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Yield and quality stability of common winter wheat varieties

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Abstract

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The research is conducted in large scale farms with conventional crop practices in more than 200 000 da. The stability of grain yield and quality of common winter wheat varieties is evaluated. Bulgarian and European well known varieties – Enola, Avenue and Albertus, have been studied during 3 consecutive years. Bread qualities as crude protein content, wet gluten content, falling number and grain yield in kilograms per dekar and test weight have been analyzed. The on-farm trial reveals relatively good and stable productive potential, depending mainly on the genotype. High negative correlation between yield and bread quality is found. Higher Avenue yields are accompanied by a higher coefficient of variation and lower bread qualities of the grain. Better content of wet gluten, crude protein and falling number are found in Albertus and Enola. Main factor, controlling variation of the bread qualities is the variety, but the environmental conditions also have significant influence on the stability of these traits. The falling number is determined mostly by the climate conditions and therefore varies greatly during the years of study. The most optimal ratio of yield, quality and stability of the wheat production is obtained with the Bulgarian variety Enola.

Keywords: wheat; grain yield; quality; stability
Abbreviations: coefficient of variation (CV); crude protein content (CP); falling number (FN); test weight (TW); wet gluten content (WG)

Introduction

Wheat is main component of the human dietary for millennia (Shewry & Hey, 2015). Its improvement has been performed for so long that nowadays we have the opportunity to achieve bigger yields with better food quality (Finney et al., 1987). Plant breeders have already identified quantitative trait loci and individual genes for genetic improvement of the next generation wheat (Turner et al., 2004; Juliana et al., 2019).

Environmental stresses as drought, extreme heat or late frosts are just part of the future challenges for the farmers. Yields must increase to meet the population needs without compromising food quality or safety (Curtis & Halford, 2014; Horvat et al., 2015). The variation of the vegetative, morphological and qualitative indicators in each variety is due to a combination of genotypic variation, ecological conditions and the expressiveness of the genome at specific parameters of the environment. This corresponds tightly to productivity, which remains a top priority for grain and seed producers, plant breeders, and to the quality of the obtained products.

Main task of the genetic improvement of common winter wheat nowadays is focused on the establishment of breeding lines and varieties, controlling the infestations of pest and diseases, with increased yield potential, minimizing the losses due to environmental stresses, with improved grain quality (Dokic & Mihaljiev, 1995; Silva et al., 2019). In the recent years the interest of breeders in technological qualities is increasing, as the milling industry requires high – quality ma-

terial for processing. Improving these grain characteristics is a complex task given the negative correlations between productivity and quality (Zecevic, 1996; Zuzukin, 1983).

Studies of wheat genotypes with good baking qualities show that they do not maintain stable values in different years. High humidity results in higher grain yield due to low grain quality, while in drier conditions productivity decreases at the expense of better grain performance. The end consumers of field crops rarely have direct contact with the farmers. Main role in the grain trade is due to multinational companies. Answering the market needs for bigger lots with specific quality the farmers need stable and predictable field production. The aim of this study is evaluation of the stability of the quality and grain yield of common winter wheat varieties in large scale fields in North Bulgaria.

Materials and Methods

The research is conducted in agricultural farms with wheat fields on more then 180 000 dka in typical grain producing region in Northwest Bulgaria in two successive growing seasons – 2016/2017 and 2017/2018. Leached chernozems and grey forest soils are predominant for the region. Optimal crop technology for bread wheat has been used. The fields were sown within typical for the region dates (1st -15th October) with optimal sawing density of 550 certified C1 seeds per m^2. The mineral fertilizing is responding the soil analyses and crop needs. Additional leaf treatment with microelements and amino acids after heading stage (SG 55) was applied. Plant protection products were used when needed.

The selection of investigated cultivars is based on their origin, productive potential and bread qualities. Albertus is premium winter wheat from Austria, registered in group A in Bulgaria and preferred for its very good milling qualities. Avenue is French selection, well known for its good yield potential. This is the widest spread wheat in Bulgarian farms. It is used as standard for group B in the official variety testing in Executive Agency for Variety Testing and Seed Control. Enola is the other standard variety in group B, created in Northeast Bulgaria. It is the most famous and used Bulgarian winter wheat in the country.

Characterization of grain yield and quality is based on harvested kilograms per dekar, test weight (TW) (kg), crude protein (CP) and wet gluten (WG) content (%), falling number by Harberg (FN) and energy (W). Analyses were performed by spectroscopic methods on NIRS Flour Analyser by FOSS CropScan 3000B.

Each cultivar is evaluated in two successive growing seasons on at least 17 fields. The total research area is 180 00 da. Average values of the yield from each field and 306 replicates of grain analyses are used for statistical analysis of variance, variation analysis and correlation between investigated traits using Statistical Software package Statistica 12.

Results and Discussion

Phenotypic variation is due to genetic and environmental factors, and their interaction. Organization and management of field production can be optimized by profound research and analyses of specific stress`s influence and genotype reaction.

The climate conditions during the research period were favorable for wheat production.

Precipitation and average air temperatures are presented on Figure 1 and Figure 2. Autumn months were warm and wet and provided sufficient time for germination, tillering and optimal development of the crop before the winter. No frost injuries have been observed in both years. The spring vegetation is earlier for Enola, following by Avenue and Albertus.

The drought in April – May 2018 coincided with the period of wheat heading, anthesis and early grain milk stage (SG 51 – 71) (Acevedo et al., 2002). Protein synthesis has been influenced negatively but later precipitations helped the vegetation recovery and realization of good yields.

The harvest in 2018 was complicated and delayed by the prolonged rainfalls. This resulted in lower test weight of the grain, bigger percent of injured grains by pathogens or sprouted. Fungicide treatment during spring vegetation has been applied against septoria *(Septoria tritici* Lobic), and later brown rust (*Puccinia recondita* Rob. Desm. f. sp. *tritici*), yellow rust (*Puccinia striiformis* West.), and powdery mildew (*Erysiphe graminis* DC).

According the analyses of variance (ANOVA), the variation of grain yield, test weight, crude protein content, wet gluten yield, falling number and energy, statistically significant influence is exerted by genotype, region, year of cultivation, and interactions between them (Table 1).

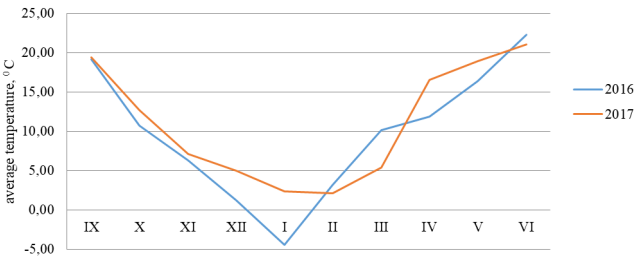
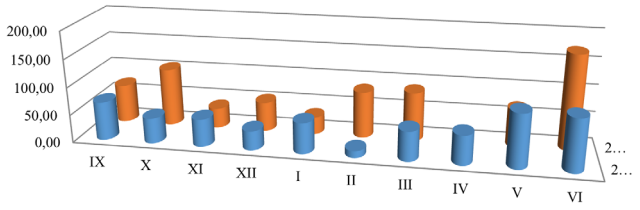


Fig. 1. Avegare montly temperatures during the wheat's vegetation period from 2016 to 2018, °C



	IX	X	XI	XII	I	II	III	IV	V	VI
2016	69,00	45,30	49,50	34,60	55,60	12,20	53,50	53,10	97,10	94,90
2017	68,80	104,00	36,00	52,90	31,10	83,30	87,70	16,40	67,00	171,60

Fig. 2. Rainfall during the wheat vegetation period from 2016 to 2018, in mm

The variation in the yield of the three studied genotypes is mostly determined by the genotype characteristics (63%) and to a much lesser extent depends on the year.

All baking qualities depend to the greatest extent on the genetic potential of the varieties, as can be seen from the strength of the influence of the factors and the interactions between them (η^2). The expressiveness and adaptability of the varieties to a specific region ($\eta^2 = 64$), climate change ($\eta^2 = 56$), the conditions of the region and the farm ($\eta^2 = 55$) also have a relatively weaker but still significant influence on the crude protein content and the response of the genotype to external factors over the years ($\eta^2 = 54$).

The influence of the factors on the variation and the yield of wet gluten is similar, as besides the genes ($\eta^2 = 96$), their behavior in different regions ($\eta^2 = 56$) and years ($\eta^2 = 54$) is important. This gives producers a reason to strive to produce varieties with high genetic potential for protein synthesis and wet gluten yield, under selected suitable soil and climatic conditions and tailored to the needs of the crop cultivation practices.

Main influence on the variation of grain yield and bread making qualities as crude protein, wet gluten content, and energy has the genotype (Table 1). Significant factor on the variation of the chemical composition (crude protein and wet gluten content) of the grain is also the genetic expression in the specific regional conditions.

Lower importance have the region itself and the year for crude protein content, the interaction between year and genotype for wet gluten content. Energy depends mostly of the genetic inheritance and less of the year conditions.

The test weight and falling number are strongly influenced by the climate conditions, mostly by the later and prolonged rainfalls before harvest. Much lower significance has the interaction between region and year conditions.

Table 1. Analyses of variance for the investigated characteristics of wheat, TW – test weight, CP – crude protein content, WG – wet gluten content, FN – falling number

Sources of variation, % from the total variation		Traits					
		Yield	TW	CP	WG	FN	W
	Region	SS	32110	191	38	154	303109	16610
		MS	16055	96	19	77	151554	8305
		η^2 %	3	39	55	41	41	12
	Year	SS	649433	3807	40	30	2755384	369340
		MS	649433	3807	40	30	2755384	369340
		η^2 %	36	93	56	12	86	76
	Genotype	SS	1974675	165	689	6667	216460	1376906
		MS	987337	83	345	3333	108230	688453
		η^2 %	63	35	96	97	33	92
	Region/ year	SS	20659	54	5	23	363717	12496
		MS	10330	27	3	12	181859	6248
		η^2 %	2	15	14	9	45	10
	Region/genotype	SS	195904	175	56	285	235415	59240
		MS	48976	44	14	71	58854	14810
		η^2 %	14	37	64	56	35	34
	Year/genotype	SS	174317	30	37	264	22743	18627
		MS	87158	15	19	132	11372	9314
		η^2 %	13	9	54	54	5	14
	Region/ year/ genotype	SS	8728	139	15	72	282937	62936
		MS	2182	35	4	18	70734	15734
		η^2 %	1	32	32	25	39	35

Average grain yields and test weight for the investigated varieties are presented on Table 2. As mentioned before the main factor determining the productivity is the genotype. Higher yields in all regions and years are achieved for Avenue (763.6 kg/da). At the same time, in areas where it performs very well, Albertus achieves much more modest results. Enola remains in the middle position on this indicator (average 688.1 kg/da). All varieties in 2018 mark a decrease in average yields, largely due to late harvest after heavy and continuously rains in Northwestern Bulgaria. At relatively favorable for the wheat vegetation environmental conditions it is important to notice the lowest stability of this trait for the highest yielding variety – Avenue (CV=10.7). The yield stability of the Bulgarian variety Enola, whose variation coefficient is low (CV=4.4), is relatively better.

The grain test weight in 2018 marks a decrease, which can be justified given the difficult situation during the harvest. According the requirements of the official standards for bread wheat group A and B the values of this indicator should not fall below 76 kg/hl. The unusual conditions imposed reconsideration and allowed to buy grain of deteriorated quality as the only variety Albertus, produced in the region of Pleven had good indicators – 79 kg/hl, and variety Enola from the region of Lom is at the lower limit of 76 kg/hl. The most productive variety Avenue has the lowest average values for test weight for both years. The stability of the three genotypes on this indicator in the investigated regions is very close, as the coefficient of variation is from 4.2 for Enola to 5.7 for Avenue.

Despite the predominant genetic component of its variation, critical factors during the growing season of the crop, mainly nutritional deficiencies of macro and micro elements, drought during grain filling, high density of grain bedbugs, etc., can seriously compromise the grain protein content (Zörb et al., 2017).

From the results shown in Table 3, it is clear that the drought in 2017 did not seriously affect the accumulation of crude protein and the differences between the two years are relatively small. The highest content was reported in the grain of the Albertus variety – on average 15% for 2017 and 16.5% for 2018. This is the only one strong wheat that meets the requirements of BDS 754-88 for a minimum of 14% protein from varieties in group A. The maximum average values for this genotype for the reporting period are 17.2%.

A basic requirement for bread wheat is that the yield of wet gluten does not fall below 22, so that it can be used for baking (Ravinder et al., 2015). Of course, the requirements for group B, to which the varieties Enola and Avenue belong, and group A – variety Albertus, are much higher – 28 and 30%, respectively (Table 3).

Unfortunately, in both years of testing, satisfactory results were not achieved in the analysis of grain from the varieties Enola and Avenue. The average values for wet gluten content of Enola are 26.3 for 2017 and 25.9 for 2018. Even worse are the data for Avenue – 23.4% and 22.9%, respectively. Only the Albertus variety maintains good results – 32.4% in 2017 and 34.8% in 2018.

The relatively more stable indicators for Avenue and Enola (CV – 2.55 and 2.02, respectively) are not sufficient grounds for an advantage in this indicator over the Albertus variety.

The falling number is indirect measurement of α-amylase activity, used as indicator for sprout damage in the grain. It is determined by the time it takes, in seconds, for a stirrer

Table 2. Average grain yield (kg/da) and test weight (kg/hl) for the investigated cultivars during 2017 and 2018

Year	Region	Average yield, kg/da			Test weight, kg/hl		
		Albertus	Avenue	Enola	Albertus	Avenue	Enola
2017	Montana	616.4	806.5	707.5	85.3	80.7	82.0
	Pleven	584.5	828.9	717.0	83.3	83.6	80.9
	Lom	551.1	859.6	712.5	81.3	81.2	81.7
	x	584.0	831.7	712.3	83.3	81.8	81.5
2018	Montana	617.2	689.5	661.0	75.1	74.6	75.3
	Pleven	538.4	653.4	643.4	79.0	75.5	75.5
	Lom	505.0	743.6	687.4	74.0	72.4	76.0
	x	553.5	695.5	663.9	76.0	74.1	75.6
Average for 2017/18		568.8	763.6	688.1	79.7	78.0	78.6
	Minimum	505.0	653.4	643.4	73.9	72.4	75.3
	Maximum	617.2	859.6	717.0	85.3	83.6	82.0
	Variance	2033.7	6673.3	908.3	20.3	19.7	10.7
	Std. dev.	45.1	81.7	30.1	4.5	4.4	3.3
	CV	7.9	10.7	4.4	5.6	5.7	4.2

Table 3. Grain quality- crude protein (CP) content (in %) and wet gluten (WG) content (in %) during 2017 and 2018

Year	Region	Crude protein content, %			Wet gluten content,%		
		Albertus	Avenue	Enola	Albertus	Avenue	Enola
2017	Montana	14.4	12.2	13.0	31.3	23.6	26.5
	Pleven	14.4	12.1	13.1	31.0	22.7	26.5
	Lom	16.2	12.4	13.1	34.9	23.9	25.8
	x	15.0	12.2	13.1	32.4	23.4	26.3
2018	Montana	15.0	12.5	13.3	31.1	23.0	25.7
	Pleven	17.2	12.1	13.3	36.7	22.3	25.2
	Lom	17.2	12.8	13.4	36.5	23.5	25.7
	x	16.5	12.5	13.3	34.8	22.9	25.5
Average for 2017/18		15.7	12.3	13.2	33.6	23.2	25.9
	Minimum	14.4118	12.0600	13.0000	31.0435	22.3100	25.2200
	Maximum	17.2333	12.8000	13.3700	36.7352	23.8800	26.5400
	Variance	1.70	0.08	0.024	7.59	0.35	0.274
	Std. dev.	1.3046	0.2843	0.15410	2.7558	0.5913	0.52320
	CV	8.28	2.30	1.17	8.20	2.55	2.02

to fall through slurry of flour and water to the bottom of a test-tube. Falling numbers greater than 350 indicate low enzymatic activity and sound quality wheat. A falling number lower than 200 indicates high enzymatic activity and poor quality wheat.

Falling number by Harberg is mainly influenced by the changes in the year and to a lesser extent in the growing area (Table 4) (Okuyama et al., 2020). The best values, as shown in Table 4, were measured for the Albertus variety grain in 2017 (average 454.5 s). In 2018 there is a general deterioration of the values of the indicator as a direct consequence of the unfavorable conditions at the end of the vegetation of the plants and the difficult harvest due to the abundant and prolonged rainfall in the whole region.

In some fields the falling number of the Albertus variety decreases to 79.2 s, and on the Avenue variety to 99 s. According to EC Regulation 687/2008 on grain quality and Regulation 26, the minimum quality requirements for bread wheat are FN to be above 220 s. In 2018, only Enola grain meets these requirements. The analysis of the results of the two years shows that there is a strong variation within each variety. The Bulgarian variety Enola is relatively the most stable with a coefficient of variation of 27.7, and the indicator of the Albertus variety changes the most.

In recent years, the purchase of bread grain is accompanied by an analysis of energy or W. Batches with W over 300 are preferred and high quality ones are accepted over 350. Of the studied genotypes again Albertus stands out with high

Table 4. Grain quality – falling number (FN) and energy (W) during 2017 and 2018

Year	Region	FN, сек			W		
		Albertus	Avenue	Enola	Albertus	Avenue	Enola
2017	Montana	435.8	401.0	407.0	419.9	255.0	324.0
	Pleven	452.0	392.4	447.2	395.6	267.0	338.0
	Lom	475.6	379.7	425.1	434.9	255.6	301.4
	x	454.5	391.0	426.4	416.8	259.2	321.1
2018	Montana	238.8	270.5	237.7	299.2	206.0	239.2
	Pleven	413.0	212.0	293.8	391.5	199.4	224.0
	Lom	79.2	99.0	244.0	378.3	198.0	236.1
	x	243.7	193.8	258.5	356.4	201.1	233.1
Average for 2017/18		349.1	292.4	342.5	342.5	230.2	277.1
Minimum		79.2	99.0	237.7	299.24	198.04	224.04
Maximum		475.6	401.0	447.2	434.93	267.00	338.00
Variance		24636.7	14751.2	9001.2	2249.92	1036.84	2487.29
Std. dev.		157.0	121.5	94.9	47.43	32.20	49.87
CV		45.0	41.5	27.7	12.27	13.99	18.00

Table 5. Correlation between grain characteristics in the investigated cultivars

	Average	St.dev.	Yield	TW	CP	WG	FN	W
Yield	673.504	98.180	1.000	0.204	-0.852	-0.831	0.135	-0.597
TW	78.738	3.924	0.204	1.000	-0.057	0.113	0.894	0.572
CP	13.759	1.659	-0.852	-0.057	1.000	0.980	-0.023	0.749
WG	27.546	4.804	-0.831	0.113	0.980	1.000	0.123	0.858
FN	327.986	122.101	0.135	0.894	-0.023	0.123	1.000	0.523
W	297.958	79.030	-0.597	0.572	0.749	0.858	0.523	1.000

values of W – the average for the two years it is 386.6, as in 2017 the grain produced in the region of Lom reached on average over 434.9 (Table 4). At the same time, the variety is distinguished by the highest stability (CV = 12.27) of the tested varieties.

The results of the analysis of grain of Avenue variety are much lower – on average below 250, as in 2018 in the majority of samples the values remain below 200. The indicator of Enola variety is relatively most variable (CV = 18), as in 2017 year the results are good (W over 300), but in 2018 remain below 250.

The studied quality indicators of the grain grown in 2016/17 and 2017/18 definitely put the Albertus variety in group A – strong wheat, flour improvers, with especially good values of crude protein, wet gluten yield and gluten release, sedimentation number and W.

The stability of these indicators is relatively lower than that of the Bulgarian variety Enola and comparable to that of the French variety Avenue. The variation of the indicators is mainly due to the genetic component and only the content of crude protein and wet gluten yield are influenced by external factors such as conditions of the region, the year and the interaction of factors.

Enola variety meets the requirements for soft wheat from group B and proves to be the most adaptable to the conditions of Northwestern Bulgaria. It achieves the most stable indicators in almost all quality analyzes, and only for W the variation is more significant, which is expected given the fact that this indicator is reported relatively recently and has not been the subject of targeted selection activities in previous decades.

Variety Avenue is a standard for group B in testing and recognition of new varieties of soft wheat in IASAS. The analysis of the obtained results does not show compliance with the quality requirements of this group. At the same time, its stability according to the studied traits surpasses the other varieties only in terms of the starch content in the grain.

The study of the relationships between productivity and the main quality characteristics of grain in the studied genotypes is essential for proper analysis and planning of not only the selection and improvement of soft wheat, but also the stability of its cultivation and sale.

In order to establish the relationships between productivity and the main quality characteristics of the grain of the three studied genotypes, a correlation analysis was performed based on the average values of the three regions for the two years of cultivation. The significant correlations found are presented in red in Table 5.

One of the ways to counteract it is through crop production technics, such as corrective nitrogen nutrition of plants during the heading period. The effectiveness of such actions also depends on the presence of sufficient moisture or precipitation in the same period, which explains why such actions were without much result in 2017 in the farms whose grain production we analyze.

A very strong negative correlation was found between yield and crude protein content (r = -0.85) and wet gluten yield (r = -0.83). The negative correlation between productivity and protein content is generally accepted and reported in many crops. It is one of the main factors complicating the selection of high-yielding and at the same time high-gluten genotypes.

The stable overcoming of this negative link for practice and farmers is through selection methods such as mutagenesis, interspecific hybridization for the transfer of genes for high protein content and others, although so far no serious progress has been published in this direction.

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Moderate in strength, but again negative, is the correlation between productivity and W (r = -0.59). The relationship between yield and test weight is shown to be slightly positive (r = 0.20). Confirming the founding of Nörnberg et al. (2015) and Zeeshan et al. (2019), the yield showed no correlation to the pre-harvest sprouting tolerance in wheat. Both positive

and negative dependencies are established between the quality indicators. Crude protein content showed a strong positive correlation with wet gluten yield (r = 0.98) and W (r = 0.75). The ratios are insignificant, i.e. there is no correlation with the falling number (r = -0.02), and the test weight (r = -0.06). Crude protein content shows no correlation to test weight, in contrast of the found by Hruskova & Svec (2009) weak correlation. Wet gluten yield is closely correlated with crude protein content (r = 0.98) and W (r = 0.86).). The correlations with test weight (r = 0.11) and falling number (r = 0.12) are weakly positive. Strong negative dependence shows only on grain yield (r = -0.83).

Conclusion

Based on the analysis of the results obtained in the comparative characteristics of productivity and quality indicators of grain of three varieties of winter soft wheat in 2017 and 2018 in Northwestern Bulgaria, the following conclusions can be made:

All three tested varieties – Albertus, Avenue and Enola, realize good yields and quality of production in the region of Northwestern Bulgaria. The highest productive potential within the study was found for the French Avenue variety. The best baking qualities are achieved with the Albertus variety.

The established parameters of the grain quality indicators – crude protein content, wet gluten yield, confirm the classification of Albertus variety in group A (strong wheat) and Enola variety in group B (medium with increased strength). The results of the analysis of Avenue grain, used as a standard for testing and recognition of new common wheat varieties in EAVTSC, in both years do not meet the requirements of Bulgarian Standards for group B.

A strong negative correlation between productivity and grain quality indicators is statistically proven. To achieve high yields of quality grain it is imperative to use agronomic methods, mainly adjustments in mineral nutrition.

The main factor determining the variation in the productivity of soft wheat is the varietal characteristics. The influence of climatic factors is much weaker, and the region has practically no statistically proven impact on yield. The intra-varietal variation of the yield is weak, as the productivity of the Enola variety is the most stable. The most variable in this indicator is the Avenue variety.

The main factor influencing the variation of the baking qualities of the soft wheat grain is the genotype. To a much lesser extent, crude protein content, wet gluten yield and declining numbers are influenced by climatic conditions, the area of cultivation and the combined influence of factors. This presupposes the desire of farmers to receive quality grain to lead first of all to the correct choice of a variety with high genetic potential for quality and only then – the choice of a suitable place and adequate agro-technical measures for its implementation.

The most stable quality indicators during the two years of testing were found in the analysis of the grain again of the Enola variety. This proves the adaptive potential of the genotype created in Bulgaria and gives farmers reason to expect security in the yields and quality of grain from this wheat.

The tested varieties must be positioned in different directions of production in order to meet the expectations of the producers – productivity – Avenue variety; high quality grain – Albertus variety; stability of yield and baking qualities of group B – Enola variety.

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References

Acevedo, E., Silva, P. & Silva, H. (2002). Wheat growth and physiology. http://www.fao.org/DOCREP/006/Y4011E/y4011e06.htm

Curtis, T. & Halford, N. G. (2014). Food security: the challenge of increasing wheat yield and the importance of not compromising food safety. *Annals of Applied Biology, 164 (3),* 354-372.

Dokic, A. & Mihaljiev, I. (1995). Role of genetics in creation of high yielding plant cultivars and increasing of food production. *Plant Breeding and Seed Production*, *2*, 177-186.

Finney, K. F., Yamazaki, Young, V. L. & **Rubenthaler, G. L.** (1987). Quality of hard, soft and durum wheats. *Wheat and Wheat Improvement – Agronomy Monograph, 3*, 254-253.

Horvat, D., Drezner, G., Sudar, R., Šımıć, G., Dvojkovıć, K., Španıć, V. & **Magdıć, D**. (2015), Distribution of wheat protein components under different genetic backgrounds and environments. *Turkish Journal of Field Crops, 20 (2).* 150-154.

Hruskova, M. & **Svec,** I. (2009). Wheat Hardness in Relation to Other Quality Factors. *Czech. J. Food Sci.*, *27*, 240-248.

Juliana, P., Poland, J. & **Huerta-Espino, J. ,** (2019). Improving grain yield, stress resilience and quality of bread wheat using large-scale genomics. *Nat. Genet., 51*, 1530–1539. https://doi.org/10.1038/s41588-019-0496-6

Nörnberg, R., Luche, H . S., Groli, E. L., Danielowski, R., Santos, R. L., Figueiredo, R. G., Silva, J. A. G., Elias, M. C., Maia, L. C. & Oliveira, A. C. (2015). The search for productivity and pre-harvest sprouting tolerance in wheat. *African Journal of Agricultural Research, 10*, 1719-1727.

Okuyama, L. A., Riede, C. & Kohli, M., (2020). Association between falling number and grain characteristics to evaluate preharvest sprouting in wheat. *Journal of Experimental Biology and Agricultural Sciences, 8(6),* 758 – 764 DOI: http://dx.doi.org/10.18006/2020.8(6).758.764

Ravinder, K., Naveen, K., Kumar, S. & Aradhita R. (2015). Isolation, characterization of wheat gluten and its regeneration properties. *J. Food Sci. Technol., 52(9),* 5930–5937 doi: 10.1007/s13197-014-1690-2

Shewry, P. R. & Hey, S. J. (2015). The contribution of wheat to human diet and health, *Food and Energy Security*, *4 (3*), 178-202, https://doi.org/10.1002/fes3.64

Silva, R. R., Zucareli, C., Fonseca, I. C. B., Riede, C. R. & Gazola, D. (2019). Nitrogen management, cultivars and growing environments on wheat grain quality. *Revista Brasileira de Engenharia Agrícola e Ambiental*, *23 (11),* 826-832.

Turner, A., Bradburne, R. P. Fish & Snape J. W. (2004). New quantitative trait loci influencing grain texture and protein content in bread wheat, *Journal of Cereal Science*, *40 (1*), 51-60.

Zecevic, V. (1996). Genetic identification of different winter wheat cultivars (*Triticum aestivim* ssp. *vulgare*). PhD Thesis, University of Novi Sad, Faculty of Agriculture, 1-98 (Sr).

Zeeshan, M., Arshad, W., Khan, M. I., Ali, S., Nawaz, A., Batool, A., Tariq, M., Akram, M. I. & Ali, M. A. (2018). Breeding for pre-harvest sprouting resistance in bread wheat under rainfed conditions. *Frontiers of Agricultural Science and Engineering*, *5(2),* 253–261.

Zörb, C., Becker, E., Merkt, N., Kafka, S. & Schmidhalter, **U**. (2017). Shift of grain protein composition in bread wheat under summer drought events. *Journal of Plant Nutrition and Soil Science, 180(1)*, 49-55.

Zuzukin, V. I. (1983). Path coefficient analysis in breeding of spring wheat. *Plant Breeding and Seed Production, 10*, 8 – 9.

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