Grain yield and some yield components in various wheat genotypes with different seed sizes

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ABSTRACT

The aim of the research in field conditions was to establish grain yield and some yield components in three wheat varieties depending on seed size, 1.8, 2.0, 2.2, 2.5 and 2.8 mm, using split-plot method in four replications. The highest number of plants (477 and 518) per m² was obtained from the 2.5 and 2.8 mm seed size, respectively. The largest number of spikes (561 and 532) per m² was obtained from the 2.8 and 2.5 mm seed size, respectively. The highest coefficient of productive tillering of 1.39 was recorded in the 1.8 mm seed size. Remaining seed fractions (2.0, 2.2, 2.5 and 2.8 mm) gave significantly lower productive tillering. There were very significant differences in wheat grain yield over years, varieties, seed sizes and the year × seed size interactions. The highest wheat grain yields of 7.22 t ha⁻¹ and 6.86 t ha⁻¹ were achieved in the case of 2.5 and 2.2 mm seed sizes, respectively. A positive strong correlation was detected between the number of overwintered plants and the grain yield (r = 0.63***). Moreover a positive strong correlation was established between the number of spikes and the grain yield (r = 0.70***), while the negative weak correlation was recorded between the coefficient of productive tillering and the grain yield (r = -0.32**). With the same sowing norm, a large seed produces a significantly higher number of plants and spikes per m² than small seed, which is important for the grain yield.

INTRODUCTION

The seed and the variety are the main factors of wide-scale wheat production, therefore, seed is especially important for obtaining high grain yields. Wheat is the most important small grain cereal in the nutrition being consumed in various forms by about 40% of the world population and providing about 20% of needed calories.

The present study was carried out to determine if productivity differed over the seed sizes, to estimate the advantage of large seeds over small ones under the conditions of new advanced/improved crop management practices and recently developed winter wheat varieties, and to determine if the interaction between the seed sizes and varieties or years existed.

Few researchers completely examined this problem and there are some contradictions between earlier researchers and modern ones. Little has been done on this issue, and current studies differ from previously performed ones. The question of the importance of the seed size is still discussed.

Madić et al. (2010) and Dimitrijević et al. (2011) have studied variability and stability of yield components of many wheat varieties. These authors determined the significant effect of varieties, years and their interactions on the expression of traits. Effects of each analysed trait on phenotypic variability have varied. According to their stability and phenotypic variability, genotypes can be used as parental components in wheat breeding programmes.

Banjac et al. (2010), observed wheat yield components and their correlations. The correlation interdependence between yield components was determined. This is important from the aspect of wheat breeding, because selection for one trait conditions the changes in another trait.

Recently developed varieties are characterised by a higher number of spikes per area unit, but they are not always positively correlated with their yield (Deletić et al. 2012). These authors indicated that the kernel weight, and then the number of spikes

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and the number of kernels per spike had a key role in the determination of the yield. Perišić (2016); Mohammad et al. (2013), pointed out that a greater number of plants could not guarantee high yields. There are complex mutual correlations between all yield components.

Mohsen et al. (2014), by observing seed traits pointed out to the role and importance of the seed size and established the advantage of large and heavier seeds.

According to previously performed studies, an advantage of the large seed over the small seed has been explained. That is why we tried to study the ambiguous issues, such as the influence of the seed size on yield components, the number of plants and spikes per m², the coefficient of productive tilling and the grain yield itself. Moreover, everything abovementioned related to the seed size should be checked under the conditions of good cropping practices and high sowing standards, since all recent studies have dealt with these measures.

MATERIALS AND METHODS

Three winter wheat varieties, differing in tilling, stem height, leaf position, duration of the growing season, genetic potential of grain yield and quality, were included in the trial, as follows: variety PKB-Christina - a mid-season variety of a lower height, good disease resistance and cold hardiness, with the high genetic potential of grain yield and quality; variety Pobeda - a mid-season variety of good cold hardiness, lodging and powdery mildew resistance, it is currently our leading variety, known for its wide adaptability and with the high genetic potential of grain yield and quality; variety Vizija - a mid-season variety with kernels of good quality, suitable for growing under the intensive and less intensive production conditions.; this variety is very adaptable and has high genetic potential of grain yield.

The four-replicate trial was set up at the Institute “Tamiš” in Pančevo and was performed from 2015 to 2017, according to the split-plot system with five different seed sizes (1.8, 2.0, 2.2, 2.5 and 2.8 mm). The elementary plot size was 5 m² (1 x 5 m). Mechanical sowing was done in the mid-October. A sowing density was 600 germinating seeds/m² and the row spacing was 10 cm. The soil type was calcareous chernozem. Sunflower was a preceding crop during all three years with the usual crop management practices used for wheat in the Republic of Serbia. The number of overwintered plants was determined in spring and the number of productive spikes was determined before harvest. Hand harvest was done in the full ripeness/maturity stage, and after threshing done with a thresher the grain yield was determined.

Data were statistically processed using the analysis of variance by MSTAT - C program, Michigan State University, Version 1. The year, variety and seed sizes were taken as factors in the analysis. The results were shown as a triennial average.

RESULTS AND DISCUSSION

Number of overwintered plants

An optimum number of plants per area unit is a very important factor for obtaining high yields; therefore, this number should be adjusted to a certain agroecological conditions and each grown variety. All of this has been done to obtain an optimum number of spikes per area unit through maximum production per spike and maximum grain yield. Growing wheat in a dense population and using proper/adequate cropping practices resulted in changes in plant microenvironment. It differs significantly than the one of the old varieties.

There was approximately the same number of plants per m² in all tested varieties, with the same treatment, and both in the same year and with the same treatment, which allowed the comparison of analysed traits (Table 1).

According to applied three-factorial analysis of variance, it was determined that there

| Source of variance | Degrees of freedom | Sum of squares | Mean squares | F Value exp | Significance |
|--------------------|--------------------|----------------|--------------|-------------|--------------|
| Repetition         | 3                  | 6409,311       | 2136,437     | 0,1123      |              |
| Variety (V)       | 2                  | 58393,644      | 29196,822    | 1,5354      |              |
| Error             | 6                  | 114095,956     | 19015,993    |             |              |
| Year (Y)          | 2                  | 247267,244     | 123633,622   | 37,8623     | **           |
| V×Y               | 4                  | 12610,756      | 3152,689     | 0,9635      |              |
| Treatment (T)     | 4                  | 629085,911     | 157271,478   | 48,1638     | **           |
| V×T               | 8                  | 91254,356      | 11406,794    | 3,4933      | **           |
| V×Y×T             | 16                 | 45993,244      | 2874,578     | 8,3691      |              |
| Error             | 126                | 411433,733     | 3265,347     |             |              |
| Total             | 179                | 1835168,244    |              |             |              |

**P≤ 1%
were significant differences in the plant number of plants per area unit in the years of investigation, due to a different seed size, and variety × seed size, year × seed size interactions. The highest number of plants per area unit (426) was recorded in 2016, and it was significantly higher than the ones recorded in 2015 and 2017. Level of significance 1%, it was determined that the plant number per unit area of varieties PKB-Christina, Pobeda and Vizija was at the same level. The largest number of plants (477 and 518) per m² was obtained from the 2.5 and 2.8 mm seed size, respectively. The number of wheat plants grown from remaining seed fractions (1.8, 2.0 and 2.2 mm) was significantly smaller. The largest plant number per m² (426) obtained in 2016 from 2.8 mm seed size at the significance level of 1%, was higher than all the other values of years x seed size interaction (Table 2).

**Spike number**

According to Protić et al. (2018), the spike length obtained in long-term studies performed in Serbia ranged from 8.1 to 9.1 cm, while interactions between varieties and years of investigation were highly significant. Analysis of variance of the number of spikes is shown in Table 3.

Based on the analysis of variance, very significant differences were determined in the number of spikes per area unit in investigation years, due to a different seed size and the year × seed size interaction. The largest number of spikes (493) per area unit was achieved in 2015 and 2016, and it was significantly higher than the one achieved in 2017. For significance level of 1 %, it was determined that spike number per unit area of varieties PKB-Christina, Pobeda and Vizija was at the same level. The largest number of spikes (561 and 532) per m² was obtained from the 2.8 and 2.5 mm seed size, respectively. The number of wheat spikes grown from remaining seed fractions was significantly smaller (Table 4).

**Coefficient of productive tillering**

Approximately the same coefficient of productive tillering was obtained in tested wheat varieties in the same year, with the same treatment,
and both in the same year and with the same treatment (Table 5).

Very significant differences in productive tillering were established by the analysis of variance over investigated years and seed sizes. Smaller seeds had higher/better tillering due to a smaller number per area unit and the year × seed size interaction.

The highest coefficient of productive tillering (1.27) was achieved in 2015 and it was significantly higher than the ones in 2016 and 2017. The highest coefficient of productive tillering (1.39) was obtained from the 1.8 mm seed size. Other seed fractions (2.0, 2.2, 2.5 and 2.8 mm) gave significantly lower productive tillering (Table 3).

Table 3. Analysis of variance of the number of spikes per m$^2$ in the case of different wheat varieties with different seed size

| Source          | Degrees of freedom | Sum of squares | Mean squares | F Value exp | Significance |
|-----------------|--------------------|----------------|--------------|-------------|--------------|
| Repetition      | 3                  | 11146,106      | 3715,369     | 2.7297      |              |
| Variety (V)     | 2                  | 9992,011       | 4996,006     | 3.6706      |              |
| Error           | 6                  | 8166,611       | 1361,102     |             |              |
| Year (Y)        | 2                  | 3612495,544    | 1806247,772  | 555,3725    | **           |
| V×Y             | 4                  | 4634,956       | 1158,739     | 0.3563      |              |
| Treatment (T)   | 4                  | 4552767,356    | 1138191,839  | 349,963     | **           |
| V×T             | 8                  | 45549711       | 5693,714     | 1.7507      |              |
| Y×T             | 8                  | 2414932,511    | 301866,564   | 92,8158     | **           |
| V×Y×T           | 16                 | 42996,822      | 2687,301     | 0.8263      |              |
| Error           | 126                | 409792,033     | 3252,318     |             |              |
| Total           | 179                | 11112473,661   |              |             |              |

**P≤ 1%**

Table 4. The number of spikes per m$^2$ in the case of different wheat varieties with different seed size

| Year | Seed size, mm | Variety (V) | PKB-Christina | Pobeda | Vizija | YT $\bar{x}$ | Y $\bar{x}$ |
|------|---------------|-------------|---------------|--------|--------|--------------|-------------|
|      | (T)           |             |               |        |        |              |             |
| 1.8  | 304           | 414         | 380           | 366    |        |              |             |
| 2.0  | 350           | 454         | 465           | 423    |        |              |             |
| 2015 | 2.2           | 538         | 502           | 598    | 541    | 493          |             |
|      | 557           | 605         | 630           | 597    |        |              |             |
|      | 610           | 668         | 630           | 636    |        |              |             |
|      | 472           | 529         | 579           |        |        |              |             |
|      | 350           | 421         | 432           | 401    |        |              |             |
|      | 382           | 501         | 461           | 448    |        |              |             |
| 2016 | 2.2           | 501         | 540           | 530    | 524    | 493          |             |
|      | 500           | 550         | 540           | 530    |        |              |             |
|      | 520           | 580         | 587           | 562    |        |              |             |
|      | 451           | 518         | 510           |        |        |              |             |
|      | 267           | 351         | 281           | 300    |        |              |             |
|      | 340           | 395         | 365           | 367    |        |              |             |
| 201  | 2.2           | 421         | 410           | 431    | 421    | 408          |             |
|      | 431           | 480         | 495           | 469    |        |              |             |
|      | 437           | 498         | 530           | 485    |        |              |             |
|      | 379           | 425         | 420           | $T \bar{x}$ |        |              |             |
|      | 307           | 395         | 364           | 365    |        |              |             |
|      | 357           | 450         | 380           | 379    |        |              |             |
| TV $\bar{x}$ | 2.2           | 487         | 484           | 517    | 496    | 465          |             |
|      | 496           | 545         | 555           | 552    |        |              |             |
|      | 522           | 579         | 582           | 561    |        |              |             |
|      | 434           | 463         | 444           |        |        |              |             |

Level of significance

| V   | Y   | T   | VY  | VT  | YT  | VYT |
|-----|-----|-----|-----|-----|-----|-----|
| LSD 5% | /   | 20.6| /   | /   | 46.1| /   |
| 1%  | /   | 27.2| 35.2| /   | 60.9| /   |
Grain yield

The variety Pobeda had the highest three-year average grain yield (6.01 t ha\(^{-1}\)), followed by the variety PKB-Christina (5.96 t ha\(^{-1}\)) and the variety Vizija (5.30 t ha\(^{-1}\)). The difference among varieties was significant (Table 7 and 8).

Significant differences in grain yields were determined over the years of testing. The year 2017 especially contributed to this, as the yield was lower than in the previous two years (2015 and 2016), because the attack of fungal diseases on vegetative organs and especially on spikes was higher (Table 7 and 8). Fungal diseases affected vegetative organs and were especially severe in spikes.

By increasing the seed size up to 2.5 mm, yield increased. In the case of the 1.8, 2.0 and 2.2 mm seed size the average yield was 3.64, 4.89 and 6.86 t ha\(^{-1}\), respectively, while in the case of the 2.5 mm seed size the average yield increased to 7.22 t ha\(^{-1}\). In contrast, in the case of the 2.8 mm seed size the average yield significantly decreased to 5.04 t ha\(^{-1}\). Differences in the grain yield depending on the seed size were significant (Table 7 and 8).

A highly significant interaction between years of investigation and the seed size was determined (Table 7).

The interactions between observed varieties and years of investigation, between varieties and the seed size, as well as the triple interaction between varieties, years and the seed size, were not significant (Table 7).

The grain yield of 15 wheat varieties derived in Serbia was observed in seven locations and three years. The proportion of genetic variance amounted to 51.56%, while the proportion of the genotype × environment interaction was 26.34% (Protić et al. 2013).

The correlation between the grain yield and some yield components

The authors detected a positive strong correlation between the number of overwintered plants and the grain yield, significant at the level of 5% and 1% (\(r = 0.63^{**}\)). A regression equation shows how property (dependent variable) changes, if we change the variable for one unit. In that way the authors made a regression equation with two variables – number of overwintered plants and grain yield, which was highly significant at the level of 5% and 1%. This equation was in the form of a linear regression line, as follows: (Figure 1).

A positive strong correlation detected between the number of spikes and the grain yield, was significant at the level of 5% and 1% (\(r = 0.70^{**}\)). In that way the authors made a regression equation with two variables – spike number and grain yield, which was highly significant at the level of 5% and 1%. This equation was in the form of a linear regression line, as follows: (Figure 2).

The authors detected a negative weak correlation between the coefficient of productive tillering and grain yield. The correlation between the number of overwintered plants per \(\text{m}^2\) and grain yield is shown in Figure 1. The regression between the number of spikes per \(\text{m}^2\) and grain yield is shown in Figure 2. The regression between the coefficient of productive tillering and grain yield is shown in Figure 3.

### Table 5. Analysis of variance of the coefficient of productive tillering in the case of different wheat varieties with different seed size

| Source of variance | Degrees of freedom | Sum of squares | Mean squares | F Value exp | Significance |
|--------------------|--------------------|---------------|-------------|-------------|-------------|
| Repetition         | 3                  | 0.067         | 0.022       | 0.1561      |             |
| Variety (V)        | 2                  | 0.693         | 0.347       | 2.4116      |             |
| Error              | 6                  | 0.867         | 0.144       |             |             |
| Year (Y)           | 2                  | 10.641        | 5.320       | 85.2685     | **          |
| V×Y                | 4                  | 0.195         | 0.049       | 0.7794      |             |
| Treatment (T)      | 4                  | 12.414        | 0.104       | 49.7412     | **          |
| V×T                | 8                  | 0.550         | 0.069       | 1.1018      |             |
| Y×T                | 8                  | 7.667         | 0.958       | 15.3599     | **          |
| V×Y×T              | 16                 | 1.354         | 0.085       | 1.3567      |             |
| Error              | 126                | 7.862         | 0.062       |             |             |
| Total              | 179                | 42.306        |             |             |             |

**\(P \leq 1\%)
tillering and the grain yield, significant at the level of 5% and 1% ($r = -0.32^{**}$). In that way the authors made a regression equation with two variables – coefficient of productive tillering and grain yield, which was highly significant at the level of 5% and 1%. This equation was in the form of a linear regression line, as follows: (Figure 3).

Protić et al. (2010), determined a moderate positive correlation ($r=0.47^{**}$) between the grain yield and the number of plants per m$^2$, as well as a strong correlation between the grain yield and the number of spikes per m$^2$ ($r=0.55^{**}$). Furthermore, a weak correlation ($r=0.24^{**}$) was established between the grain yield and productive tillering. The increase of a number of plants per m$^2$, the number of spikes by one per m$^2$, productive tillering by one, resulted in the average increase of the grain by 0.006, 0.005 and 1.174 t/ha, respectively.

Genetic yielding potential can be increased by a better use of genetic variability, solar energy, increase in the seed number and weight, total biomass of the plant, utilisation of heterosis, i.e. wheat hybrids (Denčić et al. 2010).

Teržić et al. (2018), pointed out that the highest values of the grain yield were recorded in the year with moderate temperatures and high precipitation during the growing season. A significantly positive correlation was established between the grain yield and the number of plants per m$^2$. A correlation dependence of traits varied over investigation years and was a result of the interaction of the trait within each genotype and the genotype $\times$ environment interaction.

The number of germinated seeds, was greater in smaller seeds than in larger ones, which provided regular sowing regarding the depth and the number of primary spikes per area unit (Stevanović et al. 2018).

According to results obtained by Hristov et al. (2011), the correlations between the grain yield per plant and all other analysed traits but the spike length were highly significant. The path analysis showed highly significant direct effects of the number of kernels per spike, kernel weight per spike, and the 1000-kernel weight on grain yields per plant. The correlation analysis of stability parameters indicated that stability of grain yield per plant affected only stability of the number of kernels per spike. Seven genotypes with high stability alongside with the highest average values of grain yields per plants were identified by the cluster analysis.

| Year | Seed size, mm | PKB-Christina | Pobeda | Vizija | YT $\bar{x}$ | Y $\bar{x}$ |
|------|--------------|---------------|--------|--------|--------------|------------|
| 2015 | 1.8          | 1.25          | 1.59   | 1.32   | 1.39         |            |
|      | 2.0          | 1.23          | 1.54   | 1.26   | 1.35         |            |
|      | 2.2          | 1.20          | 1.53   | 1.07   | 1.27         | 1.27       |
|      | 2.5          | 1.18          | 1.33   | 1.06   | 1.19         |            |
|      | 2.8          | 1.18          | 1.29   | 1.05   | 1.17         |            |
|      | YV $\bar{x}$ | 1.21          | 1.46   | 1.15   |              |            |
|      | 1.8          | 1.43          | 1.28   | 1.21   | 1.31         |            |
|      | 2.0          | 1.35          | 1.23   | 1.19   | 1.26         |            |
| 2016 | 2.2          | 1.15          | 1.19   | 1.14   | 1.16         | 1.18       |
|      | 2.5          | 1.01          | 1.13   | 1.10   | 1.08         |            |
|      | 2.8          | 1.01          | 1.12   | 1.11   | 1.08         |            |
|      | YV $\bar{x}$ | 1.19          | 1.19   | 1.15   |              |            |
|      | 1.8          | 1.43          | 1.23   | 1.19   | 1.28         |            |
|      | 2.0          | 1.20          | 1.16   | 1.05   | 1.14         |            |
| 2017 | 2.2          | 1.07          | 1.03   | 1.03   | 1.05         | 1.10       |
|      | 2.5          | 1.05          | 1.02   | 1.02   | 1.03         |            |
|      | 2.8          | 1.04          | 0.91   | 1.01   | 0.98         |            |
|      | YV $\bar{x}$ | 1.16          | 1.07   | 1.06   | T $\bar{x}$ |            |
|      | 1.8          | 1.37          | 1.37   | 1.24   | 1.33         |            |
|      | 2.0          | 1.26          | 1.31   | 1.17   | 1.25         |            |
| TV $\bar{x}$ | 2.2      | 1.14          | 1.25   | 1.08   | 1.16         | 1.18       |
|      | 2.5          | 1.08          | 1.16   | 1.06   | 1.10         |            |
|      | 2.8          | 1.07          | 1.11   | 1.06   | 1.08         |            |
|      | V $\bar{x}$  | 1.18          | 1.24   | 1.12   |              |            |

Level of significance

|       | V   | Y   | T   | VY  | V T  | YT  | VYT |
|-------|-----|-----|-----|-----|------|-----|-----|
| LSD 5%| /   | 0.09| 0.12| /   | /    | 0.20| /   |
| 1%    | /   | 0.12| 0.15| /   | /    | 0.27| /   |
Hristov et al. (2011) and Jocković et al. (2014), stated that yields and yield components of the winter wheat significantly varied over growing systems, applied nitrogen rates and diversity and conditions during the year of growth, as well as their complex interactions. Beside a genotype, grain yield of winter wheat significantly depends on the fertilisation system, which is one of the key factors affecting yield and its quality, which also has to be harmonised with climate and soil conditions as well as with requirements of a variety.

The grain yield of wheat depends on components such as the number of plants per m$^2$, number of spikes per m$^2$, number of kernels per spike, kernel weight in the spike, and the 1000-kernel weight. The interactions between these parameters are complex, thus the increase in values of a single parameter decreases the value of another parameter (Laghari et al. 2011; Perišić et al. 2011; Dimitrijević et al. 2011; Hristov et al. 2012; Milovanović et al. 2012; Đekić et al. 2012; Hassan et al. 2013; Mohamed et al. 2013; Hagos and Abai, 2013).

Considering the stated, it is necessary that climatic conditions are in accordance with biological requirements of plants. In the past ten years, extreme temperatures and disturbances in the amount and distribution of precipitation have significantly affected the reduction of the total production of organic matter and therefore the yield (Hristov et al. 2013; Popović et al. 2014).

Iftikhar et al. (2012), indicated that the correlation between the 1000-seed weight and the

| Source of variance | Degrees of freedom | Sum of squares | Mean squares | F Value exp | Significance |
|--------------------|--------------------|---------------|--------------|------------|--------------|
| Repetition         | 3                  | 0.513         | 0.171        | 0.176      |              |
| Variety (V)        | 2                  | 10.498        | 5.249        | 5.420      |              |
| Error              | 6                  | 6.102         | 1.016        |            |              |
| Year (Y)           | 2                  | 110.026       | 55.013       | 105.198    |              |
| V×Y                | 4                  | 3,191         | 0.798        | 1.530      |              |
| Treatment (T)      | 8                  | 152,825       | 18,091       | 73,278     |              |
| V×T                | 8                  | 6,958         | 0.869        | 1.668      |              |
| Y×T                | 8                  | 92.682        | 11.586       | 2.220      |              |
| V×Y×T              | 16                 | 8,660         | 0.542        | 1.038      |              |
| Error              | 126                | 68,980        | 0.547        |            |              |
| **Total            | 179                | 460,436       |              |            |              |

**P≤ 1%**

Table 7. Analysis of variance of Grain yield (t ha$^{-1}$) in the case of different wheat varieties with different seed size

| Year | Seed size, mm | Variety (V) | PKB-Christina | Pobeda | Vizija | YV | YT
|------|---------------|-------------|---------------|--------|--------|----|----|
| 2015 |
| 1.8  | 4.92          | 4.79        | 4.17          | 4.63   |        |
| 2.0  | 5.46          | 5.92        | 5.00          | 5.46   |        |
| 2.2  | 8.18          | 7.88        | 7.29          | 7.78   | 6.36   |
| 2.5  | 8.25          | 8.99        | 7.84          | 8.36   |        |
| 2.8  | 5.76          | 5.53        | 5.37          | 5.56   |        |
| TV   | 5.91          | 6.00        | 5.38          |        |        |
| 1.8  | 4.22          | 4.28        | 3.82          | 4.11   |        |
| 2.0  | 4.69          | 5.37        | 4.53          | 4.86   |        |
| 2016 |
| 2.2  | 7.77          | 7.94        | 7.90          | 7.87   | 6.06   |
| 2.5  | 8.18          | 9.25        | 7.81          | 8.41   |        |
| 2.8  | 5.23          | 5.02        | 4.87          | 5.04   |        |
| TV   | 6.02          | 6.37        | 5.79          |        |        |
| 1.8  | 3.58          | 4.12        | 3.33          | 3.68   |        |
| 2.0  | 4.69          | 5.37        | 4.53          | 4.86   |        |
| 2017 |
| 2.2  | 5.97          | 5.80        | 5.21          | 5.66   | 4.98   |
| 2.5  | 5.57          | 5.78        | 5.69          | 5.68   |        |
| 2.8  | 5.23          | 5.02        | 4.87          | 5.04   |        |
| TV   | 5.01          | 5.22        | 4.73          |        |        |
| 1.8  | 4.08          | 3.20        | 3.65          | 3.64   |        |
| 2.0  | 4.78          | 5.37        | 4.53          | 4.89   |        |
| 2017 |
| 2.2  | 7.05          | 6.96        | 6.58          | 6.86   | 5.53   |
| 2.5  | 7.08          | 7.73        | 6.87          | 7.22   |        |
| 2.8  | 5.23          | 5.02        | 4.87          | 5.04   |        |
| TV   | 5.96          | 6.01        | 5.30          |        |        |

Level of significance

| Error | V | Y | T | VY | VT | YT | VYT |
|-------|---|---|---|----|----|----|-----|
| 43 SD 5% | 0.44 | 0.26 | 0.34 | /   | /   | 0.58 | /   |
| 1%    | 0.67 | 0.34 | 0.44 | /   | /   | 0.77 | /   |

Table 8. Grain yield (t ha$^{-1}$) of different wheat varieties with different seed sizes
grain yield of wheat was positively statistically significant and that the 1000-keranel weight directly affected the grain yield and therefore it could be used as a direct criterion for selection in wheat breeding.

CONCLUSIONS

It was determined that there were very significant differences in the number of plants per area unit during the years of investigation, due to different seed sizes, variety × seed size and year × seed size interactions. The largest number of plants per m² (477 and 518) was obtained from the 2.5 and the 2.8 mm seed size, respectively. The number of plant grown from other seed fractions (1.8, 2.0 and 2.2 mm) was significantly smaller. Very significant differences were determined in the number of spikes per area unit during the years of investigation, due to different seed sizes and years × seed sizes interactions. The largest number of spikes area unit (493) was recorded in 2015 and 2016, and it was significantly higher than the one in 2017. The largest number of spikes (561 and 532) was obtained from the 2.8 and the 2.5 mm seed size, respectively. The number of wheat spikes grown from other seed fractions was significantly smaller. Differences in productive tillering very significantly varied over the years of investigation and seed sizes. Smaller seeds had higher tillering, due to a smaller number of plants per area unit and the year × seed size interaction. The highest coefficient of productive tillering (1.39) was obtained from the 1.8-mm seed size. Remaining seed fractions (2.0, 2.2, 2.5 and 2.8 mm) gave significantly lower productive tillering. The highest grain yield was obtained in the variety Pobeda (6.01 t ha⁻¹), followed by the variety PKB-Christina (5.96 t ha⁻¹) and the variety Vizija (5.30 t ha⁻¹). Differences between varieties were highly significant. A highly significant difference was established between the investigation years. The year 2017 especially contributed to this, as the yield was lower, compared with the previous two years (2015 and 2016). By increasing the seed size from 1.8 mm up to 2.5 mm, the yield increased from 3.64 t ha⁻¹ to 7.22 t ha⁻¹, while in the case of the 2.8 mm seed size, the yield significantly decreased to 5.04 t ha⁻¹. The highly significant interaction was established between the years of investigation and the seed size. Interactions between varieties and years, varieties and seed sizes, and varieties, years and seed sizes were not significant.

The following correlations were detected: a positive strong correlation between the number of overwintered plants and the grain yield, significant at the level of 5% and 1% (r = 0.63**), a positive strong correlation between the number of spikes and the grain yield, significant at the level of 5% and 1% (r = 0.70**) and a negative weak correlation between the coefficient of productive tillering and the grain yield, significant at the level of 5% and 1% (r = -0.32**).

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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