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# EFFECTS OF FERTILIZATION ON YIELD AND GRAIN QUALITY IN WINTER TRITICALE

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## ABSTRACT

**Study of fertilization effects were conducted in a stationary type of field trial, on a degrading vertisol soil with low pH. Eight variants of mineral nutrition (NK, $NP_1$, $NP_2$, $NP_3$, $NP_1K$, $NP_2K$ and $NP_3K$) and untreated control (without nutrition) were tested in the experiment. The rates of nitrogen application were 80 kg N $ha^{-1}$, and they were applied either individually or in combination with three phosphorus rates and the potassium fertilizer. The highest grain yields under mineral nutrition involving a combination of three mineral elements were: N, P and K (80 kg N $ha^{-1}$, 60 kg $P_2O_5$ $ha^{-1}$, 60 kg $K_2O$ $ha^{-1}$), and under $NP_2K$ treatment at a rate of 80 kg N $ha^{-1}$, 80 kg $P_2O_5$ $ha^{-1}$ and 60 kg $K_2O$ $ha^{-1}$. Based on the analysis of variance, it can be concluded that there were highly significant differences in grains yield among years of investigation and highly significant differences at 1000-grain weight and grain test weight.**

**Key words:** fertilization, yield, quality, triticale.

## INTRODUCTION

Triticale is cereal species obtained by cross-breeding of wheat and rye. Thanks to its nutritive value which is higher than maize, breeders and scientists for animal nutrition recommend it for all animal species nutrition. It could replace wheat very successfully in animal nutrition portions (Đekić et al., 2012a, b), what is very important regard the fact that demands for food are growing in the world, and wheat yields and soils area are less and less every day. Triticale is especially distinctive because of its high protein content in the grain and beneficial content of important amino acids compared with other cereals.

Triticale potential, grown under optimal conditions, is approximately similar to wheat potential regard the yield, or it is much higher than wheat potential under unfavorable growing conditions (Brown and Graham, 1978). Wheat, triticale and corn comparison present that triticale accumulates more nitrogen than wheat and corn in grain filling period and grain physiological maturation, what indicates that triticale is much more appropriate species for growing on the nitrogen poor soils (Đekić, 2010). As species, it has important role on soils with marginal characteristics as dry or acid soils, and it is also less demanding regard fertilizers and other chemicals which take place in agronomy. Triticale presents high tolerance to acid soils, as well as good productive results on sandy soils (Đekić et al., 2009). Soil acidity frequently affects agricultural production in Serbia. Triticale was grown successfully in areas where corn did not prosper, as well in the areas with moderate climate (Djekic et al., 2011). It could be generalized that triticale demonstrated very good, up to excellent tolerance in relation to the most important pathogens and small grains pests. Also, triticale presents high adaptability on local agro-ecological conditions which influence on obtaining of its stabile grains yield.

New perspective triticale lines and varieties have more and better filled grain,

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higher yield, test weight and flour content, while theirs proteins and lysine are lower compared with older varieties (Đekić, 2010; Djekic et al., 2011; Milovanovic et al., 2011). Several factors are decisive in triticale yields increasing: the cultivar, cultural practices, agro ecological conditions, local climatic and soil characteristics, mineral nutrition and adequate protection from plant diseases, pests and weeds (Đekić et al., 2010; Milovanovic et al., 2011).

Mineral fertilizers play a vital role on crop yields improving, but one of the main limitations in achieving proven crop potential is imbalanced usage of nutrients, particularly low usage of P compared with N. The optimum rate of P application is important in most crops yields improving (Jelić et al., 2013a; Popović et al., 2011, 2013). Farmers frequently use only nitrogen fertilizers for fodder crops in Serbia, while the usage of P fertilizer is negligible. These crops are often grown on marginal lands. These crops are often grown on marginal lands. Hence, theirs production is low and quality is poor.

The objective of this study was to evaluate the effect of different fertilization systems on the grain yield and quality of triticale grown on a vertisol soil. The study was also aimed at optimizing fertilization for maximum profitability in the future triticale production in semi-arid conditions of Central Serbia.

## MATERIAL AND METHODS

The study was carried out in a stationary type of field trial involving fertilization over a three years period (2004/05, 2005/06 and 2006/07). This trial was set up and sown every year in the experimental fields of the Small Grains Research Centre in Kragujevac continuously from 1970, with same variants and stationary plots in crop rotation system. Plot size was 50 $m^2$.

Triticale cultivar used in the experiment was Favorit, the dominant cultivar in the production region of Serbia. This investigation included an untreated control and seven variants of fertilization: NK (80 kg N $ha^{-1}$, 60 kg $K_2O$ $ha^{-1}$), $NP_1$ (80 kg N $ha^{-1}$, 60 kg $P_2O_5$ $ha^{-1}$), $NP_2$ (80 kg N $ha^{-1}$, 80 kg $P_2O_5$ $ha^{-1}$), $NP_3$ (80 kg N $ha^{-1}$, 100 kg $P_2O_5$ $ha^{-1}$), $NP_1K$ (80 kg N $ha^{-1}$, 60 kg $P_2O_5$ $ha^{-1}$, 60 kg $K_2O$ $ha^{-1}$), $NP_2K$ (80 kg N $ha^{-1}$, 80 kg $P_2O_5$ $ha^{-1}$, 60 kg $K_2O$ $ha^{-1}$) and $NP_3K$ (80 kg N $ha^{-1}$, 100 kg $P_2O_5$ $ha^{-1}$, 60 kg $K_2O$ $ha^{-1}$). A non-fertilized variant served as a control.

The trial was set up in a randomized block design with five replications. Fertilization was regular and followed a long-time scheme. Total amounts of phosphorus and potassium fertilizers and half the nitrogen rate are regularly applied during pre-sowing cultivation of soil. The remaining amounts of nitrogen fertilizers were applied in a single treatment at the tillering stage of triticale. It was cultivated in rotation with corn. Production technology was standard. The crop was harvested in the stage of full maturity, and grains yield was measured and adjusted at 14% moisture. Samples were taken to analysis immediately before harvest. Two parameters of grain quality, namely test weight (kg $hl^{-1}$) and 1000-grain weight (g) were analyzed according to standard procedures.

The soil was analyzed by usage of standard physical methods (soil texture, by pipette method, a variant of pyrophosphate method modified by Živković, 1966); chemical methods (soil pH was determined in a 1:2.5 soil-1 M KCl suspension after a half-hour equilibration period; hydrolytic acidity was determined by Ca acetate extraction using Kappen's method; sum of adsorbed base cations-by Kappen's method; humus content-by Kotzmann's method, total nitrogen by the Kjeldahl method, and available $P_2O_5$ and $K_2O$ levels by the Egner-Riehm Al method).

### Statistical analysis

On the basis of achieved research results the usual variation statistical indicators were calculated: average values, error of the mean and standard deviation. Statistical analysis was performed in the module Analyst Program SAS/STAT (SAS Institute, 2000).

### Study area and soil analysis

The trial was set up on a vertisol soil in a process of degradation, with heavy texture and very coarse and unstable structure. The humus content in the surface layer of soil was low (2.22%). Reduced humus content in field vertisols profiles suggested the necessity of humification usage while planning fertilization systems, as well as soil ameliorative operations for maintaining and improving of soil adsorption complex. Soil pH indicated high acidity (pH in $H_2O$ 5.19; pH in KCl 4.27), nitrogen content in soil was medium (0.11-0.15%), while the content of available phosphorus ranged from very low (1.7-2.9 mg 100 $g^{-1}$ soil) in the N and NK trial variants to very high (26.9 mg $P_2O_5$ 100 $g^{-1}$ soil) in the NPK variants of fertilization. Available potassium contents were high, ranging from 19.5 to 21.0 mg $K_2O$ 100 $g^{-1}$ soil.

**Meteorological conditions**

This study was conducted over a three-year period in the Šumadija region, Central Serbia, on a Vertisol soil, at Kragujevac location (44° 22′ N, 20° 56′ E, 173-220 m a. s. l.), with continental temperate climate which had an average annual temperature of 11.76°C typical for Sumadija district in Serbia and rainfall amount of about 580-790 mm.

*Table 1.* Middle monthly air temperature and precipitation amount from 2004 to 2007, in the 1961-2004 reference periods at Kragujevac location

| Months | Mean monthly air temperature (°C) | | | | The amount of rainfall (mm) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2004/05 | 2005/06 | 2006/07 | Average | 2004/05 | 2005/06 | 2006/07 | Average |
| VIII | 21.1 | 20.0 | 20.7 | 22.7 | 92.8 | 117.8 | 141.9 | 58.5 |
| IX | 16.2 | 17.4 | 17.7 | 16.6 | 31.0 | 115.6 | 57.4 | 62.7 |
| X | 14.6 | 11.5 | 13.3 | 12.5 | 50.1 | 49.0 | 16.7 | 45.4 |
| XI | 6.9 | 5.7 | 7.6 | 6.9 | 104.7 | 54.8 | 13.7 | 48.9 |
| XII | 3.2 | 3.4 | 3.5 | 1.9 | 19.7 | 47.9 | 51.9 | 56.6 |
| I | 1.4 | -1.7 | 6.1 | 0.5 | 36.6 | 27.9 | 45.3 | 58.2 |
| II | -1.7 | 1.5 | 6.3 | 2.4 | 66.9 | 38.1 | 32.1 | 46.6 |
| III | 4.7 | 5.6 | 9.1 | 7.1 | 44.5 | 116.1 | 62.9 | 32.4 |
| IV | 11.6 | 12.7 | 12.1 | 11.6 | 69.0 | 86.3 | 3.6 | 51.9 |
| V | 16.5 | 16.4 | 18.2 | 16.9 | 70.2 | 29.6 | 118.4 | 57.6 |
| VI | 19.3 | 19.7 | 22.8 | 20.0 | 50.8 | 84.8 | 25.3 | 70.4 |
| VII | 21.7 | 23.0 | 24.8 | 22.0 | 86.2 | 22.4 | 10.1 | 71.5 |
| Average | 11.29 | 11.27 | 13.52 | 11.76 | 722.5 | 790.3 | 579.3 | 660.7 |

Kragujevac area is characterized by a moderate continental climate, which general feature is uneven distribution of rainfall by months. Data in Table 1 for the investigated period (2004-2007) clearly indicate that the years in which the researches were conducted differed from the typical multi-year average for Kragujevac region, regarding the meteorological conditions.

The average air temperature in 2004/05 and 2005/06 was lower by 0.47°C and 0.49°C and 2006/07 was higher by 1.76°C. The sum of rainfall precipitation in 2004/05 and 2005/06 was higher by 61.8 mm and 129.6 mm, while the sum of rainfall in 2006/07 was 81.4 mm lower than the average of many years and with a very uneven distribution of precipitation per months. Spring months March and April in 2005/06 were surplus of precipitation, what affected unfavorable on the crops. During the March in 2005/06 it was 116.1 mm of rainfall, what was 83.7 mm more compared with the multi-annual average. Regard the high importance of sufficient rainfall amounts during the spring months, particularly May for triticale production, the distribution and amount of rainfall over the growing season 2006/07 were considerably more favorable, what resulted with increment of yields during that year. Apart from the rainfall deficiency during the spring months and the non-uniform distribution of rainfall across months, an increasing in average air temperatures was also observed.

## RESULTS AND DISCUSSION

The average grain yield of triticale significantly varied across years, from 1.812 t ha$^{-1}$ in 2005/06 to 4.016 t ha$^{-1}$ in 2006/07. In the three-year period, the highest average grain yield for all variants investigated was achieved in the $NP_1K$ variant with the higher phosphorus rate (4.033 t ha$^{-1}$) (Table 2). Fertilization had a significant effect on grain yield (Table 2). The average grain yield was the lowest in the unfertilized control (1.499 t ha$^{-1}$) and significantly higher in fertilized treatments, ranging from 3.898 t ha$^{-1}$ ($NP_2K$-treatment) to 4.033 t ha$^{-1}$ ($NP_1K$-treatment). $NP_3$-treatment fertilization induced a significant increase in grain yield, which was 3.566 t ha$^{-1}$ and higher as compared to the control for 2.067 t ha$^{-1}$.

*Table 2.* Grain yield, 1000-grain weight and test weight of winter triticale in stationary trial in Kragujevac

| Traits | Fertilization | Years | | | | | | Average | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2004/05 | | 2005/06 | | 2006/07 | | | |
| | | $\bar{x}$ | S | $\bar{x}$ | S | $\bar{x}$ | S | $\bar{x}$ | S |
| Grain yield (t ha$^{-1}$) | Control | 1.474 | 0.498 | 0.895 | 0.111 | 2.129 | 0.923 | 1.499 | 0.768 |
| | NK | 2.129 | 0.805 | 1.558 | 0.500 | 2.548 | 0.950 | 2.078 | 0.831 |
| | $NP_1$ | 2.029 | 0.309 | 1.410 | 0.306 | 3.351 | 0.897 | 2.263 | 0.993 |
| | $NP_2$ | 3.426 | 1.018 | 1.507 | 0.519 | 4.388 | 1.731 | 3.107 | 1.663 |
| | $NP_3$ | 3.911 | 1.536 | 1.981 | 1.029 | 4.805 | 0.896 | 3.566 | 1.641 |
| | $NP_1K$ | 4.205 | 0.629 | 2.421 | 0.923 | 5.473 | 1.543 | 4.033 | 1.648 |
| | $NP_2K$ | 3.694 | 0.796 | 2.632 | 0.771 | 5.368 | 1.504 | 3.898 | 1.535 |
| | $NP_3K$ | 3.497 | 1.059 | 2.091 | 0.682 | 4.064 | 1.445 | 3.218 | 1.337 |
| | Average | 3.046 | 1.263 | 1.812 | 0.816 | 4.016 | 1.654 | 2.958 | 1.568 |
| 1000-grain weight (g) | Control | 43.600 | 1.158 | 37.320 | 0.576 | 38.680 | 0.444 | 39.867 | 2.886 |
| | NK | 43.660 | 3.980 | 39.680 | 0.672 | 35.880 | 0.363 | 39.740 | 3.937 |
| | $NP_1$ | 45.680 | 1.092 | 39.780 | 0.618 | 39.620 | 0.482 | 41.693 | 3.006 |
| | $NP_2$ | 46.860 | 3.513 | 41.760 | 0.968 | 40.500 | 0.552 | 43.040 | 3.461 |
| | $NP_3$ | 47.320 | 1.501 | 42.400 | 0.674 | 42.600 | 1.114 | 44.107 | 2.582 |
| | $NP_1K$ | 47.860 | 1.370 | 40.980 | 0.832 | 41.040 | 1.101 | 43.293 | 3.500 |
| | $NP_2K$ | 47.740 | 1.207 | 43.160 | 0.643 | 42.180 | 0.415 | 44.360 | 2.622 |
| | $NP_3K$ | 46.560 | 1.176 | 42.220 | 1.522 | 42.200 | 1.423 | 43.660 | 2.478 |
| | Average | 46.160 | 2.546 | 40.913 | 1.967 | 40.337 | 2.266 | 42.470 | 3.464 |
| Test weight (kg hl$^{-1}$) | Control | 64.920 | 1.368 | 67.238 | 1.670 | 70.850 | 1.575 | 67.669 | 2.902 |
| | NK | 63.840 | 1.889 | 70.440 | 3.127 | 71.650 | 1.166 | 68.643 | 4.102 |
| | $NP_1$ | 65.700 | 2.802 | 70.210 | 2.165 | 71.570 | 1.559 | 69.160 | 3.320 |
| | $NP_2$ | 64.970 | 1.660 | 69.170 | 1.308 | 72.530 | 1.610 | 68.890 | 3.502 |
| | $NP_3$ | 65.690 | 1.723 | 68.690 | 0.829 | 72.210 | 1.615 | 68.863 | 3.066 |
| | $NP_1K$ | 66.020 | 1.289 | 69.890 | 0.780 | 72.370 | 1.425 | 69.427 | 2.923 |
| | $NP_2K$ | 65.620 | 1.490 | 70.130 | 1.635 | 72.610 | 1.459 | 69.453 | 3.313 |
| | $NP_3K$ | 65.450 | 1.776 | 70.290 | 2.165 | 72.530 | 1.145 | 69.423 | 3.460 |
| | Average | 65.276 | 1.760 | 69.507 | 1.979 | 72.040 | 1.445 | 68.942 | 3.291 |

Differences between grains yield of the untreated control and variants with fertilization were statistically highly significant. Fertilization with nitrogen alone resulted in a statistically highly significant increasing in grains yield, compared with the untreated control, but further increasing, when nitrogen was applied in combination with P and K fertilizers, did not result in statistically high significance. The study showed that among investigated fertilization variants the highest grain yields were achieved in variant with 80 kg $ha^{-1}$ nitrogen rate, phosphorus rate of 60 kg $ha^{-1}$ $P_2O_5$ and potassium rate of 60 kg $ha^{-1}$ $K_2O$. The significantly lower grains yield of triticale was achieved in the NK trial variants, than in the NPK and NP variants resulted from the existing phosphorus deficit in the soil, as well as low pH and high content of mobile Al in the soil solution (Jelić et al., 2013b). Nitrogen, phosphorus and potassium applications, particularly on acid soils poorly supplied with these nutrients, have a high effects on the grains yield of oats and other cereal crops (Jelić, 1996; Mohr et al., 2007; Rashid et al., 2007). The significantly lower yield in 2005/06 was due to a decline in total rainfall in the spring and its non-uniform distribution across months, accompanied by higher average air temperatures in these years. According to Đekić et al. (2010, 2012b), the best triticale yields with high quality grain were obtained on warm, bright (high solar radiation) spring weather and cooler summer weather without excessive rains during grains filling.

Thousand grain weight in the test period was highest in 2004/05 (46.16 g), higher than the three-year period by 3.69 g. The control and NK-treatment achieved the lowest average 1000-grain weight during the three years of investigation compared with other tested treatments. During the first year of investigations, the highest average value of 1000-grain weight was achieved in the $NP_1K$ and $NP_2K$-treatment (47.86 g and 47.74 g). During the second year of investigations (2005/06), the highest average value of 1000 grain weight achieved the $NP_2K$ treatments (43.16 g), while in the third year (2006/07), the highest average values of 1000-grain weight was achieved in the $NP_3$ and $NP_3K$ treatments (42.60 g and 42.20 g). A number of authors (Brown et al., 2006; Đekić, 2010; Đekić et al., 2009, 2010, 2012b; Đurić et al., 2013; Jelić et al., 2013a) underlined that 1000-grain weight is a cultivar-specific trait, with considerably higher variations being observed among genotypes than among treatments or environmental factors.

Test weight is an indicator of grain quality, particularly grain monetary value. Table 2 presents average values for grain test weight across years and treatments. During the first year the highest test weight was achieved with $NP_1K$-treatment (66.02 kg $hl^{-1}$), while the lowest was in the NK-treatment (63.84 kg $hl^{-1}$). During the second year of investigations, the mass of hectoliter in the NK treatment was the highest with 70.44 kg $hl^{-1}$, while the slightly lower test weight was realized with $NP_3K$ and $NP_1$-treatments (70.29 kg $hl^{-1}$ and 70.21 kg $hl^{-1}$). During the third year the highest test weight was achieved at $NP_2K$-treatment (72.61 kg $hl^{-1}$), followed by $NP_2$ and $NP_3K$-treatments (72.53 kg $hl^{-1}$), while the lowest test weight was in the control (70.85 kg $hl^{-1}$). The average three-year value of test weight at $NP_2K$-treatment was 69.45 kg $hl^{-1}$, while the lowest value was at control treatment (67.67 kg $hl^{-1}$).

Table 3 shows the impact of year, fertilization and interaction of year x fertilization on yield, 1000 kernel weight and test weight. The ANOVA indicated highly significant effects of the year and grain yield ($F_{exp}=29.3117^{***}$), 1000-grain weight ($F_{exp}=79.7706^{***}$) and grain test weight ($F_{exp}=153.9342^{***}$). Highly significant differences in grain yield and 1000-grain weight in the investigated triticale cultivar were found in relation with the fertilization. Furthermore, 1000-grain weight was significantly affected by the year x fertilization interaction ($P<0.05$). The interaction of grain yield and year x fertilization did not show statistical significance ($P>0.05$).

Usage of fertilizers and certain amendments on extremely acid soils in certain years, particularly those less favorable for production, almost certainly had different effects on grain filling, resulting in diverse relationships between productive and qualitative traits (Peterson et al., 2005; Jelić et al., 2013a). Presented results confirm the opinion of many authors that the traits analyzed are genetically determined, but strongly modified by the nutrient status of the environment as well as weather conditions (Đekić et al., 2010; Jelić et al., 2013b).

*Table 3*. Analysis of variance of the tested parameters (ANOVA)

| Traits | Effect of year on the analyzed traits | | | |
|---|---|---|---|---|
| | Mean sqr. effect | Mean sqr. error | F(df1.2) 2. 117 | P-level |
| Grain yield (t $ha^{-1}$ ) | 48.8121 | 1.665278 | 29.3117 | 0.000000 |
| 1000-grain weight (g) | 411.7892 | 5.162167 | 79.7706 | 0.000000 |
| Test weight (kg $hl^{-1}$) | 467.0966 | 3.034393 | 153.9342 | 0.000000 |
| Effect of fertilization on the analyzed traits | | | | |
| Traits | Mean sqr. effect | Mean sqr. error | F(df1.2) 7. 112 | P-level |
| Grain yield (t $ha^{-1}$ ) | 12.60545 | 1.82343 | 6.913061 | 0.000001 |
| 1000-grain weight (g) | 50.36381 | 9.59826 | 5.247180 | 0.000033 |
| Test weight (kg $hl^{-1}$) | 5.34287 | 11.17694 | 0.478026 | 0.848786 |
| Effect of the year x fertilization interaction on the analyzed traits | | | | |
| Traits | Mean sqr. effect | Mean sqr. error | F(df1.2) 14. 96 | P-level |
| Grain yield (t $ha^{-1}$ ) | 0.978823 | 0.967666 | 1.011530 | 0.448610 |
| 1000-grain weight (g) | 3.908774 | 2.049000 | 1.907650 | 0.034699 |
| Test weight (kg $hl^{-1}$) | 2.510641 | 2.942447 | 0.853250 | 0.610616 |

Table 4 presents the correlation coefficients between the examined traits in the years of study. By testing correlation coefficients between yield and 1000-grain weight and test weight of grain of triticale, positive and medium-dependent statistically average correlations between grain yield and 1000-grain weight were found in all three years (Table 4). However, test weight was significantly and positively correlated with grain yield only in the second year ($r=0.44^{*}$). Test weight in 2005/06 and 2006/07 was positively correlated with 1000-grain weight. The results confirm similar data that grain yield and quality formation is affected by both genetic and environmental factors (Dumlupinar et al., 2011; Jelić et al., 2013a).

*Table 4*. Correlations between the examined traits in 2004-2007

| Traits | Grain yield ($tha^{-1}$ ) | 1000-grain weight (g) | Test weight (kg $hl^{-1}$) |
|---|---|---|---|
| Correlations between the examined traits in 2004/05 | | | |
| Grain yield (t $ha^{-1}$) | 1.00 | $0.71^{*}$ | $0.17^{ns}$ |
| 1000-grain weight (g) | | 1.00 | $0.12^{ns}$ |
| Test weight (kg $hl^{-1}$) | | | 1.00 |
| Correlations between the examined traits in 2005/06 | | | |
| Grain yield (t $ha^{-1}$) | 1.00 | $0.52^{*}$ | $0.44^{*}$ |
| 1000-grain weight (g) | | 1.00 | $0.23^{*}$ |
| Test weight (kg $hl^{-1}$) | | | 1.00 |
| Correlations between the examined traits in 2006/07 | | | |
| Grain yield (t $ha^{-1}$) | 1.00 | $0.54^{*}$ | $-0.06^{ns}$ |
| 1000-grain weight (g) | | 1.00 | $0.24^{*}$ |
| Test weight (kg $hl^{-1}$) | | | 1.00 |

$^{ns}$non significant; $^{*}$significant at 0.05.

Table 5 shows the correlation coefficients between the analyzed traits, depending on studied fertilization treatments.

Significant negative correlations were observed between 1000-grain weight and test weight in all treatments. Negative and strong correlations were also found between test weight and 1000-grain weight in the $NP_1K$-treatment ($r = -0.79^{**}$), $NP_2K$ - treatment ($r = -0.89^{**}$) and $NP_3K$ treatment ($r = -0.81^{**}$), whereas the control, NK, $NP_1$, $NP_2$ and $NP_3$ showed significant negative correlations between test weight and 1000-grain weight.

*Table 5*. Correlation coefficients between the analyzed traits, depending on fertilization treatments

| Traits | Grain yield ($t\ ha^{-1}$) | 1000-grain weight (g) | Test weight ($kg\ hl^{-1}$) |
|---|---|---|---|
| Correlations between the traits analyzed in the unfertilized control | | | |
| Grain yield ($t\ ha^{-1}$) | 1.00 | $0.08^{ns}$ | $0.35^{ns}$ |
| 1000-grain weight (g) | | 1.00 | $-0.60^{*}$ |
| Test weight ($kg\ hl^{-1}$) | | | 1.00 |
| Correlations between the traits analyzed in the NK | | | |
| Grain yield ($t\ ha^{-1}$) | 1.00 | $0.03^{ns}$ | $-0.07^{ns}$ |
| 1000-grain weight (g) | | 1.00 | $-0.71^{*}$ |
| Test weight ($kg\ hl^{-1}$) | | | 1.00 |
| Correlations between the traits analyzed in the $NP_1$ | | | |
| Grain yield ($t\ ha^{-1}$) | 1.00 | $-0.16^{ns}$ | $0.20^{ns}$ |
| 1000-grain weight (g) | | 1.00 | $-0.74^{*}$ |
| Test weight ($kg\ hl^{-1}$) | | | 1.00 |
| Correlations between the traits analyzed in the $NP_2$ | | | |
| Grain yield ($t\ ha^{-1}$) | 1.00 | $0.12^{ns}$ | $0.13^{ns}$ |
| 1000-grain weight (g) | | 1.00 | $-0.61^{*}$ |
| Test weight ($kg\ hl^{-1}$) | | | 1.00 |
| Correlations between the traits analyzed in the $NP_3$ | | | |
| Grain yield ($t\ ha^{-1}$) | 1.00 | $0.28^{ns}$ | $0.28^{ns}$ |
| 1000-grain weight (g) | | 1.00 | $-0.74^{*}$ |
| Test weight ($kg\ hl^{-1}$) | | | 1.00 |
| Correlations between the traits analyzed in the $NP_1K$ | | | |
| Grain yield ($t\ ha^{-1}$) | 1.00 | $0.13^{ns}$ | $0.14^{ns}$ |
| 1000-grain weight (g) | | 1.00 | $-0.79^{**}$ |
| Test weight ($kg\ hl^{-1}$) | | | 1.00 |
| Correlations between the traits analyzed in the $NP_2K$ | | | |
| Grain yield ($t\ ha^{-1}$) | 1.00 | $-0.13^{ns}$ | $0.21^{ns}$ |
| 1000-grain weight (g) | | 1.00 | $-0.89^{**}$ |
| Test weight ($kg\ hl^{-1}$) | | | 1.00 |
| Correlations between the traits analyzed in the $NP_3K$ | | | |
| Grain yield ($t\ ha^{-1}$) | 1.00 | $-0.02^{ns}$ | $0.27^{ns}$ |
| 1000-grain weight (g) | | 1.00 | $-0.81^{**}$ |
| Test weight ($kg\ hl^{-1}$) | | | 1.00 |

$^{ns}$non significant; $^{*}$significant at 0.05; $^{**}$significant at 0.01.

The present results confirm the opinion of many authors that the traits analyzed and their correlations are genetically determined, but are strongly modified by the nutrient status of the environment and weather conditions (Bolton, 2009; Jelić et al., 2013a; Márton, 2008).

## CONCLUSIONS

On average over the three-year period, the highest average grain yield was achieved in the variant $NP_1K$ (4.033 t $ha^{-1}$). Treatments $NP_2$, $NP_3$, $NP_2K$ and $NP_3K$ achieved satisfactory results, while the poorest results were achieved by the control, NK and $NP_1$ treatments.

Considering the average values during 2004-07 period, it was evident that the yields, 1000 grain weight and test weight were highly statistically significantly different between the years (P<0.01).

Effect of fertilization treatments on the grain yield and 1000-grain weight was highly statistically significant. Also, the effect of interaction of the year x fertilization on the 1000-grain weight was significant. Investigations of year x fertilization interactions represent an important basis for further more successful growing, breeding and zoning of triticale.

Significant positive correlations of grain yield and 1000 grain weight in all three years ($0.71^*$, $0.52^*$ and $0.54^*$, respectively), and positive correlations of 1000-grain weight and test weight in the second year and third year ($0.23^*$ and $0.24^*$, respectively) were determined.

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