

UDC 633.11-155.9"2005/2008"
COBISS.SR-ID: 219344908
Original research paper



Acta Agriculturae Serbica, Vol. XX, 39 (2015);85-95

Variability of grain weight per spike in wheat grown in different ecological conditions

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Abstract: Variability of grain weight spike⁻¹ was studied in 10 wheat genotypes: 'Ana Morava', 'Julija Mono', 'Gruža', 'Kruna', 'Lasta', 'Balkan', 'Rodna', 'NS Rana 2', 'Partizanka', 'Pobeda', grown over three experimental years under different environmental factors. The experiment was set up as a randomized block design in three replications. Differences in the average values of grain weight spike⁻¹ among tested cultivars were determined in all three years. On average, for all genotypes, grain weight spike⁻¹ was highest (2.32g) in the first experimental year (2005/06), and lowest (1.95g) in the second year (2006/07). For all investigated wheat cultivars, in the third experimental year, the average value of grain weight spike⁻¹ was 2.24g, while the total average value for all cultivars and three experimental years was 2.17g. 'Ana Morava' had the highest average values for grain weight spike⁻¹ in all three experimental years, while the lowest grain weight spike⁻¹ was obtained in 'Balkan' (1.81g) in the second year 'Lasta' (1.40g) and in the third experimental year 'Partizanka' (1.91g). On average, 'Ana Morava' had the

Received: 20 October 2015 / Accepted: 18 November 2015

highest value (2.67g) of grain weight spike⁻¹, while the lowest average value (1.94g) was recorded in 'Balkan'.

Key words: alfalfa wheat, variability, spike, grain weight, environment .

Introduction

Grain weight spike⁻¹ together with numerous wheat traits contributes to the formation of total grain yield. Yield and yield components exhibit either a positive or negative correlation which adds to the complexity of determining the yield value. Specifically, stem height and spike length have a direct negative effect on grain yield (Bhagat et al., 2004; Haq et al., 2010), while tillers per plant (Khan et al., 2010) and grain weight spike⁻¹ (Ashfaq et al., 2003) have a direct positive influence on grain yield; thousand grain weight (TGW) directly negatively affects grain yield, while positive indirect effects were observed via number of grains per spike and grain weight per spike (Shoran et al., 2000). Each yield component is controlled by genes and affected by environmental factors as well as by the interaction of genetic and environmental factors. High temperature shortens the grain filling period, and induces early maturity which causes grain shrinkage and low grain weight (Khan et al., 2007). Breeding success requires wide knowledge of the characteristics of genotypes and environment as well of the genotype/environment interaction (Knežević et al., 2007). Evaluation of the genotype/environment interaction is important in the selection of superior genotypes (Dhungana et al., 2007). The distribution range of wheat is wide and occurs in different climatic areas. Due to wheat importance, the main task of breeders is to develop new genotypes with high grain yield potential, enhanced quality traits and high adaptability to environmental conditions. Success in breeding wheat for high grain yield depends on germplasm source for the choice of the best parent plants for hybridization and producing progenies with inherited characters of economic importance (Zečević et al., 2005; Akcura, 2009; Iftikhar et al., 2013). To achieve a desirable combination of traits, breeders have developed methods for creating new high-yielding cultivars, based on extensive crossing and testing of early generation progenies. The increase in grain yield is possible through increasing values of yield components: spike traits, efficiency of photosynthesis and use of nutrients (Knežević et al., 2012). The increasing capacity of spike traits responds to environmental factors, such as temperature

values, precipitation, nutrition (Petrović et al. 2008). Spike productivity is in direct correlation with the number of grain and grain weight spike⁻¹. Grain weight spike⁻¹ is positively correlated with spike weight and total grain yield (Okuyama, 2005). Moreover, breeding wheat for improved capacity of the morphological and anatomical structure of plant and organs contributes to increasing grain weight spike⁻¹ in selected cultivars (Kondić et al., 2012).

The aim of this study was to evaluate the variability of grain weight spike⁻¹ in genetically divergent wheat cultivars grown in different environmental conditions, and identify cultivars as suitable parents in wheat breeding programs to improve grain yield.

Materials and methods

The variability of grain weight per spike was studied in 10 winter wheat cultivars selected in two different Serbian wheat breeding centers (Novi Sad and Kragujevac). This research included the following cultivars: 'Ana Morava', 'Julija Mono', 'Gruža', 'Kruna', 'Lasta', 'Balkan', 'Rodna', 'NS Rana 2', 'Partizanka', 'Pobeda'. The investigation was conducted during three experimental years (2005/6-2007/8). The experiment was performed in a randomized block design in three replications under field conditions. Seeds of wheat cultivars were sown at a distance of 0.05m in rows of 1m length. Row spacing was 0.2m. For the analysis of grain weight per spike, 60 plants at full maturity stage (20 plants per replication) were used. After analysis, the average value (\bar{x}) and variance (σ^2) were computed. The significant differences between the average values were estimated by F-test values.

Climatic conditions during growing seasons

For a better understanding of the variability of the traits analyzed, environmental conditions (temperature and precipitation) were presented for three experimental years during the growing season of wheat plant (Table 1). Average temperatures were similar during the first (8.3 °C) and third (8.05 °C) years, and were also similar to the long-term period (8.5 °C). In 2006/07, the average temperature (11.0 °C) was higher than in 2005/06 and 2007/08 as well as in the long-term period. Main differences were observed in the winter period during dormancy which did not significantly affect plant growth. Sums of precipitation were higher in 2005/06 (533.7 mm) than in the other two experimental years: 2006/07 (369.9 mm), 2007/08 (430.7mm) and long-term period (417.8 mm). Precipitations in the 2006/07 growing season were the lowest

(369.9mm). This amount of precipitation was 115.9 mm, 163.8 mm and 60.8 mm lower than in the long-term period, 2005/06 and 2007/08, respectively. In May 2006/07, precipitations were four times higher than those in 2005/06 and the long-term period, and nine time higher than in 2007/08 (13.1mm), but only 3.6 mm was recorded in April 2006/07, when a drought period negatively influenced plant growth.

Table 1. Monthly and mean temperatures, and monthly and cumulative precipitation

Month	Temperature °C				Precipitation (mm)			
	2005/06	2006/07	2007/08	1990-2000	2005/06	2006/07	2007/08	1990-2000
October	11.5	13.3	10.9	11.83	49.0	16.7	69.1	61.02
November	5.6	7.6	4.5	6.4	54.8	13.7	110.4	44.29
December	3.3	3.5	0.4	1.71	47.1	51.9	28.1	44.65
January	-1.7	6.1	2.5	-0.1	27.9	45.3	37.7	30.04
February	1.5	6.3	4.4	2.62	38.1	32.1	13.0	29.87
March	5.5	9.1	8.0	5.99	116.1	62.9	61.5	33.21
April	12.7	12.1	12.6	11.6	86.3	3.6	30.1	52.88
May	16.4	18.2	17.4	16.37	29.6	118.4	13.1	52.57
June	19.7	22.8	21.8	20.37	84.8	25.3	67.7	69.28
Average	8.3	11.0	8.05	8.5	59.3	41.1	47.9	46.4
Total	74.4	99.0	72.5	76.7	533.7	369.9	430.7	417.8

Results and Discussion

In this study, grain weight spike⁻¹ showed significant differences among cultivars in all three years of the experiment. In the first year, grain weight spike⁻¹ was lowest in wheat cultivar ‘Balkan’ (1.81g) and highest in ‘Ana Morava’ (2.80g). In the second year, the lowest values were obtained in Lasta’ (1.40g) and the highest in ‘Ana Morava’ (2.25g), while in the third experimental year grain weight spike⁻¹ was lowest in ‘Partizanka’ (1.91g) and highest in ‘Ana Morava’ (2.96g) Table 2.

On average, for all three experimental years, the lowest value was found in ‘Balkan’ (1.94g) and the highest in ‘Ana Morava’ (2.67g) Table 2.

The average value of grain weight spike⁻¹ for all cultivars was 2.32g in the first year, 1.95g in the second year and 2.24g in the third. These values are significantly different (Tab.2).

The results obtained for ten wheat cultivars showed significant differences in the average values of grain weight spike⁻¹ per year, indicating diversity of

examined cultivars. Variability of grain weight spike⁻¹ depended on genotypes and year. These findings are in agreement with previous results (Knezevic et al., 2010).

In a study of 15 wheat cultivars, the average values of grain weight spike⁻¹ ranged from 1.43g in ‘Inqilab-91’ to 2.33g in ‘Wattan’ (Ashfaq et al., 2003).

Similar results on the variability of grain weight spike⁻¹ were established in some other wheat cultivars, at different rates of nitrogen nutrition (Knežević et al. 2012). Grain weight as a grain yield component is determined by genetic and environmental factors (temperature, light, nutrients, water), Agoston and Pepo (2005), and depends on filling duration and efficiency of nutrient utilization and translocation from vegetative to reproductive parts of the plant (Chanda and Singh, 2010; Zareian et al., 2014).

Table 2. Average value of grain weight (g) of analyzed wheat genotypes

Genotypes	Year			\bar{X}_A
	2005/06	2006/07	2007/08	
	$\bar{X} \pm S_x$	$\bar{X} \pm S_x$	$\bar{X} \pm S_x$	
Ana Morava	2.80 ± 0.09	2.25 ± 0.21	2.96 ± 0.22	2.67± 0.17
Julija Mono	2.28 ± 0.24	2.16 ± 0.20	2.27 ± 0.16	2.24± 0.20
Gruža	2.08 ± 0.14	1.88 ± 0.11	2.20 ± 0.15	2.05± 0.13
Kruna	2.68 ± 0.19	1.82 ± 0.18	2.16 ± 0.21	2.22± 0.19
Lasta	2.17 ± 0.13	1.40 ± 0.09	2.27 ± 0.22	1.95± 0.15
Balkan	1.81 ± 0.14	1.96 ± 0.16	2.06 ± 0.13	1.94± 0.14
Rodna	2.34 ± 0.21	1.96 ± 0.19	2.15 ± 0.11	2.15± 0.17
NS Rana 2	1.99 ± 0.14	2.05 ± 0.12	2.08 ± 0.16	2.04± 0.14
Partizanka	2.68 ± 0.18	1.96 ± 0.19	1.91 ± 0.15	2.18± 0.17
Pobeda	2.32 ± 0.15	2.08 ± 0.16	2.35 ± 0.12	2.25± 0.14
\bar{X}_B	2.32± 0.16	1.95± 0.16	2.24± 0.16	2.17± 0.16

Factors	A	B	AB
F _{computed}	4.529*	11.698**	1.822
LSD	0.05	0.402	0.384
LSD	0.01	0.585	0.537

The different values of grain weight spike⁻¹ in analyzed wheat cultivars represent a genotype response to environmental conditions during ontogenetic development. Optimal conditions for the development of productive organs (spike, spikelets, florets) and optimal conditions at flowering, pollination and

fertilization, and grain filling stages have a large contribution to the expression of higher values of yield components. Also, pre-sowing plants had an effect on wheat yield (Nasri et al., 2014). Different values of spike traits in the same cultivars in different experimental years were also found in other studies which indicated a high influence of agro-ecological factors on the expression of spike traits (Agoston and Pepo, 2005; Dakhim et al. 2012). High importance in establishing a response of genotypes to environmental conditions is given to research on the stability of yield and yield components (Dimitrijević et al., 2011).

Grain weight spike⁻¹ is a quantitative trait related to other yield components due to complex correlations. Some yield components are positively correlated, while some others are in a negative correlation (Mohsin et al., 2009). In their study (Ashfaq et al., 2003) on 15 wheat cultivars, the authors reported a direct positive influence of grain weight spike⁻¹ on grain yield, and an indirect positive effect via number of spikelets spike⁻¹, number of grains spike⁻¹ and a negative indirect effect via 1000-grain weight on grain yield per plant. These complex relations among yield components and the specificity of genotype response to environmental conditions create many difficulties to the breeding process in creating new enhanced cultivars.

In this investigation, the temperature and precipitation regimes were different across years. Each cultivar expressed a specific response to environmental conditions. Efficient breeding requires a better understanding of genotypic causes regarding the expression of traits, the effect of environmental factors and the genetic/environment interaction in all stages of plant breeding. This knowledge of genetic and environmental factors causing variability of yield components will contribute to the success of breeding programs.

The optimization of scientific farming measures as well as water supply, fertilizer and pesticide application are very important in achieving a significant increase in values for grain yield and grain yield components (Jolánkai et al., 2006). Also, it is important to estimate the level of genotype adaptation to limiting environmental factors, and assess the ability of genotype to make use of favorable environmental factors (Kovačević, 2007).

Genetic difference was the main factor affecting grain-filling characteristics and contributing to maximum grain weight at maturity. The efficiency of grain filling rate is strongly related to an increase in grain weight, which can be used as a parameter in the breeding process (Jocković et al., 2014). The genetic potential for genotype tolerance to environmental stress plays an important role in improving wheat productivity (Sohail et al., 2014).

Conclusion

The values of grain weight spike⁻¹ in this investigation showed differences among the analyzed cultivars in each experimental year. Also, differences in grain weight spike⁻¹ were observed for the same cultivars in all three experimental years. Total variability of grain weight spike⁻¹ was significantly different within each experimental year and among the experimental years. This indicates that genotype and the environment cause the variation of values for grain weight spike⁻¹, with the average value for all three years ranging from 1.94g in 'Balkan' to 2.67g in 'Ana Morava'. 'Ana Morava', 'Julija Mono', 'NS Rana 2', 'Kruna' and 'Pobeda' expressed high and stable values of grain weight spike⁻¹ in different environmental conditions, and represent perspective parents for the breeding program. On average, for all wheat cultivars, grain weight spike⁻¹ was highest (2.32g) in the first experimental year and lowest (1.95g) in the second year; its average value in the third experimental year was 2.24g. The total average value for all cultivars and three experimental years was 2.17g. Yield improvement involves the need to increase the influence of genetic factor for all yield components. Improvement in genetic control for increased capacity of productive traits is accompanied by improvement in the anatomical structure and physiological functions of vegetative and reproductive organs of wheat plants.

Acknowledgements

This investigation is part of Project TR 31092 which is financially supported by the Ministry of Education and Science of the Republic of Serbia.

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VARIJABILNOST MASE ZRNA PO KLASU PŠENICE GAJENE U RAZLIČITIM EKOLOŠKIM USLOVIMA

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Rezime

Kod deset sorti ozime pšenice: Ana Morava, Julija Mono, Gruža, Kruna, Lasta, Balkan, Rodna, NS Rana 2, Partizanka, Pobjeda, izučavana je varijabilnost mase zrna klasu⁻¹. Izučavanja su obavljena u različitim spoljašnjim uslovima koji su varirali u toku tri godine (2005/06 do 2007/08) u eksperimentu postavljenom po slučajnom blok sistemu u tri ponavljanja. Seme sorti je sejano na rastojanju od 0,05 m u redovima dužine 1,0 m, a razmak između redova je bio 0,2 m. Za analize je korišćeno 60 biljaka (20 biljaka x 3 ponavljanja) u stadijumu pune zrelosti. Ustanovljene vrednosti mase zrna klasu⁻¹ su pokazale da su se sorte međusobno značajno razlikovale u istoj eksperimentalnoj godini, kao i da su sve sorte imale različite vrednosti mase zrna klasu⁻¹ u različitim godinama izučavanja. Prosečna vrednost mase zrna klasu⁻¹ za deset izučavanih sorti bila je najveća (2,32g) u prvoj eksperimentalnoj godini (2005/06) a najmanja prosečna vrednost (1,95g) u drugoj godini (2006/07), a u trećoj godini (2007/08) prosečna masa zrna klasu⁻¹ (2,24g). Za deset izučavanih sorti pšenice trogodišnja prosečna vrednost mase zrna klasu⁻¹ bila je 2,17g. Sorta Ana Morava je imala najveću prosečnu vrednost mase zrna klasu⁻¹ u sve tri eksperimentalne godine (2,80g u prvoj, 2,25g u drugoj i 2,96 u trećoj) i najveći trogodišnji prosek za masu zrna klasu⁻¹ (2,67g). Najmanja masa zrna klasu⁻¹ je ustanovljena kod sorte Balkan (1,81g) u prvoj eksperimentalnoj godini, kod sorte Lasta (1,40g) u drugoj godini, i kod sorte Partizanka (1,91g) u trećoj eksperimentalnoj godini. Sorta Balkan je

imala najmanji trogodišnji prosek mase zrna klasu⁻¹(1,94g). Ustanovljene su značajne razlike između sorti i godina, što ukazuje da je masa zrna klasu⁻¹ svojstvo čija vrednost se ispoljava zavisno od genotipa i uslova spoljašnje sredine, kao i njihove interakcije. Potpunija znanja o prirodi ovog svojstva mogu biti korisna u procesu oplemenjivanja pšenice.

Ključne reči: pšenica, varijabilnost, masa zrna po klasu, spoljašnja sredina