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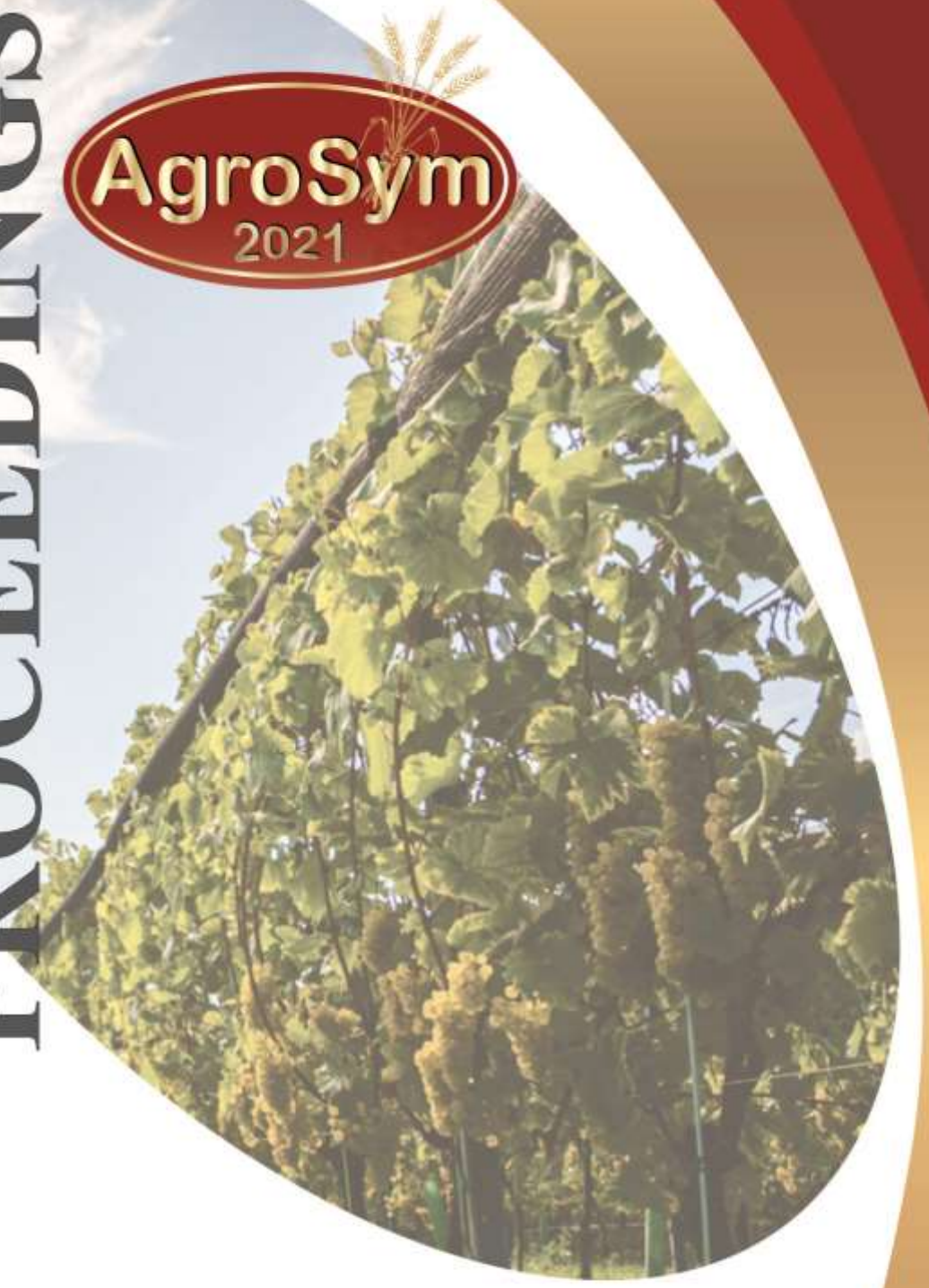

XII International Scientific Agriculture Symposium "AGROSYM 2021" October 7-10, 2021

agrosym 2021

BOOK OF PROCEEDINGS

XII International Scientific Agriculture Symposium
"AGROSYM 2021"

Jahorina, October 07 - 10, 2021

Impressum

XII International Scientific Agriculture Symposium „AGROSYM 2021“

Book of Proceedings published by

University of East Sarajevo, Faculty of Agriculture, Republic of Srpska, Bosnia
University of Belgrade, Faculty of Agriculture, Serbia
Mediterranean Agronomic Institute of Bari (CIHEAM - IAMB) Italy
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CIP - Каталогизација у публикацији
Народна и универзитетска библиотека
Републике Српске, Бања Лука

631(082)(0.034.2)

INTERNATIONAL Scientific Agriculture Symposium "AGROSYM" (12 ; Jahorina ; 2021)
Book of Proceedings [Електронски извор] / XII International Scientific Agriculture Symposium "AGROSYM 2021", Jahorina, October 07 - 10, 2021 ; [editor in chief Dusan Kovacevic]. - Onlajn izd. - El. zbornik. - East Sarajevo : Faculty of Agriculture, 2021. - Ilustr.

Sistemski zahtjevi: Nisu navedeni. - Način pristupa (URL): http://agrosym.ues.rs.ba/article/showpdf/BOOK_OF_PROCEEDINGS_2021_FINAL.pdf. - El. publikacija u PDF formatu opsega 1465 str. - Nasl. sa naslovnog ekrana. - Opis izvora dana 15.11.2021. - Bibliografija uz svaki rad. - Registar.

ISBN 978-99976-787-9-9

COBISS.RS-ID 134751233

XII International Scientific Agricultural Symposium "AGROSYM 2021"
Jahorina, October 07-10, 2021, Bosnia and Herzegovina

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VARIABILITY OF SPIKE HARVEST INDEX IN WHEAT (*TRITICUM AESTIVUM* L.)

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Abstract

Grain spike index indicate wheat productivity and can be used as criterion in wheat selection in the wheat breeding program. Aim of this investigation is study of variability of grain spike index in wheat cultivars grown under different environmental condition. Ten genetically divergent winter wheat cultivars were included in two year investigation in field experiment in randomized block design in three replications. The seeds of varieties were sown at the distance of 0.10 m in rows of 1.0 m length with the distance of 0.2 m. For analysis of grain spike index determined in proportion of grain mass spike^{-1}/mass of spike, 60 plants in full maturity stage (20 plants per replication) were used. On the base of analysis of variance by using MSTAT C (5.0 version) and computed F-test values, differences among cultivars according to value of grain mass spike^{-1}, mass of spike and also, spike harvest index were established. In the first year the highest spike harvest index was 0.82 (Fortuna) and the lowest 0.76 in Ljubičevka, with average for all varieties 0.79, while in the second year the highest spike index was 0.83 in Somborka, and the lowest 0.77 in Ljubičevka, with average value 0.80. The different values of spike harvest index indicate response of genotypes to environmental factors as well as interaction of genotype/environment.

Key words: *wheat, cultivar, variability, index of spike.*

Introduction

In wheat plant the large number of spike on the one hand and many grains spike^{-1} on the other hand is advantages in forming yield. There is differences in estimation of advantages number of spike per plant and mass of spike per plant based on negative correlation of size of spike and number of spike. The spike length has strong indirect influence on yield through number of spikelets spike^{-1} and further on number of grain and size and weight of grain (Zečević *et al*., 2004). In breeding program in the aim of creating variety with high yield, the concept of plants

contains more productive tillers, more spikes, spikelets spike^{-1}, grain spike^{-1}, mass of grain spike^{-1} (Knezevic et al., 2014**).** In many cases yield and biomass showed significant correlations with average yield and yield components example thousand grain weight. Height of plant have a weak negative association with yield. Absence of height reduction (*Rht*) gene alleles associated with high height of plant which is in negative association with harvest index (HI) (Rebetzke et al., 2011; Reynolds and Langridge, 2016). In production of total dry matter in wheat the biological yield is not main criterion for selection because grain yield is a main economic part of yield. The ratio of grain yield (economic) of plant and biological yield indicate on efficiency of genotype for formation of the economic yield or harvest index of plant (Knežević et al., 2015a). This indicate that model plant need have large spike and high mass (Knežević et al., 2011; 2019), especially high mass of grain spike^{-1} (Knežević et al., 2015b). The ratio of grain mass spike^{-1} and mass of spike variate due to fertilization of spikelets spike^{-1} or its number of fertilised florets as well number of grains spike^{-1} indicate efficiency of transport and translocation of dry matter through vessel bundles (phloem and xylem) to spike and grain of spike. Also, this indicate index of receptive capacity of grain spike^{-1} and post-anthesis photosynthetic capacity of stem. The large spike of wheat means that is a optimal number of florets per spike to ensure that their capacity of the spike does not represent a limit for fotosynthates translocation to grain. Size and number of spike per plant, number of spikelets spike^{-1} are genotype characters related to tillering (Moeller and Rebetzke, 2017) that are under genetic control and variate due to environmental condition as well as density of crops, seed rate, supply of nutrition and water in soil (Dodig et al., 2008). Aim of this investigation is study of variability of grain spike index in wheat vatieties grown under different environmental condition.

Materials and Methods

Ten genetically divergent winter wheat cultivars were used for investigation on experimental field in Kraljevo in two vegetative season 2015/16 and 2016/17. The experiment set up in randomized block design in three replications. The seeds of varieties were sown at the distance of 0.10 m in rows of 1.0 m length with the distance of 0.2 m. For analysis of grain spike index determined in proportion of grain mass spike^{-1}/mass of spike, 60 plants in full maturity stage (20 plants per replication) were used.
Based on the obtained average values of the mass of the seed and spike, the spike harvest index is calculated according to the formula:

$$Spike\ index\ (\%) = \frac{mass\ of\ seeds^{-spike}}{mass\ of\ spike}\ \text{x}\ 100$$

Statistical data processing was done using the MSTAT C 5.0 version for analysis of variance by the mono factorial system for each year. The significant differences between the average values were estimated by F-test values. The analysis of variance was performed according to a random block system with one factor and significant differences among cultivars according to grain index of spike were tested by means of test value of LSD $_{0.05}$ and LSD $_{0.01}$.

Weather conditions in the vegetation period

The total amount of precipitation and average temperature per month and per year were different in two year of experiment, during vegetative season (2015/16 and 2016/17) and differed in

relation to the long-term period (2000-2010). In the first year of the experiment, the average temperature was 9.9 ^{o}C and the total rainfall was 651.00 mm, which is significantly higher than in the second year and than in ten year period. In the second year the average temperature during the growing season was 8.7 ^{o}C and similar to ten year period while the total rainfall 523.1 mm was significant higher than in ten year period. During the grain filling phase of plants in the first year in April the average temperature was higher and in May the average precipitation was higher and favorable than in second year of experiment and than in ten year period (table 1)

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Table 1. Average monthly temperatures and total monthly precipitation in Kraljevo

Parameter	Period	Oct	Nov	Dec	Jan	Feb	March	April	May	June	Xm	Total
Temperature ^{0}C	2015/16	11,6	7,3	3,3	-0,1	8,8	7,8	14,1	15,5	21,3	**9,96**	
Temperature ^{0}C	2016/17	10,6	6,8	0,0	-4,7	5,2	10,8	11,1	16,8	22,1	**8,74**	
Temperature ^{0}C	2000-2010	11,8	6,4	1,7	-0,1	2,6	5,9	11,6	16,4	20,4	**8,5**	
Precipitation (mm)	2015/16	56,8	64,0	9,0	86,2	52,7	157,9	39,9	135,9	48,6	72,3	**651,0**
Precipitation (mm)	2016/17	84,1	77,6	9,4	22,0	35,0	57,0	82,0	100,0	56,0	41,1	**523,1**
Precipitation (mm)	2000-2010	61,0	44,3	44,6	30,0	29,9	33,2	52,9	52,6	69,3	46,4	**417,8**

*source: Republic Hydrometeorological service of Serbia

Results and Discussion

The spike harvest index varied from 0.76 in Ljubičevka to 0.82 in Fortuna variety with average value of 0.79 in the first year of experimental vegetative season. The values of spike harvest index in second year of experiment varied from 0.77 in Ljubičevka to 0.83 in Somborka variety with average value 0.80 of all varieties (table 2). Wheat varieties with higher spike harvest index (SPHI) should be with developing more kernels spike^{-1} and a higher grain mass spike^{-1}, what depends on genotypes and their plasticity and response to environmental conditions.

In research on chernozem, similar results of spike harvest index 0.75 in winter wheat in sole crop and in intercrop (wheat/pea) 0.71 was found by Grčak et al. (2019a), while in spring wheat varieties spike harvest index was 0.72 in sole crop and 0.71 in intercrop wheat/pea (Grčak et al., 2019b). In earlier investigation of 22 divergent wheat genotypes presented that index of spike was in range from 0.68 to 0.91 Petrović et al. (2002).

Table 2. Analisys of variance for grain mass spike^{-1}, mass of spike and spike harvest index

Variety	Index of spike)		Average	Grain mass spike^{-1} (g		Average	Mass of spike (g)		Average
	I year	II year	(g)	I year	II year	(g)	I year	II year	
Fortuna	0.819ab	0.784bcdef	0.802A	2.910abcde	2.250g	2.580C	3.557def	2.860gh	3.208EF
Sasanka	0.781cdef	0.784bcdef	0.783ABC	3.123ab	2.753cdef	2.938AB	4.070a	3.310ef	3.690ABC
Danica	0.804abc	0.811abc	0.808A	3.223a	2.857bcde	3.040A	4.010abc	3.567def	3.788AB
Somborka	0.787bcdef	0.831a	0.809A	3.220a	3.033abc	3.127A	4.073a	3.643bcde	3.858A
Kremna	0.794abcde	0.822ab	0.808A	3.173ab	2.900abcde	3.037A	4.043ab	3.533def	3.788AB
Kosmajka	0.815abc	0.802abc	0.808A	2.847bcdef	2.233g	2.540C	3.530def	2.787h	3.158F
Šumadija	0.791bcde	0.794abcde	0.793AB	2.947abcd	2.583efg	2.765BC	3.737abcd	3.233efg	3.485CDE
Morava	0.798abcd	0.808abc	0.803A	2.660def	2.490fg	2.575C	3.330def	3.217fg	3.273DEF
KG-56S	0.7690ef	0.784bcdef	0.769BC	2.747cdef	2.623def	2.685BC	3.570def	3.333def	3.452CDEF
Ljubičevka	0.757f	0.763def	0.761C	2.743cdef	2.617def	2.680C	3.623cdef	3.417def	3.520BCD
Average	**0.790**	**0.799**	**0.794**	**2.96**	**2.63**	**2.79**	3.557def	2.860gh	**3.52**

LSD	Variety	Year	Variety x year	Variety	Year	Variety x year	Variety	Year	Variety x Year
(0,05)	0.268	0.076	0.379	0.255	0.071	0.360	0.2949	0.0829	0.4171
(0,01)	0.385	0.101	0.545	0.366	0.095	0.517	0.4237	0.1109	0.5992

Spike harvest index is value of ratio grain mass spike^{-1} and mass of spike. In this study the grain mass spike^{-1} varied in the range from 2.66 g in Morava to 3.22 g in Danica cultivar with average value 2.96 g in first year of experiment. The values of grain mass spike^{-1} in second year of experiment varied from 2.23 g in Kosmajka to 3.03 g in Somborka variety and average value was 2.63 g (table 2).

Generally, in all studied wheat varieties in first year expressed in average higher value of grain mass spike^{-1} than in second year. This indicates response of genotypes to environmental conditions. The obtained results showed significant differences in the average values of grain mass spike^{-1} and mass of spike per year, that indicating diversity of studied varieties (table 2).

In other studies the significantly lower of grain mass spike^{-1} were obtained, in a sole crop of 1.18 g while in intercrop (wheat/pea) 1.19 g in winter wheat grown on chernozem type soil (Grčak et al., 2019a) as well as in spring wheat grain mass spike^{-1} in a sole crop was 1.02 g and in intercrop (wheat/pea) 0.87 g (Grčak et al., 2019b).

The mass of spike varied in the range from 3.33 g in Morava to 4.07 g in Somborka variety with average value 3.75 g in first year of experiment. The values of mass of spike in second year of experimental vegetation season variate from 2.79 g in Kosmajka to 3.64 g in Somborka variety and average value was 3.29 g (table 2). Generally, the all tested varieties had higher mass of spike in the first year than in second year of experiment. The mass of spike were significantly different among the varieties and between the years of experiment. (table 2).

In other investigation of ten genotypes in two vegetative seasons were found significant differences in wheat varieties for the mass of spike which varied in range from 3.44 g and 4.12 g in first vegetation season and in the range from 3.28 g to 4.8 g in second year (Knežević et al. 2011). Similar values of mass of spike established in ratio 3.30 g – 4.49 g with average of 3.97 g in the first year and 3.20 g – 3.92 g with average 3.61g in the second year of investigation, which depending of variety and environment (Knežević et al., 2019). The significantly lower average values of mass of spike were obtained in research of winter wheat variety on the chernozem soil type, in a sole crop of 1.56 g while in intercrop (wheat/pea) 1.6 g (Grčak et al., 2019a). Also on chernozem in spring wheat varieties obtained in average similar values of mass of spike in sole crop 1.41 g an in intercrop (wheat/pea) 1.23 g (Grčak et al., 2019b). The obtained differences are due to differences of studied genotype (wheat variety) and environmental condition (soil, weather conditions, nutrition).

In these studies, it was found that some varieties, although they have a higher grain mass spike^{-1}, had a lower spike harvest index. For example in Danica found grain mass spike^{-1} 3.22 g, mass of spike 4.01 g and spike harvest index was 0.804 in the first year, on the other hand in Kosmajka grain mass spike^{-1} 2.85 g, mass of spike 3.53 g and spike harvest index was 0.806. In the second year, in Danica variety, the grain mass spike^{-1} was 2.86 g, the mass of spike was 3.57 g and the spike harvest index was 0.801, while in the Kosmajka variety the grain mass spike^{-1} was the lowest 2.23 g, the mass of spike was the lowest 2.79 and the value of the spike harvest index was 0.801, the same as in Danica variety. This indicates that the mass of chaff and rachis was higher in the variety Danica, i.e. that a larger amount of assimilate deposited in the chaff and rachis and was not fully translocated into grain.

Somborka variety in first year of experiment had the highest values of grain mass spike^{-1} (3.22g) and the highest mass of spike (4.07 g) but values of spike harvest index 0.79 it was not the largest, but it was smaller than in Morava, which in the first year had the lowest grain mass spike^{-1} of 2.66 g, the lowest mass of spike 3.33 g and the high value of the spike harvest index 0.799. Generally, in average all studied wheat varieties in first year expressed higher values of grain mass spike^{-1} as well mass of spike than in the second year. However, spike harvest index was higher in the first year in two variety (Fortuna 81.8% and Morava-79.9%) than in the second year (Fortuna 78.7% and Morava-78.5%).

These data indicate different efficiency of uptake, utilization of water and minerals and different efficiency of photosynthesis and translocation of photosynthesized organic matter into grain. Also, the obtained values of the spike harvest index indicate that they are not a reliable criterion for predicting higher values of grain mass spike^{-1} and grain yield, In early studies showed that correlation between spike HI, estimated on the basis 10 spike sample and plot harvest index, was low and statistically nonsignificant. Based on this study, one could not recommend using spike HI as a predictor of plot harvest index (Hucl and Graf, 1992).

For achieving high mass of grain spike^{-1} and grain yield of wheat the significant role has efficiency of photosynthesis related to efficiency of water absorption and plant nitrogen absorption, utilization and translocation into grain in highly favorable environmental conditions. Flag leaf area and green leaf duration have impact in grain filling and in relation to spike forming of grain number and potential size of grains significantly contribute to grain mass. Genetic and physiological characterization of wheat variety can help in creation new high yielding variety by crosses in terms of complementary traits and alleles (Reynolds and Langridge, 2016).

Table 3. Components of variance for spike harvest index, grain mass spike^{-1} and mass of spike

	Spike harvest index						Grain mas spike^{-1}					Mass of spike				
Source of variance	DF	SS	MS	F	Components of variance		SS	MS	F							
					σ^2	%				σ^2	%				σ^2	%
Repetitions	2	30.121	15.060	3.5698*	-	-	0.206	0.103	2.7149^{ns}	-	-	0.184	0.092	1.8222^{ns}	-	-
Variety	9	168.349	18.705	4.4337**	1,868	25,63	2.609	0.290	7.6285**	0,039	29,32	3.492	0.388	7.6722**	0,052	23,85
Year	1	10.753	10.753	2.5487^{ns}	0,109	1,50	1.588	1.588	41.7796**	0,051	38,35	3.234	3.234	63.9492**	0,106	48,63
Variety x year	9	67.464	7.496	1.7768^{ns}	1,092	14,98	0.490	0.054	1.4317^{ns}	0,005	3,76	0.699	0.078	1.5354^{ns}	0,009	4,13
Error	38	160.319	4.219	-	4,219	57,89	1.444	0.038	-	0,038	28,57	1.922	0.051	-	0,051	23,39
Total	59	437.006	-	-	7.288	100,0	6.337	-	-	0.133	100,0	9.531	-	-	0.218	100,0

The analysis of the components of variance showed that genotype had the greatest influence (25.63%) on expression of spike harvest index, while the share of environment was 1.50% and the share of interaction G/E was 14.98% (table 3). Different results reported Petrović et al. (2002) which found higher impact of environment. The highest impact on grain mass spike^{-1} had environmental condition (38.35%) and higher than genotype (29.32%), while the least impact had interaction G/E (3.76%). Analysis of component of variance showed that environment had the highest impact (48.63%) on expression of mass of spike and higher than impact of genotype (23.85%) while the impact of interaction G/E (4.13%) was the least (Table 3). The environmental factors as well temperature, precipitation, nutrition have influence on increasing of capacity of spike (Petrović *et al*., 2008; Knežević *et al*., 2016) and grain yield (Marijanović *et al*., 2010).

Conclusion

In this study were established that the mass of spikes, grain mass and harvest index of spike are different between varieties and between years of experiment. The highest values of spike harvest index (83.1%) in Somborka variety expressed in the second experimental year, while the least (75.7%) in wheat Kosmajka in the first experimental year. The genotype had the greatest influence (25.63%) on expression of spike harvest index. The highest values of grain mass spike^{-1}, (3.22 g) in Danica and Somborka variety expressed in the first experimental year, while the least (2.23 g) in wheat Kosmajka in second experimental year. The highest values of mass of spike (4.07 g) in Somborka variety expressed in the first experimental year, while the least (2.79 g) in wheat Kosmajka in second experimental year.

Acknowledgements

The research was funded by the Ministry of Education, Science and Technological Development of Republic of Serbia (TR 31007).

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