mikić: Investigation; Ljiljana Brbaklić: Supervision.

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Varijabilnost prinosa zrna i osobina kvaliteta sorti pšenice u uslovima južne Panonske nizije

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Sažetak: Kako bi se zadovoljili zahtevi mlinarske industrije i proizvođača strnih žita, neophodno je da zrno pšenice ima dobar tehnološki kvalitet i da usev ostvaruje visoke i stabilne prinose. U radu je analizirano 30 sorti ozime pšenice tokom četiri uzastopne vegetacione sezone (2015/16, 2016/17, 2017/18, 2018/19) na lokalitetu Rimski šančevi, Srbija. Proučavane osobine su bile pod kontrolom genotipa, spoljašnje sredine i njihove interakcije. Primenom analize varijanse (ANOVA) utvrđeno je da se uticaj faktora razlikovao u zavisnosti od proučavane osobine. Masa 1000 zrna je najviše varirala u zavisnosti od genotipa, sadržaj proteina i sedimentaciona vrednost od uticaja spoljne sredine, dok je interakcija genotipa i sredine imala najveći efekat na hektolitarsku masu i prinos pšenice. Primenom analize glavnih komponenti, utvrđena je značajna pozitivna veza između sadržaja proteina i sedimentacione vrednosti, kao i mase 1000 zrna i hektolitarske mase. Takođe je dobijeno da su prinos i masa 1000 zrna u pozitivnoj međuzavisnosti, kao i sedimentaciona vrednost i hektolitarska masa. Jaka negativna veza je zabeležena između prinosa zrna i sadržaja proteina. Sadržaj proteina i hektolitarska masa nisu pokazale međusobnu zavisnost. Sve analizirane osobine su značajne u programima oplemenjivanja pšenice, pri čemu je važno stvarati kvalitetne sorte visokog potencijala za prinos i tolerantne na nepovoljne uslove spoljne sredine.

Ključne reči: hektolitarska masa, prinos, protein, pšenica, sorta, *Triticum aestivum* L.